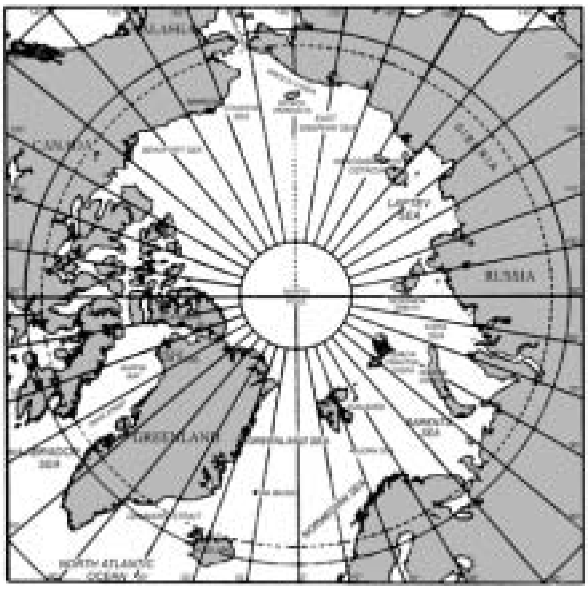
THE ARCTIC OCEAN



General

The Arctic Ocean contains all the waters surrounding the North Pole, and bounded by the continents at the N shores of Alaska, Canada, Greenland, Norway, and Russia. The Arctic Ocean also includes associated waters such as the Canadian Arctic Archipelago, Baffin Bay, the Lincoln Sea, the Greenland Sea, the Norwegian Sea, the Barents Sea, Beloye More (White Sea), the Kara Sea, the Laptev, the East Siberian Sea, the Chukchi Sea, and the Beaufort Sea.

Little is known of the conditions in the Arctic Ocean N of Spitsbergen and the N end of Greenland, but soundings indicate great depths.

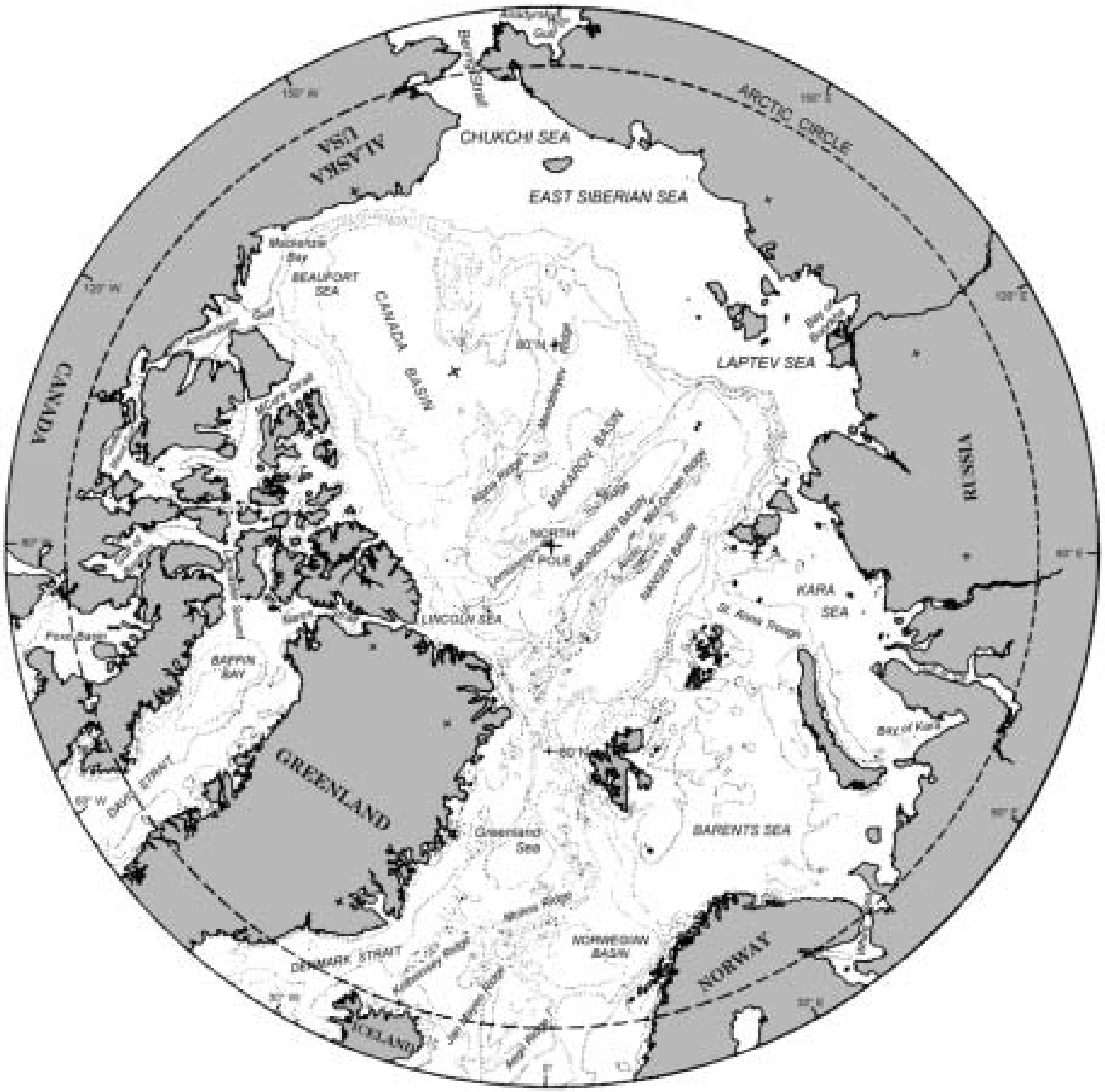
The Denmark Strait separates Iceland from Greenland; the general depths are between 180 and 540m. A depth of 110m was reported to lie in the middle of the strait in position 65˚53'N, 29˚40'W.

The N polar region, the Arctic, consists of an elongated central water area a little smaller than the United States, almost completely surrounded by land. Some of this land is high and rugged with permanent ice caps, but part of it is low and marshy when thawed. Underlying permafrost prevents adequate drainage, resulting in large numbers of lakes and ponds and extensive areas of muskeg, soft spongy ground with characteristic growths of certain types of moss and tufts of grass or sedge. There are also large areas of tundra, low treeless plains with vegetation consisting of mosses, lichens, shrubs, willows, etc., and usually having an underlying layer of permafrost. The northernmost point of land is Kap Morris Jessup, Greenland, which lies about 380 miles from the pole. The central part of the Arctic Ocean is a basin with an average depth of 3,657m. However, the bottom is not level, having a number of seamounts and deeps. The greatest depth is probably a little more than 4,876m.

At the North Pole, the depth is 4,312m. Surrounding the polar basin is an extensive continental shelf, broken only in the area between Greenland and Svalbard (Spitsbergen). The many islands of the Canadian Archipelago are located on this shelf. The Greenland Sea, E of Greenland; Baffin Bay, W of Greenland; and the Bering Sea, N of the Aleutians, each has its independent basin. In a sense, the Arctic Ocean is an arm of the Atlantic.

The total area of the Arctic Ocean has been estimated to be about 5,427,000 square miles. The Arctic or North Polar Sea which extends from the pole to about 80˚N contains two basins, each with depths over 3,962m, separated by a ridge or system of ridges, one of which, the Lomonosov Ridge, extends from the N of Greenland to the New Siberian Islands. The Marvin Ridge lies a little to the W of the Lomonosov and parallel to it, in the region between the North Pole and Ellesmere Island. These enormous submarine features rise from the floor depth to between 1,005 and 1,371m below the surface. The Greenland Sea and the Norwegian Sea, each over 2,987m deep, are separated by a ridge about 1,981m deep, and the northernmost of the two (Greenland Sea) is separated from the North Polar Sea by the Nansen Ridge, about 1,524m deep.

The Arctic Basins



The S boundary of the Norwegian Sea is formed by the Wyville Thompson Ridge which projects from Scotland to Iceland with an extension lying between Iceland and Greenland. A similar ridge extends across the Davis Strait, W of Greenland, forming the S boundary of Baffin Bay. This extensive ridge system, only about 609m below the surface, effectively divides the Arctic Ocean system from the North Atlantic proper.

The Arctic Ocean has three deep basins separated by parallel ridges.

The Nansen Basin (Eurasian Basin) (Nansen Deep) (85˚N., 50˚E.) adjoins the continental shelves of the Barents Sea and the Kara Sea. It deepens gradually to the N and reaches depths of more than 3,500m. The **Arctic Mid-Ocean Ridge** (Gakkel Ridge) (86˚N., 40˚E.) lies N of the Nansen Basin. This ridge is believed to be a continuation of the Mid-Atlantic Ridge and is similarly seismically active. Rather than being a ridge in the true sense, it consists of a series of seamounts and fracture zones, with a maximum relief of about 1,000m separated by a rift valley which forms a 4,000m cleft along the centerline.

The **Amundsen Basin** (Fram Deep) (88˚N., 40˚E.), with depths of more than 4,200m, lies farther N. The North Pole is situated in this basin just before the steep rise to the **Lomonosov Ridge** (89˚N., 160˚E.), which bisects the Arctic Ocean from N Greenland to Novo Sibirskiye Ostrova and rises to depths of less than 1,000m.

The **Makarov Basin** (Makarov Deep) (85˚N., 170˚E.), with a depth of 4,000m, lies between the Lomonosov Ridge and the East Siberian Sea. It is bounded on the E side by the the **Mendeleyev Ridge** (Alpha Ridge) (80˚N., 178˚E.) which rises to a depth of 1,200m and is joined to the continental shelf, near the E limit of the area covered by this volume, by a broad, triangular plateau.

The bottom deposits consist of mainly mud in the deep basins, with sand predominating on the ridges.

Baffin Bay has a maximum depth of just over 1,980m and the waters between the Canadian Arctic Islands have depths of 487m or less. Hudson Bay has a general floor depth of about 198m; Hudson Strait has a depth at its E end of a little over 396m. The continental shelf off the N Siberian coast is up to 435 miles wide; elsewhere it is quite narrow, with the exception of Hudson Bay and Foxe Basin, which are of shelf depths entirely.

The water masses in this system are the Arctic water; the Atlantic water; the Pacific water; and the deep water of the several basins. The coastal water and upper layer of the North Polar Sea are strongly influenced by drainage from the land.

The Arctic water is formed in the North Polar Sea from three sources: Atlantic water; drainage from the land; and water from the melting of ice. The result is a layer of water of generally negative temperatures and salinities below 34 grams of salt per kilogram of seawater. This layer is generally between 91m and 274m thick. Below it is a thicker layer of Atlantic water, entering the North Polar Sea between Spitsbergen and Greenland, with positive temperatures up to 3˚C but generally much lower, 0.5˚ to 1.5˚C. This layer reaches down to depths of 701 to 792m, below which is the mass of Arctic bottom water extending to floor depths, again with negative temperatures and salinities close to, but just below, 35 parts per thousand. Recent research seemed to show that these three layers are not so distinct as formerly thought.

Cautions

Oil Rigs—Wellheads

Drilling rigs are used to drill test wells if surveys confirm the possibility that oil or gas may be profitably extracted. Rigs are marked by lights; fog signals are sounded from them; and on some, flares burn at times to dispose of waste gases. But buoys, lighters and other obstacles, which may not be marked by lights or fog signals, are often moored near rigs. Wires often extend up to 1 mile from drilling rigs; mariners are advised to give rigs a wide berth.

There are four major types of drilling rigs in use at present on offshore fields:

1. Jack-up rigs are towed into position where their steel legs are lowered to the sea bed; the drilling platform is then jacked up clear of the water. They are used in depths up to about 100m.
2. Semi-submersible rigs consist of a platform on columns which rise from caissons submerged deep enough to avoid much of the effects of sea and swell. These rigs use 8-point anchoring systems, with anchor chain extending up to 0.75 mile from the rig. Large buoys, usually unlit, are moored above the anchors. Vessels are cautioned not to transit between the rig and the buoys.
3. Large semi-submersible rigs are self-propelled and may proceed unassisted by tugs at speeds up to 6 knots. Semi-submersible rigs may have displacements up to 25,000 tons and are used for drilling in depths up to about 180m, or in the case of self-propelled ones, up to about 300m.
4. Drillships are built with a tall drilling rig amidships, and usually with a helicopter deck near the stern. A typical drillship has a displacement of 14,000 tons, a length of 136m, and a maximum speed of 14 knots. Drillships working in depths of less than about 200m use an 8-point anchoring system. When drilling in deeper water, the position is maintained by gyro compasses and sonar linked to a dynamic station-keeping system of eleven computer-controlled propellers. Drillships are used in depths up to about 2,000m, and in favorable conditions can drill to a depth of 6,000m below the sea bed.

In the course of exploratory work, numerous wells are drilled. Wells which will not be required again are sealed with cement below the sea bed and abandoned. Suspended wells, which may be required at a later date, have their wellheads capped and left with a pipe and other equipment projecting from the sea bed. Such wellheads are sometimes marked by buoys to assist recovery and warn vessels that they are a hazard to navigation or fishing.

Production platforms are required to develop an oil or gas discovery. Many of these platforms, which may be manned or unmanned, are built to last the lifetime of the field which may be as long as 30 years, and are of massive construction. They are marked by lights; fog signals are sounded from them; and on some flares burn at times.

Mooring buoys, usually uncharted, are often moored as much as 1 mile from production platforms. Mariners are advised to give production platforms a wide berth.

Standby boats, used for routine servicing and emergency evacuation, are moored in the vicinity of the manned rigs and platforms. They are on call 24 hours and are subject to movement at any time.

The mariner is cautioned that, at times, the lights on some of the installations may be extinguished or obscured from a certain direction. This is especially true of unmanned platforms or wellheads, where maintenance may not be routinely carried out.

Under International Law, a coastal state may establish safety zones around such installations and devices as it may have constructed on the continental shelf to explore and exploit its natural resources. These installations include moveable drilling rigs, production platforms, wellheads, and single point moorings that may lie either inside or outside the state's territorial waters. An installation or device may be surrounded by a safety zone to a distance of 0.275 mile, measured from its outer edge. Ships of all nations are required to respect these safety zones.

Entry into these zones is prohibited, except in the following cases:

1. To repair a submarine cable or pipeline near the zone.
2. Either to provide services for an installation within the zone, or to transport persons or goods to or from it, or, with proper authorization, to inspect it.
3. To save life or property.
4. On account of stress of weather.
5. When in distress.

Draft Clearance

Deep-draft ships face the problem of navigating for considerable distances with a minimum depth below the keel in offshore areas.

Though considerable international effort has been expended recently in surveying a number of routes for these vessels, it should be realized that in certain critical areas depths may change quickly, and that present hydrographic resources are insufficient to allow these long routes to be surveyed frequently.

When planning a passage through a critical area, vessels should take full advantage of such co-tidal and co-range charts as are available. Possible occurrences of negative surges and possible reductions of depth below the keel due to settlement or squat should be considered.

Hydrographic surveys have inherent technical limitations, due partly, in offshore areas, to uncertainties in the tidal reductions. Furthermore, in some areas the shape and the depth of the ocean floor is constantly changing. Nautical charts can seldom be absolutely reliable in their representation of depth, and when tidal predictions are applied to the charts as if they were actual tide levels, the uncertainties are clearly compounded.

Ocean Data Acquisition System (ODAS)

The term Ocean Data Acquisition System (ODAS) covers a wide range of devices for collecting weather and oceanographic data. However, the devices of most concern to vessels consist of buoy systems which support instruments. These buoy systems may be expected to become more numerous each year and may be found in polar waters.

The buoy systems vary considerably in size and are either moored or free-floating. As far as possible, positions of the former will always be widely promulgated, and if considered to be of permanent enough nature, will be charted. In both types, the instruments may be either in the float or attached at any depth beneath it.

The buoys are colored yellow and marked ODAS with an identification number. The moored buoys are usually display a yellow light, showing a group of five flashes every 20 seconds.

ODAS buoys may be encountered in unexpected areas and often in deep water where navigational buoys would not be found. It should be noted that valuable instruments are often suspended beneath these systems or attached to the mooring lines. In some cases, the moorings have been cut loose beneath the buoy by unauthorized salvors, with the consequent loss of the most valuable part of the system.

The moored buoys may be up to 7.5m in diameter and 2 to 3m in height. The free-floating buoys are usually much smaller, 2m wide, and do not display a light.

Geophysical Features

Tundra Belt

The S shores of the Arctic Ocean are fringed by a belt of barren country, sometimes steep, rocky, and descending in less abrupt cliffs to the sea, but more often sloping down gently in mudbanks and sandhills. In Russia and by the scientific community, this belt is known as the tundra, and it is the region beyond the limit of forest growth. By far the greater part of the tundra is a gently undulating peaty plain, full of lakes, rivers, swamps, and bogs.

Mountains

The Ural Mountains extend approximately along the meridian of 60˚E from the Arctic Ocean nearly to the Caspian Sea and roughly separate Russia, in Europe, from Siberia. Kryazh Paykhoy is quite independent of the Urals proper, from which it is separated by a marshy tundra some 30 miles wide. It has a NW trend along the S shores of Kara Sea, and although this range is cut through by Proliv Yugorskiy Shar, it is continued in Ostrov Vaygach and Novaya Zemlya. Its dome-shaped summits, which are over 500m high, are completely destitute of trees, and its stony crags are separated by broad marshy tundras. The Obdorsk or Northern Urals, which begin within a few miles of the head of Karskaya Guba (69˚18'N., 64˚59'E.) and extend SW as far as the 64th parallel, form a distinct range, stony and craggy, sloping steeply and gently SE towards the marshes of European Russia. In some parts the main chain has on its W side two or three secondary chains, formed by the upheaval of sedimentary rocks, and it is towards the S extremity of one of these that the tallest peaks of the Urals occur, Sablia, 1667m high, at 64˚47'N and Toll-pos-is, 1687m high, at 63˚55'N.

Kryazh Byrrang approaches the sea in the vicinity of **Gavan Dikson** (73˚30'N., 80˚28'E.), on the E side of the entrance of Yeniseyskiy Zaliv.

Rivers

The principal rivers flowing into the Arctic Ocean from Russia are the Ob, Yenisey, Pyasina, Lena, Yana, Indigirka, and Kolyma.

Straits

Davis Strait is bound on the N by the parallel of 70˚N, the S limit of Baffin Bay; on the E by the SW coast of Greenland; on the S by the parallel of 60˚N between Greenland and Labrador; and on the W by Baffin Island, to the S of 70˚N, and the E limit of Hudson Strait.

Davis Strait, at its narrowest part, which occurs near where the strait is crossed by the Arctic Circle, is about 180 miles wide. This part, being on the Davis Strait Ridge, is also the shallowest. Here there are occasional soundings of less than 365m, whereas the depths increase rapidly both to the N and to the S. The deepest water is found in the southern entrance, where there are depths of over 329m.

On the Greenland side, the bottom rises steeply to a continental shelf that is narrow in its S part. This shelf broadens to the N, where the strait is narrowest. The N portion is divided into two principal banks, Lille Hellefiskebanke and Store Hellefiskebanke. Along the SW part of the coast, the 200m curve lies from 15 to 30 miles offshore, with a number of small banks lying just outside and with occasional deeps extending into or near the shore. Off Store Hellefiskebanke, the N bank, the 200m curve lies from 65 to 70 miles offshore. At the entrance of Baffin Bay, the deepest part of Davis Strait lies nearer to Baffin Island than to the Greenland shore.

The S part of the W coast of Greenland forms the E shore of Davis Strait and its S approach. This may be considered to include all of the coastline between Kap Farvel and Disko Island, a distance of more than 600 miles. This coastal region consists of a narrow strip of ice-free land, behind which rises the Inland Ice, the great ice mass that covers the interior of Greenland. The ice-free strip of the stretch of coast bordering Davis Strait is very narrow in the S part, and broadens to the N, attaining a width, in the vicinity of Holsteinsborg, of about 100 miles. The land fringe is cut by numerous fjords and inlets and broken up into islands of varying sizes.

Baffin Bay is bound on its E side by the W shore of Greenland and on its W side by Baffin Island, Devon Island, Ellesmere Island, and several smaller islets. This bay projects NNW from its S limit at 70˚N for about 530 miles to Nares Strait, which leads to the Arctic Ocean, about 300 miles NE.

Nares Strait, a channel leading NNE from Baffin Bay to the Arctic Ocean, passes between the W side of the N part of Greenland and the E coast of Ellesmere Island in Canada. Nares Strait, from S to N, consists of Smith Sound, Kane Basin, Kennedy Channel, Hall Basin, and Robeson Channel. The N end of Robeson Channel opens out into a portion of the Arctic Ocean named the Lincoln Sea. Nares Strait is about 300 miles long from the S end of Smith Sound to the N end of Robeson Channel, and varies in width from about 10 to 25 miles except in Kane Basin, where it opens out to a width of about 85 miles. Deep water to within a short distance of the contiguous shores is found throughout the channels and basins forming the waterway, except on the E side of Kane Basin.

The land on the W, or Ellesmere Island, coastline rises precipitously from the frozen sea to irregular mountains whose partly rounded peaks are generally marked by ice caps. Great glaciers fill the valleys and discharge icebergs into the various bays and fjords. Only the projecting rocky headlands and some of the lower points in the bays are free of snow and ice so that at least nine tenths of the surface is permanently covered by ice. This is in marked contrast to the Greenland coast where all the outer cliffs and shores are comparatively free from snow and ice. The cause of this remarkable difference is probably due to the currents along the respective coasts; on the coast of Ellesmere Island the Arctic current with its continuous current of ice blocks the bays and fjords, while on the Greenland coast the N flowing current is comparatively free of ice and allows the open water to raise the general temperature. The prevailing E winds also carry more moisture to the W side, which is masked at times by fog when there is brilliant sunshine on the Greenland coast.

Vesterisgrunnen (73˚30'N., 9˚10'W.) is a seamount, over which the least depth is 163m.

Denmark Strait separates Iceland from Greenland; the general depths are between 180 and 540m. A depth of 113m was reported near the middle of the strait (65˚53'N., 29˚40'W.).

The Northwest Passage spans the North American Arctic from Davis Strait and Baffin Bay in the E to Bering Strait in the W, and has four potentially feasible routes. The E entrance or exit for all routes lies through Lancaster Sound. Ice conditions may be forced to choose the alternative passage by way of Fury and Hecla Strait, but too difficult to be seriously considered.

The islands of the Canadian Arctic Archipelago form the emerged part of the continental shelf that extends poleward from the North American mainland and joins it to Greenland. Except for Baffin Bay and Davis Strait, all the channels lie on this shelf, which is deeper than most continental platforms, especially in the E part of the archipelago. This fact, together with the many old, raised beach lines and other evidence of emergence found throughout the formerly glaciated parts of the Canadian Arctic, supports the widely accepted theory that the whole area has been depressed, presumably as the result of glaciation, and is now gradually rising again.

Ice

Formation and Growth

In temperate and tropical latitudes the ocean acts as a storehouse of radiant heat from the sun. The visible and infra red wave lengths are largely absorbed in the surface layers, and the heat so stored is given off to the air at night and at other periods when the air is colder than the sea surface. In higher latitudes, as the nights begin to grow longer in the autumn, insufficient heat is stored in the short daylight period to compensate for the losses at night, and the temperature of the surface waters is therefore lowered. As the season progresses the altitude of the sun becomes lower day by day, less radiation is received, and more is reflected from the sea surface owing to the low angle of incidence of the rays. Finally, the water reaches the freezing point and further loss of heat results in the formation of ice.

Conditions then become even less favorable for the retention of radiant heat from the sun since ice reflects much more of the visible radiation than does water. Cooling of the air in contact with the ice is accelerated, and as this cold air spreads, more ice is formed.

Influence of Salinity

Fresh water freezes at 0˚C, but the salt present in sea water causes it to remain liquid until a lower temperature is reached. The greater the salinity, the lower the freezing point. Ordinary sea water, with a salinity 35 parts per 1,000, does not begin to freeze until it has been cooled to -1.9˚C.

Salinity may also affect the rate of freezing through its influence on the density of the water. Fresh water contracts on cooling and thus sinks below the surface until a temperature of 4˚C is reached. On further cooling it expands, so that its density decreases. If the cooling takes place at the surface with no other process of mixing at work, the coldest water stays there in a layer. It is then necessary for only this surface later to be cooled to the freezing point for ice to form. Water with a salinity of 5 parts per 1,000 has its greatest density at 2.8˚C, so the entire body of water must be cooled to that temperature before density currents cease. The temperature of maximum density decreases faster than the freezing point with increasing salinity. The two temperatures coincide at a salinity of 24.7 parts per 1,000. This means that with a salinity of 24.7 parts per 1,000 greater, density currents operate until the freezing point is reached, and theoretically the entire body must be cooled to this temperature before ice can form on the surface.

In nature, however, rapid cooling of still water often occurs under conditions where heat is removed from the surface layers faster than it can be supplied from the deeper layers through convection currents, so that ice will form on the surface before the deeper layers have approached the freezing point. Salinity gradients in the sea may also diminish the thermal convection currents. Because of discharge from rivers or melting of ice, the top layers have a lower salinity and the difference of density may be so great that the surface layer, although cooled to the freezing point, will be too light to sink below the warmer but more saline water underneath.

A practical outcome of the foregoing is that if a body of water originally of uniform density is losing heat at the surface, ice will be formed most readily in fresh water, less readily in sea water of low salinity, and least readily in sea water of high salinity. The greater heat removal required to freeze sea water is due not only to its relatively low freezing point, but also to the increased tendency of the cooled surface water to sink as the temperature of maximum density decreases.

Ice-forming Process

Due to its fairly high specific heat and low thermal conductivity, water loses heat slowly, so that the surface temperature of a large body of water will lag behind the rise and fall of the mean air temperature. In the Murmansk White Sea (65˚N to 70˚N), rivers usually freeze about 3 weeks after the mean air temperature falls below 0˚C. This phenomenon is probably representative of many similar regions.

Ice forms first in shallow water, near the coast or over shoals and banks, particularly in bays, inlets, and straits in which there is no current, and in regions with reduced salinity, such as those near the mouths of rivers. It spreads from these areas as centers. Such ice, broken up and carried seaward by winds or currents, starts further ice formation in deeper water, where floating ice that has not melted during the previous season also acts in the same way. Wave action ordinarily hinders the formation of ice to some extent by mixing the waters of the upper layers. Old ice damps sea or swell and, at the same time, by cooling and freshening the water and providing nuclei of ice crystals, assists the beginning of the freezing process. Quickly recurring fresh winds with raised sea will hinder ice formation, breaking it up several times. The greater the depth, with water of salinity greater than 24.7 parts per 1,000, the later is the time of freezing. As a matter of fact, complete freezing may never occur, as in the case of the central part of the White Sea; hence the necessity for following the deep water route in order to reach high latitudes during the season of ice formation.

The first sign of freezing is an oily or opaque appearance of the water, due to the formation of needle like spicules and thin plates of ice about one third of an inch across, known as frazil crystals. These consist of fresh ice, free of salt, and increase in number until the sea is covered by slush of a thick, soupy consistency.

Snow, falling into water, aids freezing by cooling and by providing nuclei for ice crystals. Except in sheltered waters, an even sheet of ice seldom forms immediately; the slush, as it thickens, breaks up into separate masses and frequently into the characteristic pancake form, the rounded shape and raised rim of which is due to the fragments colliding with each other. The formation of slush damps down sea or swell, and if the low temperature continues, the pancakes adhere to each other, forming a continuous sheet.

Rate of Ice Growth

Sea ice may grow to a thickness of 7 to 10cm in the first 24 hours, and from 5 to 8cm more in the second 24 hours. Ice is a poor conductor of heat and the rate of its formation drops appreciably after the first 10.2 to 15.2cm have formed; a snow cover, if present, still further reduces the conductivity. Once a layer of ice is formed, snow falling on the surface retards growth by its insulating power. This is particularly true of loosely packed snow.

A common assumption in the north is that heavy snow in the fall means a rapid break up in the spring. With the subsequent decreasing rate of growth, ice which has grown steadily throughout the winter is seldom more than 1.2m in thickness by the following summer.

Perennial sea ice may grow in thickness during the summer by refreezing of thaw water. Snow on the surface melts, and the water runs down through cracks and holes to form a layer of fresh water under the ice. Since the temperature of the underlying salt water is usually lower than the freezing point of fresh water, a layer of fresh water ice is formed on the bottom of the sea ice. In summer, therefore, a flow melts away on top, but at the same time may be growing slowly on its undersurface. By this process, mud, stones, seaweed, or shells originally frozen to the under side of grounded flows may work right up to the surface. Diatoms frozen to the under side will similarly rise. An autumn period follows, with lower temperature but without ice formation, the supply of fresh water being no longer renewed and the sea temperature not being low enough for the freezing of salt water to begin again. In the second winter, growth continues by salt water freezing. If the ice is unbroken through the second winter, its thickness may reach 2.1 to 2.4m at the most. Ice in the Arctic polar basin is seldom less than 1 to 1.4m thick, and Nansen reports a maximum thickness of 4.1m produced by about 4 years of normal growth.

The action of blocks and flows being forced over each other or turned on end by some form of pressure is called rafting. Ice of much greater thickness than ordinary flows can be formed by rafting, tidal overflow, or other types of flooding such as spray and splashing, but such areas will be of limited extent.

Paleocrystic Ice

The extreme development of sea ice is found in the channel between Grant Land and the NW coast of Greenland. Here the early explorers encountered ice masses so thick and irregular that they were assumed to be closely packed bergs of glacial origin. Later observations, however, indicate that this paleocrystic ice consists of remnants of Arctic pack that is blocked by the tip of Peary Land from drifting down the E coast of Greenland and instead is trapped along the N coast of Greenland and Grant Land. Intensive hummocking of this pack over a period of years produces tremendous flowbergs.

Arctic Ice vs. Antarctic Ice

Differences in underlying factors specific to the region develop corresponding differences in the features of the ice. An example of one of these agencies is the low mean annual temperature of the Antarctic. The warmth of the Arctic summer has no parallel in the far S and, mainly because of this thermal difference, the ice sheets of the northern polar regions are unlike those of the southern. The margin of the Antarctic cap, overflowing its land support, is free to spread over the sea until fracture detaches huge strips, sometimes including 10 to 20 miles of its front. In Greenland, by contrast, the edge of the inland ice ends on land, and icebergs irregular in shape are formed. The tabular or box-shaped berg is therefore, characteristic of the Antarctic while the pinnacled, picturesque berg is typical of the North.

The Antarctic sea ice surrounds the continent, while the Arctic sea ice is a central mass surrounded by land. The ice moves around and outward from Antarctica and gathers in a belt formed by the meeting of SE and NW winds in the vicinity of 60˚S. There is a close correspondence in the formation of this belt of ice with that formed in the Arctic which follows down Davis Strait and eastward off Greenland. In the Antarctic it is unusual for sea ice to be more than 1 or 2 years old. The drift in both the Weddell and Ross Seas carries the pack out into the open oceans in a little over a year.

In the Arctic, flows of great age are frequent. Ice formed off the Siberian coast takes from 3 to 5 years to drift across the polar basin and down the eastern coast of Greenland. Ice of this age becomes pressed and hummocked to a degree unknown in ice formed in lower latitudes. The warmth of the Arctic summers also has its effect and the result is worn down, more or less even, flows of great thickness known as "polar cap ice." During the summer, melting on the surface is considerable, as a rule about 2 feet, and pools of fresh water are formed on the flows. This is not a very marked feature off the E coast of Greenland, N of latitude 72˚N, but in Baffin Bay the flows become covered with a maze of deep pools. In the Antarctic, surface pools on flows in the pack are almost unknown. The outstanding difference between Arctic and Antarctic ice, which is apparent to the navigator, is the softer texture of the latter.

Ice Distribution

The sea ice terms used in the description are those adopted by the World Meteorological Organization in 1968. A glossary of these terms and photographs of typical ice formations are published in Pub. No. 9, The American Practical Navigator, (Bowditch), which also contains information on the formation and movement of sea ice, and operations and navigation in ice.

Bering Strait-Bering Sea-Chukchi Sea-Beaufort Sea

During winter and spring, ice covers nearly the entire NE half of the Bering Sea. The S portion of the ice covered area of the Bering Sea contains thin first year ice 30 to 71cm near the end of the growth cycle. The N portion and immediate coastal areas N of 62˚N attain medium first year growth 71 to 122cm.

The Bering Strait is covered throughout the growth cycle with thin and medium first year ice.

North of the Bering Strait, in the Chukchi Sea, the ice cover is medium and thick first year growth (greater than 48 inches, or 122 centimeters) during most of the growth cycle.

The Beaufort Sea is covered with vast expanses of thick first year and multi-year ice, 300cm thick during most of the growth cycle. The first year ice is generally confined to an area within 100 miles of the N Alaskan coast. Some years it may be more than 200 miles.

By early summer, the Bering Sea is normally free of sea ice. Ice concentration in areas N of the Bering Strait continues to decrease as summer progresses, and the ice edge retreats N in the Chukchi Sea. At the same time, the area N of Canada between Mackenzie Bay and Amundsen Gulf begins to decrease in ice concentration, and the ice edge retreats from the coast as sea ice disintegration accelerates. During the summer months, June to October, the Columbia Glacier becomes unstable along its face due to glacial melting and runoff. A calving bay forms dumping ice into Columbia Bay. Tidal currents drift ice from the bay into Prince William Sound. Ice production and distribution generally reaches a maximum in August and has been on the increase.

The ice edge normally continues to retreat N in both areas and eventually merges into one continuous edge reaching a maximum N position during the latter half of September. An ice free passage around Point Barrow to Mackenzie Bay is then possible, except during moderate ice years when the ice does not retreat very far from the coast. Transiting the area E of Point Barrow is hazardous, for belts or patches of ice may break away from the main pack and pose a threat to vessels with unreinforced hulls. A strong N wind could force enough ice down to the coast to trap a vessel.

During fall, beginning in October, the pack edge reverses direction and begins to move S. The average ice drift during October and November is from Alaska toward Russia. Southwest or W drift in the Bering Sea and Bristol Bay area (between November and April) causes a seaward flow of ice from near the Alaskan coast. The ice cover adjacent to the fast ice or the coast does not grow as much as sea ice that has drifted farther seaward.

Canadian Arctic Archipielago

The Labrador coast line is dominated by the cold, S flowing Labrador Current. The coast is normally closed to all shipping from late December to early June by drift ice from the N and local fast ice. Fast ice begins to form in the N coastal indentations (late November) and slowly expands farther S. By late December, it has reached the S coastal limit. As the fast ice formation progresses S, it also progresses seaward. A normal ice year produces fast ice 20 to 30 miles seaward from the coast. Melting and break up is accomplished in the reverse order. Drifting ice brought S from Baffin Bay and Hudson Strait by the Labrador Current first appears off Cape Chidley in early December. By late December, drift ice has reached the S extremity of Labrador. Its concentration depends on the amount of ice being released from Baffin Bay, the speed of the Labrador Current, and the prevailing winds. North or W winds spread the ice, decreasing the concentration. Southerly or easterly winds tend to "pack" the ice into high concentrations. Icebergs lie off the Labrador coast year around, with the amount depending upon the activity of glaciers in W Greenland and the previous winter's conditions of Baffin Bay. The largest number of bergs are present during early spring.

The only significant weather around Newfoundland that affects the ice observer is the persistent fog that shrouds the E coast for long periods in summer. The fog is caused by prevailing SW winds blowing first across the Gulf Current and then the cold Labrador Current.

Ice conditions in the Davis Strait and Baffin Bay vary greatly due to wind, current, and the severity of winter effects. September is the month in which the least ice should be found in this area with scattered rotten remnants of the pack ice, small flows, bergs, bergy bits and growlers remaining. The freezing process for both fast and pack ice begins in October. An interesting feature of Baffin Bay is the North Open Water, a recurring polynya.

The constricting effect of Smith Sound shuts off the supply of ice from the N causing an ice jam in the vicinity of Cape Sabin. South of the ice jam, ice is removed by winds and currents, producing a zone of lower ice concentration; and the counterclockwise rotation of the water, meeting with the southerly current from Robeson Channel, creating an area of upwelling or turbulence that prevents ice formation. In any event, open water exists even in mid-winter. Frobisher Bay ice conditions are subject to great variation year to year. It is usually open to icebreaker entry by late July and unescorted entry by late August, closing to shipping in mid-October and to icebreakers by mid-November. The best month for transit is September. The determining factor for opening Frobisher Bay is not so much the fast ice or local bay ice, but sea ice drifting from Baffin Bay and Hudson Strait. Also, grounded flows of heavily hummocked ice linger in the area to block shipping. The ports close when fast ice, beached ice, and ice foot formations occur along the shore in the upper bay. The great tidal change (7.5 to 9m) aids in beaching ice.

The easternmost most islands of the Canadian Archipelago normally have 152.4cm of ice in the upper fjords by January or February while the central third of the fjords have about 63.5cm. A tidal range of 2.4 to 3.3m keeps the ice elastic. Breakup begins in March and by May; the ice is heavily puddled and rotten. Throughout the Canadian Archipelago, the water moves S from the Arctic Ocean through the Queen Elizabeth Islands and joins the E flow through McClure Strait, Viscount Melville Sound, Barrow Strait, and Lancaster Sound into Baffin Bay. Most of the waterways are completely covered with ice except for short periods in the late summer or early fall. Many are never open to transit, even by an ice breaker.

Greenland

The W coast of Greenland is usually ice free as far N as Sondre Strom. There, fast ice will halt shipping by late December. The extent of both fast and pack ice increases to a maximum in March, extending as far S as Disco Bay. The ice in Baffin Bay is in continual motion, averaging 1.2 in thickness with the heaviest concentrations lying on the W side as far S as Cape Dyer. The disintegration begins in April. By mid-June, the pack ice S of 73˚N. is well puddled. Greenland coastal area is essentially ice free as far N as Upernavik. By mid-July, Thule is ice free and remains so through September. The route between Thule and Alert is never ice free, and is navigable only by icebreakers. In August, Smith Sound is usually 6 to 7 octas of ice. The wind speed/direction determines whether the lead will be along the E or W coast of the Robeson Channel.

The E Greenland coastal area is regarded as one of the most inaccessible areas in the world. This is because of the continual flow of multi year ice from the Arctic Ocean drifting with the East Greenland Current. Approximately 90 per cent of the total ice that is lost from the Arctic each year is carried S in this strong current. Throughout the year, drifting ice extends 100 to 300 miles off shore to the N of Scoresby Sound. To the S of Scoresby Sound, the maximum offshore extent is reached in April when the ice may extend nearly 200 miles offshore. The minimum is reached in August or September when only belts and patches are present. The drifting pack ice is at its maximum S extent from December through May when it rounds Kap Farvel. Fast ice may be found in protected coastal indentations, except S of Scoresby Sound. The fjords are cleared throughout the winter by the foehn effect. Icebreakers can usually enter Scoresby Sound between early August to mid-October if extreme caution is used. Kulusuk is resupplied each year from mid-August through September by icebreakers. The vast ice cap, measuring as thick as 3,048m in the interior, spills out through the mountainous rim down fjords as glaciers. This action generates numerous ice bergs that drift S and threaten shipping.

Russia

The N shore of Russia is dominated by winter ice, frozen fast from the Chukchi Sea to the Kara Sea until June. The influx of warm water from the North Atlantic Drift (an extension of the Gulf Current) and the run off from the Ob, Yenisei, Lena and Kolyma rivers causes the pack ice to melt rapidly. By mid-July, a narrow shore lead develops along the coastline. By August, there is a navigable area extending along the entire coast that remains open until October. In October, the N and NE winds push the Arctic pack onto the shore, closing the Chukchi and Laptev Seas. This is followed by the closing of the East Siberian Sea, and finally, the Kara Sea in November. By December, the strait between Novaya Zemlya and the mainland is closed by winter ice. In late December or early January, fast ice forms in the protected bays of the Barents Sea. The western edge of the Barents Sea is kept fairly ice free by the North Atlantic Drift.

Svalbard

Svalbard experiences heavy fast ice formation along its N and E coasts during the winter, with only a narrow band of fast ice or ice free areas along the S and W coasts. The N coast is usually navigable by late August or early September, but the E coast thaws slowly, if at all. Henlopen Strait has some ice throughout the summer.

Iceland

Due to the North Atlantic Drift, Iceland usually remains ice free throughout the year, except for some fast ice in its harbors on the N coast. Occasionally some weak fast ice will form in bays along the S coast. The heavy pack ice will drift to within 50 miles of the W coast of Iceland.

Ice Patrol Service

The sinking of the Titanic in 1912 prompted the maritime nations with ships transiting the Grand Banks area off Newfoundland, Canada, to establish an iceberg patrol in the area. Since 1913, the International Ice Patrol (IIP) has been responsible for monitoring the extent of iceberg danger. The Ice Patrol is funded by the twenty member nations signatory to the Safety of Life at Sea (SOLAS) Convention who reimburse the United States for this service. It has proven to be an outstanding example of effective international cooperation for the preservation of life and property at sea.

International Ice Patrol (IIP)

The IIP provides a service which monitors the extent of the iceberg danger in the vicinity of the Grand Banks of Newfoundland. Information on Limit of All Known Ice (LAKI) is broadcast to all shipping. The IIP uses reports from various sources. They include icebergs detected by IIP, Canadian reconnaissance flights, and reports of sighting made by the passing vessels.

The iceberg limits vary considerably through the ice season and between seasons. The number of icebergs crossing 48˚N have been tracked. This count has an advantage, by providing a single value for the season severity, but also the disadvantage that it runs loose (trackline deviation) from the predicted iceberg population that require mariners to keep clear of the danger zone. The size of the LAKI also dictates aircraft requirements for IIP reconnaissance.

The following describes icebergs reported to the IIP:

Name (Code)	Height	Length
Growler (G)	less than 1m	less than 6m
Smaller Iceberg (S)	1-15m	6-60m
Medium Iceberg (M)	16-45m	61-122m
Large Iceberg (L)	more than 45m	more than 122m

Shape Description	
Tabular (T)	Flat topped iceberg with a length/height ratio greater than 5:1.
Non Tabular (N)	Covers all icebergs that are not tabular shaped, as described above. This includes icebergs that are dome-shaped, sloping, blocky, and pinnacled.

Ice Terms

The following glossary of ice terms gives definitions of descriptive terms in general use for the many kinds of ice found at sea. The terms are based on the Ice Nomenclature established by the World Meteorological Organization (WMO).

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

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

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

Bare ice—Ice without snow cover.

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

Bergy bit—A large piece of floating glacier ice, generally showing less than 5m above sea level but more than 1m and normally about 100-300 m^2 in area.

Bergy water—An area of freely navigable water in which glacier ice is present in concentrations less than 10 per cent. There maybe sea ice present, although the total concentration of all ice shall not exceed 10 per cent.

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

Big flow—(also see flow).

Bight—Extensive crescent-shaped indentation in the ice edge, formed by either wind or current.

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

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

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

Close pack ice—Pack ice in which the concentration of 70 to 80 per cent is composed of flows mostly in contact.

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

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

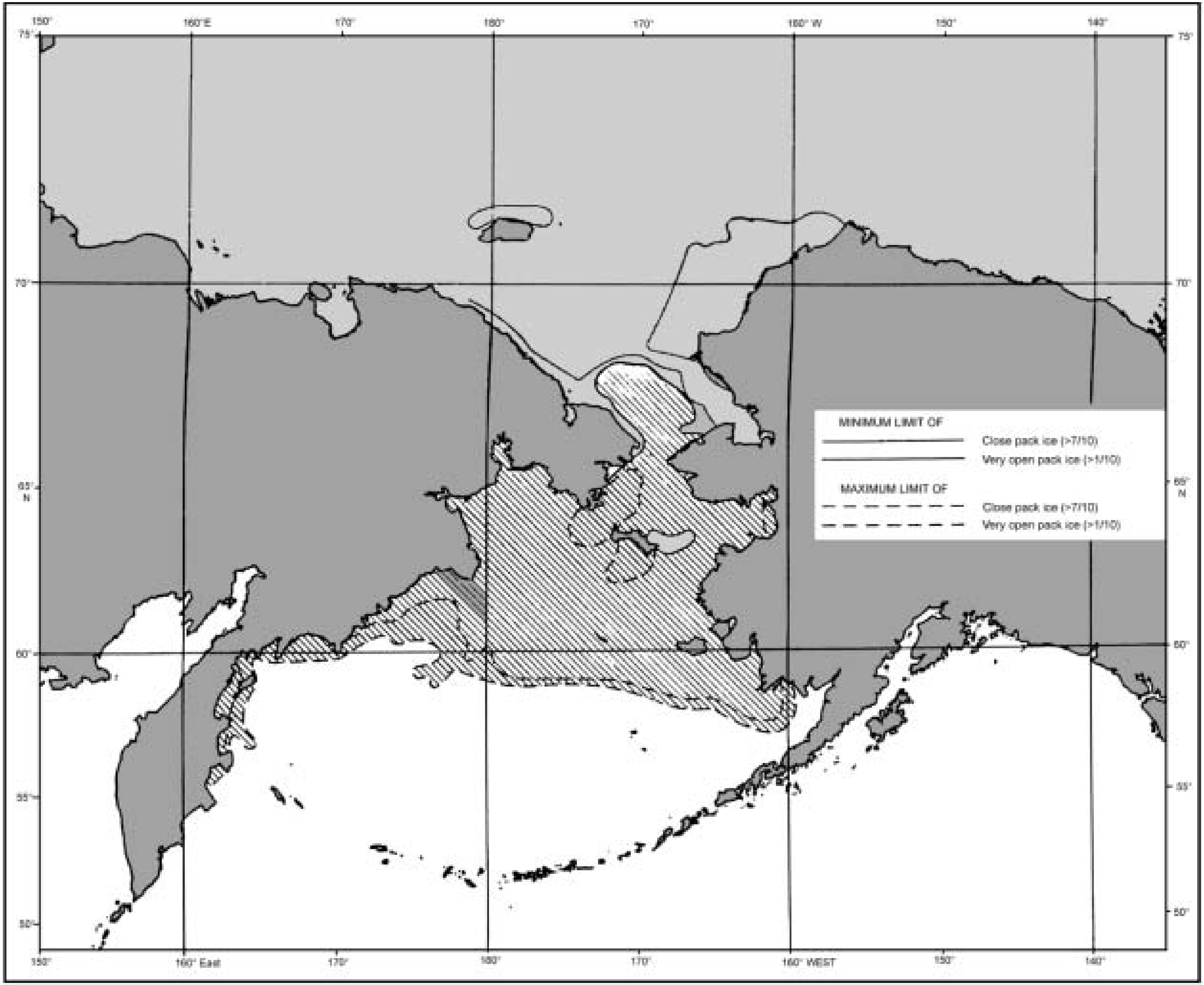
Compact pack ice—Pack ice in which the concentration is 100 per cent and no water is visible.

Concentration—The ratio expressed in tenths describing the amount of the sea surface covered by floating ice as a fraction of the whole area being considered. Total concentration includes all stages of development that are present, partial concentration may refer to the amount of a particular stage or of a particular form of ice and represents only a part of the total.

Concentration boundary—A line approximating the transition between two areas of pack ice with distinctly different concentrations.

Consolidated pack ice—Pack ice in which the concentration is 100 per cent and the flows are frozen together.

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



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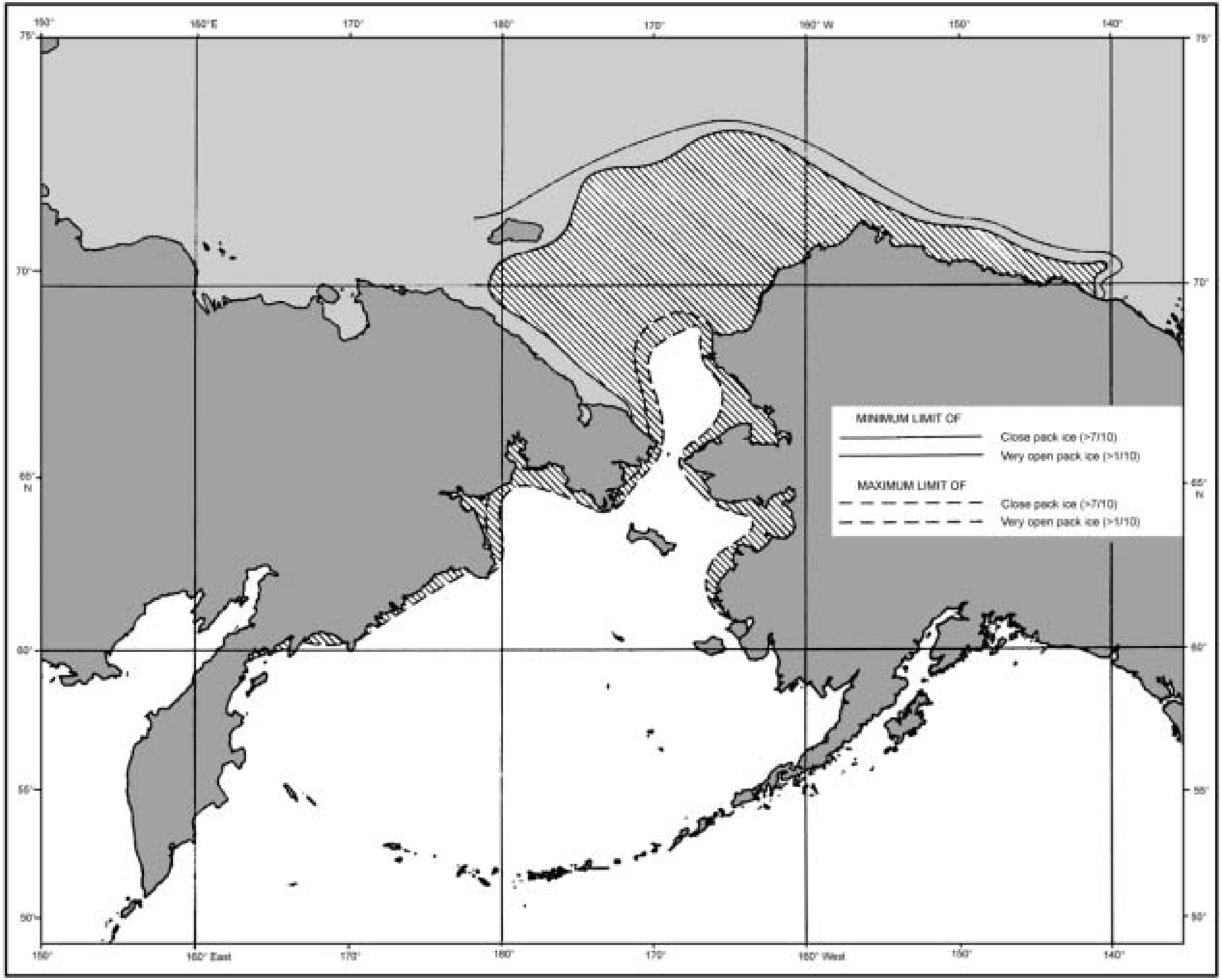

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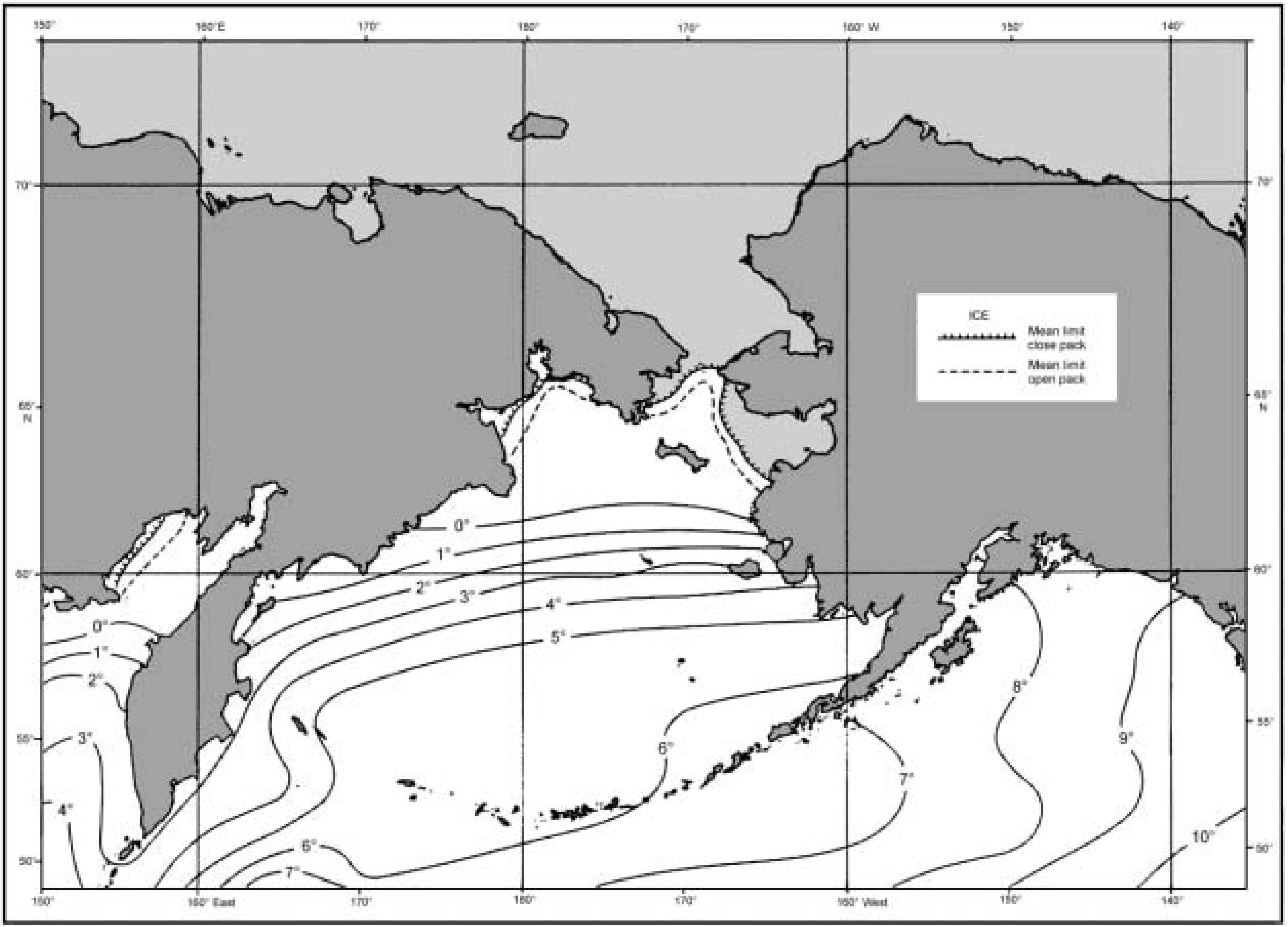
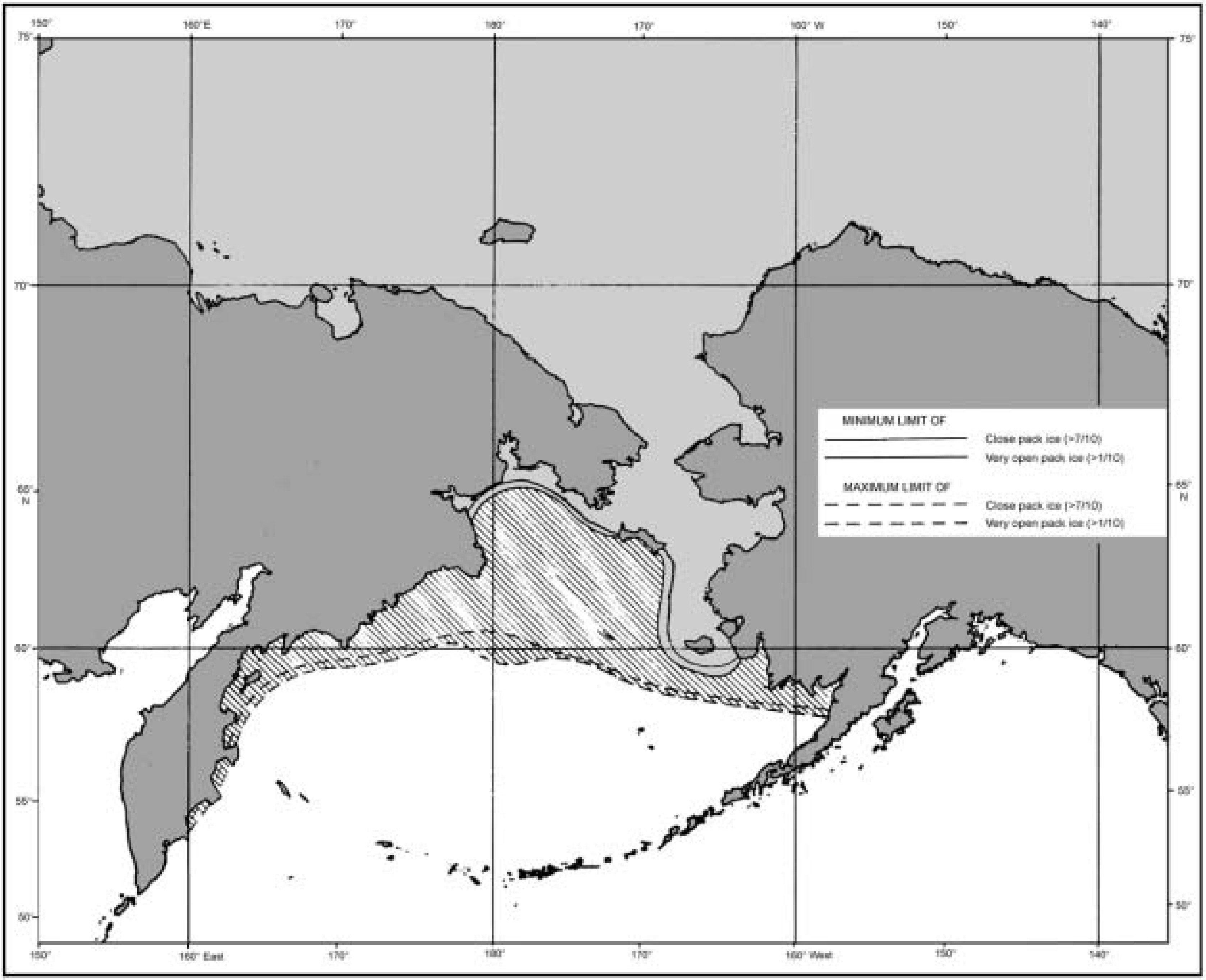


Mean Sea Surface Temperature (˚C) and Mean Sea Ice Limits—November



Limits of Sea Ice at the End of December

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Arctic Ocean Index

Crack—Any fracture of fast ice, consolidated ice or a single flow which has been followed by separation ranging from a few centimeters to 1m.

Dark nilas—Nilas which is under 5cm in thickness and is very dark in color.

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

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

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

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

Drift ice—Term used in a wide sense to include any area of sea ice other than fast ice no matter what form it takes or how it is dispersed. When concentrations are high, i.e. 70 per cent or more, drift ice may be replaced by the term pack ice.

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

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

Fast ice—Sea ice which forms and remains fast along the coast, where it is attached to the shore, to an ice wall, to an ice front, between shoals or grounded icebergs. Vertical fluctuations may be observed during changes of sea level. Fast ice may be formed in from sea water or by freezing of drift ice of any stage to the shore, and it may extend a few meters or several hundred kilometers from the coast. Fast ice may be more than 1 year old and may then be prefixed with the appropriate age category (second-year, or multi-year). If it is thicker than about 2m above sea level it is called an ice shelf.

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

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

Finger rafted ice—Type of rafted ice in which flows thrust "fingers" alternately over and under the other.

Finger rafting—Type of rafting whereby interlocking thrusts are formed, each flow thrusting "fingers" alternately over and under the other. Common in nilas and gray ice.

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

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

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

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

Flaw polynya—A polynya between pack ice and fast ice.

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

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

1.	Giant	Over 10 km across
2.	Vast	2-10 km across
3.	Big	500-2,000m across
4.	Medium	100-500m across
5.	Small	20-100m across

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

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

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

Fracture zone—An area with a great number of fractures.

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

Frazil ice—Fine spicules or plates of ice, suspended in water.

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

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

Giant flow—(also see flow).

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

Glacier berg—An irregularly shaped iceberg.

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

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

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

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

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

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

Grounded ice—Floating ice which is aground in shoal water (also see stranded ice).

Growler—Smaller piece of ice than a bergy bit or flowberg, often transparent but appearing green or almost black in color, extending less than 1m above the sea surface and normally occupying an area of about 20 m^2.

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

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

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

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

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

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

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

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

Ice boundary—The demarcation at any given time between fast ice and drift ice or between areas of drift ice of different concentrations (also see ice edge).

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

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

Ice canopy—Drift ice from the point of view of the submariner.

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

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

Ice field—Area of floating ice consisting of any size of flows, which is greater than 10 km across (also see patch).

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

Ice-free—No sea ice present. There may be some ice of land origin present (also see open water).

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

Ice island—A large piece of floating ice protruding about 5m above sea level which has broken away from an Antarctic ice shelf, having a thickness of 30 to 50m and an area of from a few thousand square meters to 500 km^2 or more, and usually characterized by a regularly undulating surface which gives it a ribbed appearance from the air.

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

Ice jam—An accumulation of broken river ice or sea ice caught in a narrow channel.

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

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

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

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

Ice patch—An area of pack ice less than 10 km across.

Ice piedmont—Ice covering a coastal strip of low-lying land backed by mountains. The surface of an ice piedmont slopes gently seaward and may be anything from about 50m to 30 miles wide, fringing long stretches of coastline with ice cliffs known as ice walls. Ice piedmonts frequently merge into ice shelves.

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

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

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

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

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

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

Jammed brash barrier—A strip or narrow belt of new, young, or brash ice (usually 100 to 5,000m wide), formed at the edge of either drift or fast ice or at the shore. It is heavily compacted mostly due to wind action and may extend 2 to 20m below the surface but does not normally have appreciable topography. Jammed Brash Barrier may disperse with changing winds but can also consolidate to form a strip of unusually thick ice as compared to the surrounding pack ice.

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

Large fracture—More than 500m wide.

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

Lead—Any fracture or passageway through sea ice which is navigable by surface vessels.

Level ice—Sea ice which is unaffected by deformation or contortion.

Light nilas—Nilas which is more than 5cm in thickness and rather lighter in color than dark nilas.

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

Medium first-year ice—First-year ice 70 to 120 cm thick.

Medium flow—(see flow).

Medium fracture—200 to 500m wide.

Medium ice field—An ice field 15 to 20 km across.

Moraine—Ridges or deposits of rock debris transported by a glacier. Common forms are: ground moraine, formed under a glacier; lateral moraine, along the sides; medial moraine, down the center; and end moraine, deposited at the foot. Moraines are left after a glacier has receded, providing evidence of its former extent.

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

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

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

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

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

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

Open ice—Floating ice in which the concentration is 40 per cent to 60 per cent with many leads and polynyas, and the flows are generally not in contact with one another.

Open water—A large area of freely navigable water in which sea ice is present in concentrations less than 10 per cent. When there is no sea ice present, the area should be termed ice free.

Pack ice—Concentration of 70 per cent or more of drift (also see drift ice).

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

Pingo—A mound formed by the upheaval of subterranean ice in an area where the subsoil remains permanently frozen. Pingos are also found in Arctic waters, rising about 30m from an otherwise even seabed, with bases about 40m in diameter and surrounded by a shallow moat; they are then termed submarine pingos. Generally in the ocean, pingos are more or less a conical mound of fine, unconsolidated material characteristically containing an ice core.

Polynya—Any non-linear shaped opening enclosed in ice. Polynyas may contain brash ice and/or be covered with new ice, nilas, or young ice; submariners refer to these as skylights. Sometimes the polynya is limited on one side by the coast and is called a shore polynya or by fast ice and is called a flaw polynya. If it recurs in the same position every year, it is called a recurring polynya.

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

Rafted ice—Type of deformed ice formed by one piece of ice overriding another (also see finger rafting).

Rafting—Pressure processes whereby one piece of ice overrides another. Most common in the new and young ice (also see finger rafting).

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

Recurring polynya—A polynya which recurs in the same position every year.

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

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

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

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

Rime—A deposit of ice composed of grains more or less separated by trapped air, some adorned with crystalline branches, produced by the rapid freezing of super-cooled and very small water droplets.

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

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

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

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

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

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

Shearing—An area of ice is subject to shear when the ice motion varies significantly in the direction normal to the motion, subjecting the ice to rotational forces. These forces may result in phenomena similar to flaw.

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

Shear ridge field—Many shear ridges side by side.

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

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

Shore melt—Open water between the shore and the fast ice, formed by melting and/or due to river discharge.

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

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

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

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

Small flow—See flow.

Small fracture—50 to 200m wide.

Small ice cake—An ice cake less than 2m across.

Small ice field—An ice field 10 to 15 km across.

Snow-covered ice—Ice covered with snow.

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

Standing flow—A separate flow standing vertically or inclined and enclosed by rather smooth ice.

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

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

Submarine pingo—See pingo.

Tabular berg—A flat-topped iceberg. Most tabular bergs form by calving from an ice shelf and show horizontal banding (also see ice island).

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

Thick first-year ice—First-year ice over 120cm thick.

Thin first-year ice/white ice—First-year ice 30 to 70cm thick. May sometimes be subdivided into first stage 30 to 50cm thick and second stage 50 to 70cm thick.

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

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

Vast flow—See flow.

Very close pack ice—Pack ice in which the concentration is 90per cent to less than 100 per cent.

Very open pack ice—Pack ice in which the concentration is 10 per cent to 30 per cent and water preponderates over ice.

Very small fracture—1 to 50m wide.

Very weathered ridge—Ridge with peaks very rounded, slope of sides usually 20˚ to 30˚.

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

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

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

White ice—(see Thin first-year ice/white ice).

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

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

Ionospheric Disturbance

A Sudden Ionospheric Disturbance (SID) is caused by abnormal X-ray emissions from a solar optical flare. The flare radiation enters the earth's ionosphere, where it increases the ionization at heights of 40 to 55 km. The resultant radio wave attenuation is strongest directly under the sun, and gradually weakens as the sun's zenith angle decreases. The SID is therefore relatively weak at high latitudes. The radio wave attenuation reaches its maximum value within a few minutes after the start of the SID. The return to normal depends on the duration of the solar flare, and may take from several minutes up to as much as 3 to 4 hours.

In a Polar Cap Absorption (PCA) occurrence, as is the case in a sudden ionospheric disturbance, radio waves are absorbed in the lower ionosphere, and low frequencies are attenuated much more strongly than high frequencies. A PCA occurrence differs from an SID in several important respects; it occurs only in the polar regions, above the 50th to 60th parallel of north or south latitude; it lasts much longer than a SID and it affects a wider range of frequencies (about 0.2 to 100 MHz). During the 1949-59 sunspot cycle, about forty moderate to strong PCA occurrences took place, each with an average duration of two days. Nearly half of these PCAs occurred in 1957-59, near the peak of the sunspot cycle, but none during the sunspot minimum years of 1952 through 1955. High frequency radio links with transmitting and receiving terminals within the Arctic Circle may become inoperative during the daylight hours of a PCA occurrence; communication may be reestablished several hours after sunset, but a second blackout may occur the next day after sunrise. However, such re-establishment of communication would not be possible for links located in the high Arctic where the sun does not set during mid-summer months.

A PCA event is caused by sporadic emission of highly energetic charged particles from the sun, called "solar cosmic rays." As a result of their electrical charge, the earth's magnetic field deflects the solar cosmic rays from the equator toward the polar regions, where most of them are absorbed at heights of 50 to 100 km. The PCA events usually start within a few minutes or hours of a large solar flare, but they continue long after the initiating flare has died out, in some instances for five or six days. The radio wave attenuation depends not only on the flux of solar cosmic rays, but also on the intensity of sunlight in the lower ionosphere. The attenuation is maximum near noon, and often becomes quite weak at night.

Bearings

Natural landmarks are plentiful in some areas, but their usefulness is restricted by the difficulty in identifying them, or locating them on the chart. Along many of the coasts of the Arctic Ocean, the various points and inlets bear a marked resemblance to each other. In addition, the appearance of the coast is often very different when many of its features are masked by a heavy covering of snow or ice.

Bearings of landmarks are useful, but they have limitations. When bearings of more than two objects are taken, they may fail to intersect at a point because the objects may not be charted in their correct relation to each other. Even a two-point fix may be considerably in error since the objects used may be charted in correct relationship to one another, but in the wrong position geographically. However, in restricted waters, it is usually more important to know the position of the vessel relative to the nearby land and shoals than to know the accurate latitude and longitude. The bearings and distances of uncharted, locally known objects then become valuable.

When a position is established relative to nearby landmarks, it is good practice to use this to help establish the identity and location of some prominent feature a considerable distance ahead. Through this practice, unidentifiable or uncharted features can be used to establish future positions.

In high latitudes, it is not unusual to make use of bearings of objects which are located a considerable distance from the vessel. Because of the rapid convergence of the meridians in these areas, such bearings are not correctly represented by straight lines on a Mercator chart. Therefore, if this projection is used, the bearings should be corrected in the same manner that radio bearings are corrected, because both can be considered to be great circles. However, neither visual nor radio bearings require a correction when plotting on a Lambert Conformal or a Polar Stereographic chart.

Magnetic Field

The dip poles, commonly referred to as the magnetic poles, are the points on the earth's surface at which the horizontal component (H) of the total magnetic field decreases to a minimum (approaches zero), and where the magnetic field is nearly all vertical. At such a point, a dip needle will stand straight up and down.

The magnetic poles should not be confused with the geomagnetic poles. Although the term geomagnetic pole does not have a rigorous definition and usage varies among different textbooks, the most common definition is a theoretical point at which the axis of a central dipole field intersects the earth's surface. However, the earth's magnetic field is not a pure dipole as it contains approximately 5 per cent quadrupole and external magnetic field components. Therefore, the two principal magnetic dipoles (North and South) do not correspond with the geomagnetic poles.

There is a misconception that the needle of a magnetic compass points to the magnetic pole. Actually, the direction indicated by such a needle is the local horizontal direction of the earth's magnetic lines of force. These lines eventually converge at the magnetic poles but wander considerably. A compass cannot be used in regions near the magnetic pole to find direction as it will remain in any direction in which it happens to be placed. In reality, a rather large area, in which a compass cannot be used, surrounds the magnetic pole because of the low magnitude of H. Where H is approximately 6,000 nanoteslas (nT) or less, the compass is frequently erratic. The magnetic compass is not reliable for underway navigation where H is 3,000 nT or less. In comparison with the North Magnetic Pole, the region surrounding the South Magnetic Pole, where the compass is unreliable, is much smaller.

Magnetic Poles

The Department of Defense (DoD) computed the location of the North Magnetic Pole on January 1, 1995, to be 79˚00'N, 105˚06'W and the location of the South Magnetic Pole to be 64˚44'S, 138˚38'E. These locations were computed using the 1995 Epoch World Magnetic Model, WMM-95, which was used in the compilation of charts published by NIMA from January 1995 to January 2000. A 2000 version of the Epoch World Magnetic Model is now available for use, replacing the 1995 model.

WMM-2000 is the product of a cooperative effort between the United States Naval Oceanographic Office (NAVOCEANO) and the United Kingdom's British Geological Survey (BGS). It is the official model for both the U.S. and U.K. defense establishments.

Magnetic Variation

Magnetic variation information printed on topographic maps and nautical charts is derived from a model, which must be redefined at least every five years.

The principal reason is that the earth's magnetic field changes appreciably in that period of time, and it has not been

CONVERSION ANGLE TABLE FOR VISUAL BEARINGS IN POLAR WATERS

Mid Latitude	Difference of Longitude									Mid Latitude
°	0°	0.5°	1°	1.5°	2°	2.5°	3°	3.5°	4°	4.5°	°
	°	°	°	°	°	°	°	°	°	°	
61	0.0	0.2	0.4	0.7	0.9	1.1	1.3	1.5	1.7	2.0	61
62	0.0	0.2	0.4	0.7	0.9	1.1	1.3	1.5	1.8	2.0	62
63	0.0	0.2	0.4	0.7	0.9	1.1	1.3	1.6	1.8	2.0	63
64	0.0	0.2	0.4	0.7	0.9	1.1	1.3	1.6	1.8	2.0	64
65	0.0	0.2	0.5	0.7	0.9	1.1	1.4	1.6	1.8	2.0	65
66	0.0	0.2	0.5	0.7	0.9	1.1	1.4	1.6	1.8	2.1	66
67	0.0	0.2	0.5	0.7	0.9	1.2	1.4	1.6	1.8	2.1	67
68	0.0	0.2	0.5	0.7	0.9	1.2	1.4	1.6	1.9	2.1	68
69	0.0	0.2	0.5	0.7	0.9	1.2	1.4	1.6	1.9	2.1	69
70	0.0	0.2	0.5	0.7	0.9	1.2	1.4	1.6	1.9	2.1	70
71	0.0	0.2	0.5	0.7	0.9	1.2	1.4	1.7	1.9	2.1	71
72	0.0	0.2	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.1	72
73	0.0	0.2	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.2	73
74	0.0	0.2	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.2	74
75	0.0	0.2	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.2	75
76	0.0	0.2	0.5	0.7	1.0	1.2	1.5	1.7	1.9	2.2	76
77	0.0	0.2	0.5	0.7	1.0	1.2	1.5	1.7	1.9	2.2	77
78	0.0	0.2	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	78
79	0.0	0.2	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	79
80	0.0	0.2	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	80
81	0.0	0.2	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	81
82	0.0	0.2	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	82
83	0.0	0.2	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	83
84	0.0	0.2	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	84
85	0.0	0.2	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	85

The table should be entered with the middle latitude and the difference in longitude (between the object and the vessel). The angles listed in the table (corrections) represent the difference between the great circle bearing and the rhumb line direction (Mercator). The sign of the correction to be applied is as follows:

Latitude of Vessel	Object/Landmark (direction from vessel)	Correction Sign
South	East	-
South	West	+
North	East	+
North	West	-

possible to predict the secular change with confidence more than a few years into the future.

Variation, also known as magnetic declination, is measured in angular units and named East or West to indicate the side of True North on which the N part of the magnetic meridian lies. East variation is positive and West variation is negative.The DoD publishes grid variation charts which illustrate the angle between the grid and magnetic meridians at any place.

Magnetic Anomalies

Significant magnetic anomalies may exist due to local magnetization in the earth's crust. These geologically produced magnetic fields cannot be modeled on a world-wide basis. Individual detailed geomagnetic surveys are required. Local conductivity anomalies will affect the way external magnetic fields generate currents in the crust, which in turn generate induced magnetic fields. These induction fields will also be local in character. Observations of erratic compass behavior should be reported with details of the particular circumstances at the time. Any disturbances to the geomagnetic field can also interfere with magnetic navigation. The flow of the solar wind (which contains electrons and protons) past the earth creates magnetic disturbances at the earth's surface. Some of these disturbances are known to be highly localized, while others occur over wide areas. Auroras are the visible result of a significant magnetic storm.

There are four different periodicities of magnetic disturbances. Although magnetic storms can occur at any time, they are most numerous during the period of maximum activity in the 11-year sunspot cycle. There is a weak semi-annual periodicity, where the level of disturbance is at a maximum in October and April. More prominently, magnetic storms tend to have a 27-day repetition period due to the synodic rotation period of the sun, that is, the apparent rotation period as seen from the earth. Magnetic storms typically last 2 to 3 days. The substorms which accompany them only last from 1 to 3 hours and tend to occur more frequently and more strongly at local midnight.

During a particularly intense magnetic storm, such as occurred in March 1989, electrical currents are generated in the magnetosphere and the ionosphere. The magnetic fields of these currents also induce fluctuating voltages in the earth and cause additional current. The total current can significantly alter the geomagnetic field observed at the earth's surface and change its direction as much as several degrees and its magnitude as much as 10 per cent.

In various parts of the world, magnetic ores on or just below the sea bed may give rise to local magnetic anomalies resulting in the temporary deflection of the magnetic compass needle when a ship passes over them. The areas of disturbance are usually small unless there are many anomalies close together. The amount of the deflection will depend on the depth of water and the strength of the magnetic force generated by the magnetic ores. However, the magnetic force will seldom be strong enough to deflect the compass needle in depths greater than about 1,500m. Similarly, a ship would have to be within 0.8 mile of a nearby land mass containing magnetic ores for a deflection of the compass needle to occur.

Local magnetic anomalies are depicted by a special symbol on charts and are mentioned in Sailing Directions (Enroute). The amount and direction of the deflection of the compass needle is also given, if known.

Deflections may also be due to wrecks lying on the bottom in moderate depths, but investigations have proved that, while deflections of unpredictable amount may be expected when very close to such wrecks, it is unlikely that deflections in excess of 7˚ will be experienced, nor should the disturbance be felt beyond a distance of 250m.

Greater deflections may be experienced when in close quarters of a ship carrying a large cargo such as iron ore, which readily reacts to induced magnetism.

Submarine power cables carrying direct current can cause deflection of the magnetic compass needle in vessels passing over them. The amount of the deflection depends on the magnitude of the electric current and the angle that the direction of the cable makes with the magnetic meridian.

Magnetic Anomalies—Northern Coast of Russia

Due to high latitudes the horizontal component of the earth's magnetic field is very small throughout this area. The effects of both local magnetic anomalies and of magnetic storms therefore create a much greater deflection of the compass needle compared to lower latitudes. Additionally, the area lies in or near the region of maximum auroral frequency, where there is a high level of magnetic disturbance. During a severe magnetic storm the resultant deflection of the compass may amount to several tens of degrees.

In the Kara Sea the average number of days per month on which the range of the deflection of the compass needle due to magnetic storms may reach a value of 4˚ may amount to 10. In the Laptev Sea severe magnetic storms occur not more than 4 or 5 days per month, but deflections of as much as 4˚ may occur on as many as 10 days per month. In the East Siberian Sea deflections of up to about 4˚ may occur about 10 to 12 days per month.

The magnetic variation in these regions also undergoes a diurnal fluctuation reaching its maximum about 0600 and 1800 hours, and its minimum about 1100 and 2300 hours. Under normal magnetic conditions the range of these fluctuations is about 11' at Proliv Matochkin Shar, 16' at Ostrov Dikson, 70' on a line between Mys Chelyuskina and Mys Anisiy, Ostrov Kotel'nyy, and 20' off the Lena delta. A report of much larger fluctuations was observed at Bukhta Ledyanaya.

From the above observations, although incomplete, it is found that the value of the magnetic variation changes rapidly from E to W, and the change is not uniform in many places. Navigators when in this area should:

1. Observe the behavior of the compass.
2. Check the compass error at frequent intervals.
3. Avoid using compass bearings until the vessel stabilizes on its new course.

Magnetic observatories have been established at Proliv Matochkin Shar, Ostrov Dikson, and Mys Chelyuskina. They will provide information regarding alterations in the earth's magnetic field on radio request.

During the navigational season, the Dikson radio station broadcasts information on the state of the earth's magnetic field. These broadcasts are primarily intended for the use of vessels bound between Proliv Yugorskiy Shar or Proliv Matochkin Shar and Ostrov Dikson; they will also provide an indication and occurrence of magnetic storms.

Observations of local magnetic anomalies have been made at the following places:

Proliv Yugorskiy Shar; the Barents Sea; Ostrova Barentsa; Zaliv Russkaya Gavan; Zemlya Vil'cheka; Proliv Avstriyskiy; Ostrov Mak Klintoka; Sharapovy Koshki; Obskaya Guba (N approach); Obskaya Guba; Gavan' Dikson approach; Shkhery Minina; Ostrov Torosovyy; between Mys Sterlegova and Mys

Dubinskogo; Ostrova Kruzenshterna; between Ostrov Pravdy and Zaliv Taymyrskiy; Bukhta Ledyanaya; Arkhipelag Nordenshel'da; Ostrov Russkiy (NW coast); between Gafner Fjord and Mys Chelyuskina; Proliv Shokal'skogo; Bukhta Snezhnaya; Ostrov Pioner; Zaliv Kalinina; Zaliv Krasnoy Armii; and Proliv Melyokov.

Magnetic Anomalies—East Coast of Greenland, Iceland, andSvalbard

The magnetic variation changes sufficiently, for example, a passage between Bjornoya (74˚30'N., 19˚00'E.) and Scoresby Sund (70˚20'N., 22˚00'W.) would experience a change of 33˚.

Local magnetic anomalies have been experienced in the fjords and off the coast of Iceland, in the vicinity of Jan Mayen and Bjornoya, and in the proximity of Spitsbergen.

Vessels navigating in these areas, especially when in depths of less than 90m, must keep a careful watch on the movements of the magnetic compass. Reports have been received that the permanent magnetism of vessels were temporarily affected, the disturbance can last for hours to several days. Strong disturbances have been noted in areas, especially in the vicinity of Iceland, in depths of 135m; disturbed areas may exist in other places in similar or greater depths. Vessels navigating in less depths, especially in the areas known to be affected, should ascertain their positions by sextant angles or objects in transit.

Magnetic Anomalies—West Coast Greenland and the Canadian Arctic Archipelago

In 2000, the North Magnetic Pole was situated in the Arctic Ocean NNW of Ellef Ringnes Island; it is continuing to migrate NNW. In this area the magnetic compass becomes progressively sluggish and less reliable for navigation; however, there are other areas such as Hudson Bay where the magnetic variation also changes rapidly.

These adverse conditions may be accentuated by local magnetic anomalies, observed from time to time, in several places off the W coast of Greenland, in Hudson Strait, and in Hudson Bay; also in the NW corner of Foxe Basin, the NW part of Baffin Bay, the E part of Parry Channel and in Admiralty Inlet, in Amundsen Gulf, and in Coronation Gulf.

A careful watch must be kept on the magnetic compass behavior when vessels navigating the W Greenland and Canadian Arctic waters. Any magnetic disturbances experienced on a vessel at any part of the arctic region should be recorded in detail and reported.

Polar Navigation

Navigation by magnetic compass in polar regions is much less reliable than in equatorial and mid-latitudes. Low directive force on the compass card, the enhanced effects of magnetic storms near the magnetic poles, the relatively sparse knowledge of local anomalies in regions outside commercial traffic areas, and the slow drift of the actual magnetic pole positions all contribute. As a minimum, the most current magnetic information and charts should be carried. Any chart older than the current model should be replaced.

Charts of the geomagnetic field are available from the Department of Defense (DoD). Magnetic variation charts are published every five years. Charts of the total intensity, vertical intensity, horizontal intensity, and inclination (magnetic dip) are published every 10 years.

Meteorology

Weather-related Phenomena

This area is commonly affected by depressions which develop over the Atlantic and enter the Norwegian Sea via the Iceland, Faeroes, Scotland gap. Occasionally depressions approach the area from N of Iceland though this is more usual in summer. They generally travel on a broadly NE track passing to the W of Norway and then often turn E or ENE round Nordkapp into the Barents Sea. Sometimes still deepening as they reach Norwegian waters, depressions usually begin to fill as they move NE to the colder waters area. Occasionally, a secondary depression may form at the tip of the warm sector. While the secondary depression moves away in a general E direction, the main depression may become slow-moving and erratic.

Another class of depression reaches the area from more northern latitudes. Often called "polar depressions," they are characterized by a large and intense area of showers, usually of snow, which are bunched together to form a cyclonic circulation. The lows are carried along in cold NW to NE airstreams and may continue to S Norwegian waters or towards Finland and N Russia.

Superstructure Icing

In certain weather conditions, ice accumulating on hulls and superstructures can be a serious danger to vessels. Ice accumulation may occur because of fog with freezing conditions; freezing rain or drizzle; and sea spray or salt water breaking over vessels when the air temperature is below freezing (about -1.9˚C).

The most dangerous form of icing is caused by sea spray, sometimes known as "Glaze Ice," which has high density and great powers of adhesion.

In evaluating the potential for superstructure icing, two categories were subjectively selected. Moderate ice accumulation seems to occur when the air temperature is less than or equal to -2˚C and the wind is stronger than or equal to 13 knots. If the air temperature decreases to -9˚C or below and the wind reaches 30 knots or more, ice accumulation takes place at an accelerated rate. This category is termed severe. For example, on a small fishing vessel of 300 to 500 tons displacement, ice accumulation in the severe category would exceed about 4 tons per hour.

Radio and radar failures due to ice accumulating on aerials and insulators may be experienced soon after superstructure icing begins. The ice tends to form high up on vessels and a large amount of accumulation may result in a loss of freeboard and stability.

The probability of forecasting gales with freezing air temperatures is made difficult by the sparseness of meteorological and oceanographic information in the Antarctic region. For this reason, superstructure icing represents a serious hazard to navigation anywhere S of the Antarctic Circle.

Immersion Hypothermia

Immersion hypothermia is the loss of heat when a body is immersed in water. With few exceptions, humans die if their normal rectal temperature of approximately 37.6˚C drops below 25.8˚C. Cardiac arrest is the most common direct cause of death. Except in tropical waters warmer than 20˚ to 25˚C, the main threat to life during prolonged immersion is cold or cold and drowning combined.

Cold lowers body temperature, which in turn slows the heart beat, lowers the rate of metabolism, and increases the amount of carbon dioxide in the blood. Resulting impaired mental capacity is a major factor in death by hypothermia. Numerous reports from shipwrecks and accidents in cold water indicate that people can become confused and even delirious, further decreasing their changes of survival.

The length of time that a human survives in water depends on the water surface temperature and, to a lesser extent, on a person's behavior. Body type can cause deviations, since thin people become hypothermic more rapidly than fat people. Extremely fat people may survive almost indefinitely in water near 0˚C if they are warmly clothed.

The cooling rate can be slowed by the person's behavior and insulated gear. In a study which closely monitored more than 500 immersions in the waters around Victoria B.C. temperatures ranged from 4˚ to 16˚C. Using this information it was reasoned that if the critical heat loss areas could be protected, survival time would increase. The Heat Escape Lessening Posture (HELP) was developed for those in the water alone and the Huddle for small groups. Both require a life preserver. HELP involves holding the upper arm firmly against the sides of the chest, keeping the thighs together, and raising the knees to protect the groin area. In the Huddle, people face each other and keep their bodies as close together as possible. These positions improve survival time in 9˚C water to four hours, approximately two times that of a swimmer and one and one half times that of a person in the passive position.

Near drowning victims in cold water (less than 21˚C) show much longer periods of revivability than usual. Keys to a successful revival are immediate cardiopulmonary resuscitation (CPR) and administration of pure oxygen. Do not bother with total rewarming at first. The whole revival process may take hours and require medical help.

Survival Time versus Water Temperature		
Water Temperature	**Exhaustion or Unconsciousness**	**Expected Time of Survival**
0˚C	15 minutes	15-45 minutes
0˚-5˚C	15-30 minutes	30-90 minutes
5˚-10˚C	30-60 minutes	1-3 hours
10˚-15˚C	1-2 hours	1-6 hours
15˚-20˚C	2-7 hours	2-40 hours
20˚-25˚C	3-12 hours	3 hours-indefinite
25˚C	Indefinite	Indefinite

Windchill and Frostbite

When the body is warmer than its surroundings it begins to lose heat. The rate of loss depends on the barriers to heat loss such as clothing and insulation, the speed of air movement and the air temperature. Heat loss increases dramatically in moving air that is colder than skin temperature (33˚C). Even a light wind increases heat loss while a strong wind can actually lower the body temperature if the rate of loss is greater than the body's heat replacement rate. In the Arctic, windchill results from the intense cold and strong winds. This combination affects not only comfort but the morale and safety of the crew.

The equivalent windchill temperature relates a particular wind and temperature combination to whatever temperature would produce the same heat loss at about 3 knots, the normal speed of a person walking. At extremely cold temperatures, wind and temperature effect may account for only two thirds of the heat loss from the body. For example, in 4˚C temperatures about one third of the heat loss from the body occurs through the lungs in the process of breathing. On the other hand heat loss is not as great in bright sunlight.

When the skin temperature drops below 10˚C there is a marked constriction of the blood vessels leading to vascular stagnation, oxygen want, and some cellular damage. The first indication that something is wrong is a painful tingling. Swelling of varying extent follows, provided freezing has not occurred. Excruciating pain may be felt if the skin temperature is lowered rapidly, but freezing of localized portions of the skin may be painless when the rate of change is slow.

Cold allergy is a term applied to the welts which may occur. Chilblains usually affect the fingers and toes and are manifested as reddened, warm, itching, swollen patches. Trench foot and immersion foot present essentially the same picture. Both result from exposure to cold and a lack of circulation. Wetness can add to the problem as water and wind soften the tissues and accelerate heat loss. The feet swell, discolor, and frequently blister. Secondary infection is common and gangrene may result.

Injuries from the cold may, to a large extent, be prevented by maintaining natural warmth through the use of proper footgear and adequate, dry clothing; by avoiding cramped positions and constricting clothing; and by active exercise of the hands, legs and feet.

Frostbite usually begins when the skin temperature falls within the range of -10˚ to -16˚C. Ice crystals form in the tissues and small blood vessels. Once started, freezing proceeds rapidly and may penetrate deeply. The rate of heat loss determines the rate of freezing, which is accelerated by wind, wetness, extreme cold, and poor blood circulation. Parts of the body most susceptible to freezing are those with surfaces large in relation to their volume, such as toes, fingers, ears, nose, chin and cheeks.

Navigational Information

Electronic Navigation

International Maritime Satellite Organization (INMARSAT)

Around the world satellite communication systems have now become synonymous with reliable and quality transfer of information. The International Maritime Satellite Organization (INMARSAT) is an international consortium comprising over

75 partners who provide maritime safety management and maritime communications services.

The INMARSAT system consists of a number of satellites, which maintain geosynchronous orbits, and provides quality communications coverage between about 77˚N and about 77˚S, including locations with less than a 5˚ angle of elevation.

INMARSAT-A, the original system, provides telephone, telex, and fax services. However, this system is being replaced by INMARSAT-B, which, by the use of digital technology, is providing the services with improved quality and higher data transmission rates. INMARSAT-C provides a store and forward data messaging capability, but no voice communication.

Global Maritime Distress and Safety System (GMDSS)

The Global Maritime Distress and Safety System (GMDSS) provides a great advancement in safety over the previous usage of short range and high seas radio transmissions.

The GMDSS has been adopted by the International Convention for the Safety of Life at Sea (SOLAS) 1974. It applies to cargo vessels of 300 grt and over and all vessels carrying more than 12 passengers on international voyages. Unlike previous regulations, the GMDSS requires vessels to carry specified equipment according to the area in which they are operating. Such vessels navigating in polar regions must carry VHF, MF, and HF equipment and a satellite Emergency Position Indicating Radiobeacon (EPIRB).

Information on the GMDSS, provided by the U.S. Coast Guard Navigation Center, is accessible via the Internet, as follows:

U. S. Coast Guard Navigation Center
http://www.navcen.uscg.mil/marcomms/default.htm

SafetyNET

NAVTEX is an international automated direct printing service for th promulagation of navigational and meteorological warningsand urgent information to ships. It is a component of the World Wide Navigational Warning Service (WWNWS) and is an essential element of GMDSS.

The SafetyNET broadcast system provides the same information as NAVTEX to vessels on the high seas beyond NAVTEX coverage (generally about 200 miles offshore) and is delivered by the INMARSAT-C system.

Global Positioning System (GPS)

The NAVSTAR Global Positioning System (GPS) is a satellite-based system, operated by the U.S. Air Force, which provides very accurate positioning, time, and velocity information to multiple users. It is an all-weather system with world wide and continuous usage which will replace OMEGA and other such hyperbolic radio navigation systems. The space component of GPS consists of 24 satellites, of which a minimum of six are observable from any place on earth. GPS receivers convert data from the satellites to produce three-dimensional positions (latitude, longitude, and altitude). They compute information for fixes in terms of the World Geodetic System (1984) reference ellipsoid; hence, a datum shift correction may be required before a position can be plotted on a chart.

GPS provides two services for navigation positioning, but accuracy of a fix also depends upon the capability of user equipment.

Standard Positioning Service (SPS) is the standard level of positioning and timing accuracy. It is available without restrictions to any user on a continuous world-wide basis and provides horizontal accuracy to approximately 100m.

Precise Positioning Service (PPS) is limited to authorized users and provides horizontal accuracy to approximately 30m.

Note.—For further information concerning the International Maritime Satellite Organization (INMARSAT), the Global Maritime Distress and Safety System (GMDSS), the SafetyNET system, and the Global Positioning System (GPS), see Pub. No. 9, The American Practical Navigator (Bowditch); Pub. 117, Radio Navigational Aids; and Annual Notice to Mariners No. 1.

Optical Phenomena

Optical phenomena, whose frequency reaches a maximum in polar regions, range from electromagnetic displays to intricate geometrical patterns. The Aurora and Saint Elmo's Fire are electromagnetic displays. Halos, coronas, parhelia, sun pillars, and related effects are optical phenomena associated with the refraction and diffraction of light through suspended cloud particles; mirages, looming, and twilight phenomena such as the "green flash" are optical phenomena associated with the refraction of light through air of varying density. Occasionally sunlight is refracted simultaneously by cloud suspensions and by dense layers of air producing complex symmetric patterns of light around the sun. A mirage is caused by refraction of light rays in a layer of air having rapidly increasing or decreasing density near the surface. A marked decrease in the density of the air with increasing altitude is the cause of such phenomena known as looming, towering, and superior mirages. Looming occurs when objects appear to rise above their true elevation. Objects below the horizon may actually be brought into view. This apparent effect often leads to a serious underestimation of horizontal distances. Unimpressive landmarks, small icebergs and distant ships may acquire startling characteristics through apparent vertical stretching; this phenomenon is known as towering. A superior mirage is so named because of the appearance of an image above the actual object. Ships have been seen with inverted image above and an upright image floating above that. Apparent crowding of icebergs often results from the following affects of looming and superior mirages: flows lifted from below the horizon, reduced distances, skyward reflection of surface ice, and appearance of a mirage horizon on which the surface bergs are faintly duplicated.

Inferior mirages result from the upward bending of light rays in an unstable air mass. In the Arctic this phenomenon is observed locally whenever a superheated land mass or a wide expanse of open water is overrun by cold air, a condition that is most likely to occur in summer. Sinking below the horizon of relatively close objects may result in an overestimation of horizontal distances.

Occasionally a complicated vertical temperature distribution may transform hilly coastlines and small ice barriers into impressive walls of lofty pinnacles. This phenomenon is known as Fata Morgana.

On clear days, just as the upper rim of the sun disappears below the horizon, green light is sometimes refracted from the solar spectrum. This brief phenomenon is called the "green flash."

Floating ice crystals (cirriform clouds, light snow flakes, ice fog, or drifting snow) may cause the refraction of light into a variety of faintly colored arcs and halos. This phenomenon, which may be recognized from the fact that the red band is closest to the light source, includes halos, arcs that open toward or away from the sun, mock images, and various geometrical figures that may be located in various parts of the sky with reference to the sun.

Fogbows, resulting from refraction through suspended water particles, are seen in the region of the sky directly opposite from the sun, or the antisolar point. These bows, although occasionally brilliantly colored, are normally seen as broad white bands with faintly colored borders. Rainbows are also observed in the Arctic.

When atmospheric particles are about equal in size to the wavelength of light, diffraction is likely to occur. Diffractional phenomena frequently show properties analogous to those of refraction except for the reversal in the spectrum colors; violet now being closest to the source of light. Many of the optical phenomena witnessed in the Arctic arise through diffraction. The Brocken Bow, or Glory, appears on clouds or fog banks as a colored ring around the projected shadow of the observer's head. The solar and lunar coronas, which are observed only through high clouds, resemble the halo except that they may assume increasingly larger diameters as the size of the particle decreases. When the light from the sun or the moon is diffracted by cirrus or cirrostratus, iridescence may sharply delineate the outline of clouds in brilliant green, blue, pink, orange, or purple. Polar observers may also witness the reversed colors of reflected iridescence near the antisolar point.

Reflection of sunlight takes place whenever the intervening particles are larger than the wavelength. Thus, sunlight that is reflected from ice crystals is transformed into sun pillars and parhelic circles. When both phenomena occur in combination they form the remarkable sun cross. Paricelenci circles are observed with moonlight.

Among the other reflection phenomena commonly observed in the Arctic are iceblink, landblink, and water sky. Iceblink and landblink are caused primarily by the yellowish white glare of highly reflective ice and snow fields on the underside of a stratus overcast. Water sky is a relatively dark reflection from open water. The sharp contrast in sky brightness, which may be seen from great distances, is often used to advantage in guiding polar ships toward otherwise invisible channels, hence, the name sky map. The bleak monotony of the Arctic regions is often dispelled by colorful sunrises and sunsets caused by multiple scattering of sunlight.

The Aurora Borealis (Northern Lights) and St. Elmo's Fire are two types of electrical phenomena frequently observed in this region. The zone of maximum auroral frequency extends along the periphery of a 20 to 25 degree circle whose center is at the magnetic pole. Consequently, the belt of maximum auroral activity is located approximately along a line connecting Severnaya Zemyla, Tromso, the S extremity of Greenland, northern Labrador, and Aklavik. Auroras are generally associated with moonless nights. An artificial maximum exists in winter because of the long hours of darkness. No conclusive evidence is available to show that a seasonal variation in the frequency of auroras exists. However, periods of intense sunspot activity are reflected in a maximum occurrence of this electrical phenomenon.

Generally auroras may be classified as having either a ray structure (rays, currents, draperies, corona) or a nebulous appearance (homogenous quiet arc, homogenous band, pulsating arcs, pulsating surfaces, diffuse luminous surfaces, and feeble glow). Flaming auroras, which fall in neither category, may be added to this list. Moreover, auroras may remain uniformly red, green, or purple, or assume a rapid succession of these colors. Brilliant shifting auroras are invariably accompanied by magnetic storms and electrical interference with communications.

St. Elmo's Fire is occasionally observed in this area, but because of its faintness it is most commonly observed during the night hours and when there are dark overcast days. These eerie flickers of bluish light are usually caused by the unusual electrification of the snow filled air which is most likely when the wind is strong. St. Elmo's Fire is restricted to the tips of such objects as ship masts, wind vanes, and airplane wings.

Abnormal Refraction

Abnormal refraction is not confined to particular geographical areas; however, meteorological conditions in the Arctic are such that this phenomenon may be expected more frequently. Arctic regions are most conducive to this condition due to the marked difference between sea and air temperatures, and as a result, there are frequent occurrences of extra long range visibility or some form of mirage when comparatively warm light winds pass over cold ice surfaces, or when cold winds blow over open water. This refraction is also caused when temperatures over open water are higher than those over an adjacent ice-covered coast.

Looming, which is the apparent rising of an object over the horizon, is one form of abnormal refraction. This occurs quite frequently at sea in high and middle latitudes and is manifest by the appearance of distant objects, which may actually be below the normal horizon at the moment of observation.

Looming can appear in two forms, one in which the observed object is apparently increased in height but not in size, or in which the object is increased in size and appears much nearer the observer.

The atmospheric condition responsible for looming is an abnormal decrease in the density of the air from the surface upward, with the resultant downward curvature of the light rays. As the density decreases with height, the more marked are the visual aberrations. When the rate of decrease in density is variable at low heights, the shape of the looming object becomes bulged and distorted. There may also be a thinning, flattening or pointing of the reflected image, in such a case a distant rounded peak may loom in its natural shape, appear with a distant flat summit, or with a distorted summit and appearing in closer proximity than its base. The appearance may also differ when viewed from the height of the masthead as opposed to the deck level.

Another form of abnormal refraction, known as superior mirage, is manifested by the apparent reflection from a mirror-like atmospheric condition where a pronounced inversion exists at a distance of several meters above the surface. An abnormal change in density results from this inversion producing very marked refraction. To the eye, it appears as an inverted image above the object and under certain conditions, a second image appears erect, close above the inverted image. In some instances the actual object may not be seen, but the inverted image or the erect image can only be seen.

The common factor with both looming and superior mirage is the condition of inversion of temperature where a warm layer of air is present over the sea at a suitable height. However, in the case of superior mirage, there is a more abrupt change from cooler to warmer air at certain heights.

Mirage effects near land appear from the ship as an unnatural image of the coastline, perhaps appearing singly, double or even triple. The mirage may also convey the impression that the coast is either more distant or closer than in actuality.

At sea, beyond range of land, ships and icebergs are the commonest forms of mirage. Ocean fog also contributes to mirage effects as the same factors such as temperature and humidity variations are present. Mirage is not visible in dense fog, but the erroneous reporting of fog itself may result from these suitable atmospheric conditions.

Routes

Recommended Routes

The Recommended Routes has within it routes to and from ports and junction points in the Arctic Ocean, and where applicable, navigational notes on a particular passage. For the most part these routes are as direct as safe navigation permits; in some cases, divergences are made to avoid dangers to navigation or maximize/minimize the effects of a favorable/adverse current.

The arrival or departure positions are generally anchorages or pilot grounds.

Navigation in Waters Adjacent to Russia

The latest Russian charts and publications give only sufficient information for navigation to the ports open to international trade. NIMA Charts and Sailing Directions, as they are corrected and revised, will in general only give the information provided by Russia. Other navigational aids may exist and caution will be necessary to avoid the possibility of mistaken identification.

Atlantic to the Pacific (Northwest Passage)

Spans the North American Arctic from Davis Strait and Baffin Bay in the E to Bering Strait in the W, and has four potentially feasible routes. The E entrance or exit for all routes lies through Lancaster Sound (74˚15'N., 80˚00'W.); the W entrance or exit is in Amundsen Gulf (70˚45'N., 125˚00'W.).

In 1969, the first commercial ship, the S.S. Manhattan, a large tanker displacing nearly 150,000 tons and specially reinforced for this purpose, traversed the Northwest Passage via Lancaster Sound, Barrow Strait, Viscount Melville Sound, Prince of Wales Strait, and Amundsen Gulf. Throughout this voyage, a Canadian icebreaker was in constant attendance and on numerous occasions was forced to free this larger ship.

An attempt was made to penetrate the length of M'Clure Strait, but heavy ice beset the ship on several occasions, and this attempt had to be abandoned in favor of the route through Prince of Wales Strait.

Atlantic Routes to the Arctic Ocean

There are two practicable routes for surface vessels from the Atlantic Ocean between Canada and Greenland to the Arctic Ocean; both are restricted to icebreakers for short periods, normally in the latter part of August.

The first route lies through Nares Strait, which leads off the N end of Baffin Bay.

The second route runs through Jones Sound, which opens off the NW side of Baffin Bay, Norwegian Bay, Eureka Sound and Nansen Sound; the two latter sounds form the channel between Ellesmere Island and Axel Heiberg Island.

Inner Routes—West Coast of Greenland

Between Frederiksdal (60˚00'N., 44˚40'W.) and Kraulshavn (74˚07'N., 54˚04'W.) there are sheltered inner routes through the channels among the islands which fringe the W coast of Greenland. Local knowledge is required to use these routes which, in general, can be used by coastal vessels up to 40m in length and 3.5m draft. Some parts are navigable by larger vessels while, in other places, they are restricted to small craft only. Descriptions of those routes which have been surveyed are given in Pub. 181, Sailing Directions (Enroute) Greenland and Iceland.

Northern Sea Route

The Northern Sea Route passes out of the Barents Sea into the Kara Sea by way of one of the four following routes:

1. Through Proliv Yugorskiy Shar; this strait lies between Ostrov Vaygach (70˚N., 60˚E.) and the mainland.
2. Through Proliv Karskiye Vorota; this strait separates the N end of Ostrov Vaygach from Novaya Zemlya.
3. Through Proliv Matochskin Shar; this strait nearly divides Novaya Zemlya in half.
4. Around the N end of Novaya Zemlya.

This is a shipping lane that extends from Murmansk to the Bering Strait along the entire Arctic seaboard of Russia. This route is considered as also including extensions to Arkhangel'sk, in the White Sea (Beloye More), to various ports up the navigable rivers flowing into the Arctic Ocean, and to Vladivostok via the Bering Strait. The Northern Sea Route is normally available to shipping from mid-July to the end of October; the dates varying each year with the prevailing ice conditions. The total distance along the extended route is about 5,800 miles and the passage between Vladivostok, at the E end, and Arkhangel'sk and Murmansk, at the W end, usually takes about 6 weeks.

Since 1980, it was reported that the route was kept open by ice breakers for 100 to 120 days a year from late July to early November, the dates varying each year depending on ice conditions. The objective is to open the route for the whole year and this has been achieved to some extent at the W end. It is not expected that year-round navigation at the E end will be practicable before 1985. About 15 icebreakers were operating along the route in 1980, three of them nuclear powered, but of these, only five were at the E end.

Most vessels using the Northern Sea Route are ice-strengthened for navigation and are usually restricted to a maximum draft of 7.6m; this is because, apart from anchorage limitations, deeper draft vessels run the risk in unfavorable conditions of being forced into shallow water, grounding, and being crushed by the ice. Coal burning vessels of 1,500 to 2,500 tons are generally used locally along the route.

The Organization for the Administration of the Northern Sea Routes was established for the purposes of ensuring the safety of mariners and protecting from pollution the sea and the northern coast of Russia.

In January, 1973 a convoy of vessels, escorted by ice breakers, arrived in Murmansk from the estuary of Reka Yenisey, after a voyage of 17 days.

In 1979 and 1980, the Russian icebreaker fleet kept navigation open all the year round in the western section between Murmansk (68˚59'N., 33˚04'W.) and Reka Yenisey (71˚24'N., 83˚01'N.).

In view of the low visibility frequently experienced, radiobeacons are, in general, the most valuable form of navigational aid along the northern sea route; however, insufficient reliable information has been received to enable such aids to be included in NIMA Charts and Publications. Up to date information should be obtainable from the icebreaker pilotage service. In 1979, it was reported that automatic lights and radio beacons were being installed on the N coast of Russia.

Icebreaker pilotage is available, on request, for the whole of the Northern Sea Route. For the W part of the route, from the W entrance to Kara sea to 125˚E, pilotage is provided from Gavan' Dikson (73˚30'N., 80˚31'E.). Gavan Dickson is also the headquarters of Navigation Service West. For the eastern part, from 125˚E to the Bering strait, it is provided from Pevek (69˚45'N., 170˚20'E.), the headquarters of Navigation Service East.

Ice breaker pilotage is compulsory for all vessels using Proliv Borisa Vil'kitskogo or Proliv Shokal' Skogo, between approximately 98˚ and 108˚E, the precise limits depending on the prevailing ice conditions.

Icebreaker pilotage is also compulsory for vessels passing through Proliv Dmitriya Laptev (73˚N., 142˚E.) and Proliv Sannikova (74˚30'N., 140˚E.).

Icebreaker pilotage may be effected in one of the following ways:

1. A pilot embarked in each ship.
2. Ships, with or without pilots on board, being led by an icebreaker or ice strengthened vessel.
3. Guidance from a patrolling aircraft.
4. Instructions broadcast by radio.

The decision as to which method shall be employed on each section of the route will be taken by Navigation Service West, or East, or by the captain of the icebreaker. These authorities will also issue instructions as to where the icebreaker or the pilot are to be met, and the route to be followed by ships proceeding independently.

Track of the Northern Sea Route

Vessels heading E from Nordkapp, Murmansk, or the White Sea can pass either N or S of Ostrov Kolguyev. From Nordkapp or Murmansk the N route is shorter; from the White Sea the S route is less in distance, but passes close by the dangerous Koshki Ploskiye (Tonkiye Koshki), and also along the low Timanskiy Bereg, where foggy weather is common. Due to the ice accumulation E of Ostrov Kolguyev, vessels may be forced to take the S route along Timanskiy Bereg where there might be a relatively ice-free channel available.

The optimum route depends on the time of the year, ice and weather conditions, and experience of the master of the vessel. Some vessels which have found the channel E of Ostrov Kolguyev closed by ice have gone N, then approached Ostrov Matveyev (69˚28'N., 58˚30'E.) and Ostrov Dolgiy and made their way along the coast, where it is possible that there may also be a channel free from ice leading to Reka Pechora.

Vessels using Proliv Yugorskiy Shar are generally bound to the Kara Sea, which, due to ice is rarely navigable earlier than August. When there is generally no ice W of Proliv Yugorskiy Shar; such vessels take the N route past Ostrov Kolguyev.

Vessels bound for Reka Pechora, because of the brief period of navigation in Pechorskaya Guba, try to pass Ostrov Kolguyev between the middle of June and the middle of July, when the sea E of Ostrov Kolguyev is usually filled with ice; these vessels take the S route along Timanskiy Bereg.

Generally, when bound for Pechorskaya Guba or Proliv Yugorskiy Shar from either Nordkapp or the White Sea, the S route is recommended until August and the N route after August.

The waters and coasts E of Mys Kanin Nos have not been closely examined and all usual precautions should be taken.

From Nordkapp or the White Sea, vessels intending to pass S of Ostrov Kolguyev should make for Mys Kanin Nos in order to check position, but take care to keep in depths of more than 40m due to the strong and variable currents off the N coast of Poluostrov Kanin.

From a position 14 miles NNW of Mys Kanin Nos, steer 100˚ for 68˚44'N, 45˚53'E, and then alter course to 103˚ to pass 12 miles S of Koshki Ploskiye. When 15 miles S of the light structure at the E end of Koshki Ploskiye, steer 060˚ until in 69˚05'N, 52˚40'E, keeping more than 10 miles off Timanskiy Bereg. Then, if bound for Pechorskaya Guba, steer 090˚ for a position with Gulyayevskaya Koshka No. 3 Light (68˚54'N., 55˚32'E.) bearing 174˚, distance 10 miles. Vessels bound for Proliv Yugorskiy Shar head to pass 5 miles N of Ostrov Matveyev. When approaching Ostrov Matveyev, caution is necessary to avoid being set S into the passage between that island and Ostrov Dolgiy, or on to the latter island, and vessels should keep, if possible, in depths of not less than 27m. If uncertain of the position in thick weather, or at night in autumn, when in the vicinity of Ostrov Matveyev and when in a depth of 18m or less, vessels should anchor immediately.

From Nordkapp or the White Sea, vessels intending to pass N of Ostrov Kolguyev make for 69˚59'N, 48˚12'E. If heading for Pechorskaya Guba, steer 120˚, which leads in depths of more than 40m off the NE coast of Ostrov Kolguyev to 69˚05'N, 52˚40'E, given above, then continue as previously directed. If proceeding to Proliv Yugorskiy Shar, from the former position, steer to pass 5 miles N of Ostrov Matveyev. See Pub. 183, Sailing Directions (Enroute) Northern Coast of Russia for more information and directions.

Vessels bound for the Kara Sea

When approaching 32˚E, vessels bound for Kara Sea must apply for sailing directions by radio to the Chief of the Kara Sea Navigation Service, located on Ostrov Dikson (73˚30'N, 80˚20'E.). Instructions will then be given for the vessel to proceed either through the straits S of Novaya Zemlya or pass N of that island. In addition, information on ice conditions will be provided, and whether the assistance of an icebreaker will be required, together with the position of the icebreaker and the position of the pilot vessel if proceeding through Proliv Yugorskiy Shar, along with the call signs of such vessels. Vessels should then proceed as instructed, notifying the Kara Sea Navigation Service 24 hours before reaching either Proliv Yugorskiy Shar or the N point of Novaya Zemlya.

West Approach to the Kara Sea

Vessels approaching the Kara Sea from the W will have determined via radio from the Chief of the Kara Sea Navigation Service, situated on Ostrov Dikson, which of the four possible routes mentioned above is clear of ice. The vessel must give 24 hours notice of approach and must at the same time ask for further sailing instructions, and for recommendations regarding the possibility of navigating Kara Sea either alone, or with icebreaker assistance; the vessel will then be informed as to where to meet the pilot vessel or icebreaker and provided with the code numbers of such vessels.

Vessels navigating the Kara Sea and Reka Yenisey, must keep the authorities informed as to their positions through the nearest radio station, Amderma or Dikson; the position, weather, and sea conditions must be reported twice each day at 0300 and 1500 (Moscow time). In the event of ice being encountered, the vessel's position, and weather and sea condition, must be reported immediately; a vessel in need of icebreaker assistance must await instructions as to movements, and requests for such assistance must be made through Dikson radio station.

The master of a vessel which requires icebreaker assistance should bear in mind that the icebreaker can arrive at the position of the vessel within 48 hours of the request to the Chief of the Kara Sea Navigation Service, but if in the opinion of the Service the ice situation is not of emergency, a plane will be sent to investigate the ice zone; the Service will then advise the vessel as to how to proceed, without aid, to open water, or to move to another area more favorable from the point of view of ice conditions.

The above regulations also apply to vessels proposing to proceed W from Kara sea. Of the four above routes, the shortest passage from Nordkapp (North Cape) to Ostrov Belyy is through Proliv Matochkin Shar, the next shortest through Proliv Karskiye Vorota, and the next through Proliv Yugorskiy Shar. If proceeding to Obskaya Guba, the route N of Novaya Zemlya is shorter than by Proliv Yugorskiy Shar, and if proceeding to the mouth of Reka Yenisey it is even shorter than that by Proliv Karskiye Vorota.

Subject to the above general regulations, when approaching Kara sea, the vessel should determine which of the straits is clear of ice and steer for it. The Arkhangel'sk and Proliv Matochkin Shar radio stations transmit data of the ice observations of the Kara Hydrometeorological Stations daily, to which will be added, during the navigational season, particulars of the ice, which will be communicated to vessels in Kara sea at the same.

Due to the limited range of visibility, the observations of the Kara stations only give the ice conditions in their vicinity. If, for example, Yugorskiy Shar and Vaygach report the absence of ice in the straits and at sea on the horizon, this does not always signify that there is no ice at all near the straits; for the edge of the ice may be from 15 to 20 miles from the entrance to them, having been borne away by the tidal currents and the wind. Therefore, before finally selecting the route for passing into Kara sea, the observations of the stations for several days previously should be studied. A sharp drop in the temperature of the surface water at the stations with the wind blowing from the sea; fog remaining on the horizon at sea; the prevalence of winds from the direction in which the ice may be moving; all this taken together may help to give a good idea of the ice conditions.

Should a vessel have no information concerning the ice except that sent by the radio stations, it should proceed to Proliv Yugorskiy Shar or Proliv Karskiye Vorota, preferably the former; if these straits are closed by ice or the ice is concentrated immediately E of them, it should proceed to Proliv Matochkin Shar, provided the latter is not ice bound or the observatory cannot see any ice at sea.

If all the straits are clear of ice, but the state of the ice beyond is unknown, at the beginning of navigation it is best for the vessel to make for the S straits, since the ice E of them is usually weaker in structure and more passable than on the parallel of Proliv Matochkin Shar. The route through Proliv Karskiye Vorota should only be selected in preference to that through Proliv Yugorskiy Shar when it is quite certain that there is no ice farther E or that it is open and easy to pass through; usually, if the ice remains NE of Proliv Yugorskiy Shar, it is also E of Proliv Karskiye Vorota.

If the ice conditions in the SW part of the Kara Sea and E of Proliv Matochkin Shar are unfavorable, it is sometimes possible and even easier to proceed round the N end of Novaya Zemlya. There have been years when the routes through all the straits or E of them, as well as round the N end of Novaya Zemlya, have been closed by ice.

Should ice conditions in the SE part of the Barents Sea hinder a vessel bound into Kara Sea and force her to await better conditions, there is no available anchorage affording shelter from all winds. In such conditions, a vessel should either take shelter under the lee side of Ostrov Kolguyev or run for temporary shelter in Guba Belyush'ya or Guba Chernaya, should these not be closed by ice. It should be kept in mind that should there be considerable quantities of ice in the E part of Pechorskaya Guba, though the entrance to Guba Chernaya may be clear of ice, a shift of wind S will send the ice into the entrance and may temporarily obstruct it. Shelter from easterly winds can also be obtained in Bukhta Indiga.

Proliv Yugorskiy Shar is marked by ranges and beacons and navigation through it presents no great difficulty, but, for all that, it requires great care. The channel is also buoyed, but the buoys cannot be relied on. Due to the ice they may not be in position or they may be carried away by it. Vessels are strongly advised not to attempt the passage of the strait in fog, because of the strong tidal currents.

Vessels proceeding to Proliv Yugorskiy Shar from the W are usually subject to a N drift, and often in thick weather find themselves N of the entrance to the strait, possibly off Lyamchina Guba; sometimes also between Ostrov Matveyev and Proliv Yugorskiy Shar a vessel may be subject to the effect of strong irregular currents setting N and NNW at a rate of 4 knots. In this case the vessel may find herself off Ostrova Karpova, near one of which there is an outlying rock which from a distance resembles a beacon. Occasionally, although such cases must be considered as exceptional, vessels during the 90 mile passage from Poluostrov Russkiy Zavorot to Ostrov Matveyev have been carried 6 miles S.

Proliv Karskiye Vorota, being much wider and deeper than Proliv Yugorskiy Shar, is not well marked; its shores are rugged and have numerous dangers extending off them, mainly from the SE coast of Novaya Zemlya. Though many vessels have passed safely through Proliv Karskiye Vorota, which tends to show that there are no sunken dangers in the middle part of it, this cannot be confirmed until it has been properly examined. In case of fog, a fairly frequent occurrence, it is very difficult to anchor in the strait because of the depth. Navigation through Proliv Matochkin Shar presents no difficulties. In thick weather both entrances are difficult to identify, and it is better not to enter it in fog.

Although there is a greater probability of encountering heavy and difficult ice in the passage N of Novaya Zemlya, and although it is only infrequently navigated by cargo vessels, there are numerous cases of special vessels having used this route and in some years they have not met with any ice; this proves that the route presents no special difficulties to vessels built for navigating in the ice.

A vessel using this route should make her landfall off the prominent Poluostrov Admiralteystva, and then range the NW coast of Novaya Zemlya, bearing in mind that icebergs from the various glaciers on this coast may be encountered, especially N of Mys Nassau.

The course from Proliv Karskiye Vorota or Proliv Yugorskiy Shar to NW of Ostrov Belyy depends upon the position of the ice in the Kara Sea. If the sea is clear of ice, a course may be steered from Proliv Karskiye Vorota direct to a position about 25 miles NW of **Mys Ragozina** (73˚23'N., 70˚00'E.), the NW end of Ostrov Belyy, or from Proliv Yugorskiy Shar to about 55 miles W of Mys Skuratova, and then to about 25 miles NW of Mys Ragozina. It is also recommended to steer from Proliv Yugorskiy Shar direct towards Mys Kharasovoy, and identify the light beacon there, and then to proceed N, keeping from 10 to 20 miles off the western coasts of Poluostrov Yamal and Ostrov Belyy, avoiding the banks. If there is much ice in the Kara Sea, it may be necessary to steer SE along the coast, keeping S of the ice, and gradually turn N along the W coasts of Poluostrov Yamal and Ostrov Belyy.

Ostrov Belyy to Proliv Borisa Vil'Kitskogo or Proliv Shokal'skogo

For a vessel proceeding from the vicinity of Ostrov Belyy to the Laptev Sea by way of one of these straits, there is a choice of two routes depending upon ice conditions. The first, or inshore route, is that ranging the mainland shore. The second, or offshore route, passes W of Ostrov Sverdrup, then N in order to make Ostrov Uedineniya, then E so as to pass between Ostrov Kirova and Ostrov Voronina, and into either of the straits.

During N or W winds, the inshore route becomes hindered by great concentrations of ice being pressed towards the coast and the various islands near it. Under such conditions a vessel may sometimes be able to proceed by taking advantage of the loosened ice under the lee of islands, shoals or grounded ice. This route requires great caution, due to the incomplete nature of the surveys and to the possibility of the existence of uncharted dangers. For this reason a vessel should only proceed among the various islands lying close off the mainland in case of absolute necessity and when ice conditions are easier among them than farther offshore. In some years the fast ice remains during the early part of the navigation season along the coast, and even as late as the middle of the season in the various inlets. The seaward limit of the fast ice may generally lie about the 18m contour.

During prolonged N winds it frequently happens that the pressure of ice towards the coast is so heavy as to render passage near the coast very difficult or impossible until the wind shifts S. In such cases a route farther offshore may be practicable, since there may be more open conditions under the lee of the banks N of the 79˚N.

From the Kara Sea to Laptev Sea

There are three possible routes from Kara Sea to Laptev Sea: through Proliv Borisa Vil'kitskogo, through Proliv Shokal'skogo, and N of Severnaya Zemlya. Of these three routes the shortest, best marked, and best known is Proliv Borisa Vil'kitskogo (78˚N., 104˚E.). Icebreaker assistance is usually required during the early part of the navigation season. The choice between Proliv Borisa Vil'kitskogo and Proliv Shokal'skogo will depend mainly on the ice conditions in them and in the Laptev Sea. An icebreaker has passed from the Kara Sea N of Severnaya Zemlya and proceeded to the SW part of the Laptev Sea. This route has not been in use by shipping.

Proliv Shokal'skogo can be navigated by vessels of virtually any draft dependent only upon ice conditions in it and in the Laptev Sea. In the early part of the navigation season, up to the beginning, and sometimes even until the middle of September, the ice is usually fairly dense along the E shores of Severnaya Zemlya and Poluostrov Taymyrskiy; in some seasons this ice is a serious obstacle to navigation.

In years when there are large amounts of ice its S boundary may reach almost as far S as the coast in the vicinity of Khatangskiy Zaliv and Anabarskiy Zaliv. As this ice melts and breaks up its S edge retreats N, sometimes fairly rapidly, and considerable areas, in which the flows are sparse or which may be completely clear of ice, may appear. In view of the fact that the clearing of the ice in the N part of the Laptev Sea is produced by the effect of the warm outflow from the various rivers and takes place from S to N, it may be assumed that the ice will be least dense E of Proliv Borisa Vil'kitskogo than E of Proliv Shokal'skogo. It should also be kept in mind that icebergs abound in Proliv Shokal'skogo and constitute a serious danger in thick weather. In spite of these remarks, ice conditions may prove to be easier in Proliv Shokal'skogo than in Proliv Borisa Vil'kitskogo.

The possibility of using the route N of Severnaya Zemlya has been demonstrated by the icebreaker Sibiryakov, which rounded Mys Molotova on August 15th, 1932, and proceeded S to the NE coast of Poluostrov Taymyrskiy. The icebreaker Sadko, when N of Mys Molotova in 1935, reported that there was a clear passage into Laptev sea, though ice could be seen on the E horizon.

Proliv Borisa Vil'kitskogo to Khatangskiy Zaliv

Should there be no ice in the Laptev Sea, a vessel proceeding to Khatangskiy Zaliv and having passed through Proliv Borisa Vil'kitskogo should steer to pass about 6 miles N of Ostrova Komsomol'skoy Pravdy; it should then steer about 118˚ to pass about 18 miles off the extremity of Poluostrov (Taymyr)

Povorotnyy. When approaching Ostrov Andreya in thick weather, soundings will afford some indication of the vessel's distance offshore. The vessel should continue on course 118˚ until on the meridian of the E extremity of the northernmost of Ostrova Petra (Pyotr Islands), when it should steer 142˚ for about 43 miles, and when on the parallel of the S extremity of the S of Ostrova Petra, Ostrov Yuzhnyy, it should alter course to 180˚ and proceed until it has passed the 4.6m patch reported to lie about 13 miles ESE of Mys Vos'mogo Marta, when it may haul W so as to identify Marii Pronchishcheva beacon. Then it should steer to pass about 6 miles E of Ostrov Preobrazheniya, which is an excellent landmark.

When pack ice is present in the Laptev Sea, vessels are usually assisted by an ice breaker; should it be possible for them to proceed unescorted; directions as to choice of route will be given by the ice breaker.

Proliv Borisa Vil'kitskogo to Bukhta Tiksi

A vessel proceeding to Bukhta Tiksi, having passed about 6 miles NE of the NE end of Poluostrov (Taymyr) Povorotnyy, should steer for 76˚51'N, 112˚45'E, and then steer ESE to a position 25 miles NE of Ostrov Sagyllakh Ary (Kharyyalakh), which has a radio beacon on it, thus passing between the coastal shoals off the NE side of the Lena Delta and the outlying dangers. A wreck, whose position is approximate, has been charted in this vicinity.

Because of the low-lying land and fringing shoals of the delta of Reka Lena, it is impossible to fix a vessel's position by landmarks. Soundings are of little assistance, and celestial observations may be impossible or inaccurate because of weather conditions. Careful attention to dead reckoning and frequent current observations is necessary.

Non-tidal variations in sea level of about 3m, or in some cases as much as 5m, may occur in parts of the Laptev Sea and the East Siberian Sea, including Proliv Dmitriya Lapteva and Proliv Sannikova; warnings of the onset of these variations are given in local forecasts.

Proliv Borisa Vil'Kitskogo to Proliv Dmitriya Lapteva

Vessels bound E via Proliv Dmitriya Lapteva should continue on the above ESE course up to 130˚50'E, then change course for the W entrance of the Strait. Several shoals have been reported near this track and little is known of the depths; precautions are advised.

Proliv Borisa Vil'Kitskogo to Proliv Sannikova

Vessels bound E via Proliv Sannikova should pass N of **Ostrov Semonovskiy** (74˚14'N., 133˚12'E.). Caution is necessary as the island has disappeared; Banka Semenovskaya, a shoal with a depth of 1.8m, now exists in its place.

When at about 130˚E, the depths will decrease rapidly from about 29.3 to 40.2m, to about 11.9 to 20.1m. This decrease in depths is more sharply defined N of 75˚N than S of that parallel. The high coast of Ostrov Stolbovoy and the cliffs near the S end of Ostrov Kotel'nyy are all good landmarks.

Having reached the meridian of Ostrov Stolbovoy, the depths will increase to about 18.3 to 21.9m. Vessels have experienced a northerly set of 40 miles on passage from Proliv Borisa Vil'kitskogo to Proliv Sannikova, and have found themselves near Ostrov Bel'kovskiy; this island is steep-to and soundings give no warning of a vessel's approach to it. Should a vessel, having passed over the comparatively shallow depths N of Ostrov Semonovskiy, find that the depths increase to about 40.2m, this will probably be an indication that she is N of the track. It should be kept in mind that isolated depths of 40.2 to 43.9m exist off the N end of Ostrov Stolbovoy, which is steep to, so that extreme caution is necessary in thick or foggy weather.

East Siberian Sea and Western Approaches

There are three possible routes from the Laptev Sea to the East Siberian Sea; through Proliv Dmitriya Lapteva, through Proliv Sannikova, or N of Novo Sibirskiye Otrova. Proliv Dmitriya Lapteva is available only for vessels drawing not more than 6.7m.

Proliv Sannikova (74˚30'N., 140˚E.) can be used by vessels of virtually any draft, but though its navigation from W to E is comparatively easy, passage in the opposite direction is rendered difficult for vessels drawing more than 7.9m by the shallow nature of the W part of the East Siberian Sea, the depths and currents in which are little known.

Vessels passing through Proliv Sannikova from E to W should steer for 73˚40'N, 150˚00'E. Then they should steer to make good a WNW course until 142˚E, when they should steer to make good a W course and pass through the strait along 74˚30'N. It should be kept in mind that the strait and its E approaches have not been closely examined, and isolated shoals or patches may exist. Should it not be possible to determine the direction and rate of the current from astronomical observations, the vessel should anchor from time to time and take observations of the current before proceeding further.

East Siberian Sea and Eastern Approaches

During the navigation season, the shipping route from Proliv Longa (70˚N., 180˚.) W as far as Reka Kolyma (69˚30'N., 161˚E.) is restricted by ice conditions to a shore lead which is usually opened by offshore winds and narrowed by onshore winds. Only temporary passages are formed along the section of coast between Mys Billingsa and Mys Shmidta, where ice conditions are most uncertain and the lead may be closed completely. Vessels up to 1,500 dwt with a draft of not over 4.5m, are reported to be the most suitable unstrengthened types for this passage. Deeper draft vessels must be strengthened and may require icebreaker assistance for the most efficient passage. The W part of the East Siberian Sea, as far E as the Reka Kolyma, is usually clear during the navigation season S of a line from Ostrova Lyakhovskiye to Ostrova Medvezh'i.

Westbound vessels having arrived at a position about 30 mile N of Mys Shelagskiy proceed to 70˚23'N, 169˚04'E; then the route recommended by the Russian Sailing Directions is to head WSW to a position about 5 miles N of Mys Bol'shoy Baranov which is a good mark on this section of coast. Then vessels bound for the straits of Novosibirskiye Ostrova set a course to pass NE of Ostrova Medvezh'i, keeping about 10 miles off the group. Vessels bound for Ostrov Chetyrekh-stolbovoy NNW from a position 5 miles N of Mys Bol'shov Baranov.

Passage—The Chukchi Sea

Vessels passing through the E section of the Chukchi Sea from the Bering Strait to the Beaufort Sea are recommended to use the following directions:

From the Bering Strait, E of Fairway Rock, in 65˚38'N, 168˚31'W, proceed to 68˚21'N, 167˚18'W, W of Point Hope. From W of Point Hope proceed to 68˚58'N, 166˚40'W, NW of Cape Lisburne. From NW of Cape Lisburne proceed to 70˚34'N, 162˚25'W, NW of Icy Cape. From NW of Icy Cape proceed to 71˚20'N, 156˚55'W, W of Point Barrow.

Ice conditions may affect navigation N of Point Hope.

Bering Sea Coast Routes

This route is part of the Northwest Passage, which connects the Pacific Ocean with the Atlantic Ocean N of the American Continent. A through passage is rarely attempted by any one vessel in a single season because of the shortness of the season and unpredictability of ice conditions.

Southeast Coast of Siberia—Coastal Routes

Because of exceptionally unfavorable weather conditions, caused by ice and long periods of fog, the Russian authorities have instituted recommended one-way tracks, separated by as much as 20 miles in places, for the use of shipping off the SE coast of Siberia. Ships should follow the recommended tracks, but if forced to deviate from them, should do so to starboard if possible.

The tracks run through an extensive Russian exercise area off the SE coast of Poluostrov Kamchatskiy and through a mined area off Mys Shipunskiy.

Vessels bound N to Provideniya (64˚20'N., 173˚25'W.) should use the following track:

50˚45.0'N, 157˚36.0'E.
51˚41.0'N, 158˚51.0'E.
53˚00.0'N, 160˚39.0'E.
54˚31.6'N, 162˚49.0'E.
59˚45.0'N, 170˚01.8'E.
59˚45.0'N, 171˚04.5'E.
61˚52.5'N, 176˚57.6'E.
61˚59.0'N, 179˚24.0'E.
64˚05.0'N, 173˚57.0'W.
and then continue into harbor as recommended.

Vessels bound S from Provideniya should use the following track:

64˚09.0'N, 174˚03.5'W.
62˚08.0'N, 179˚18.0'E.
62˚00.0'N, 176˚36.6'E.
59˚50.0'N, 170˚40.6'E.
59˚50.0'N, 169˚31.0'E.
58˚52.0'N, 168˚00.0'E.
55˚59.0'N, 163˚50.0'E.
54˚34.0'N, 162˚25.0'E.
53˚00.0'N, 160˚25.0'E.
51˚47.0'N, 158˚37.5'E.
50˚50.0'N, 157˚20.0'E.

Northern Sea Route

To cover the recommended tracks of the S extension of the Northern Sea Route along this coast, on the W side of the Bering Sea, there are marine radiobeacons with ranges exceeding 75 miles on all the salient points of the E coast of Poluostrov Kamchatskiy. These beacons are grouped together with a beacon on **Mys Mayachnyy** (52˚53'N., 158˚42'E.), in the approach to Petropavlovsk. In addition, there is a radiobeacon close E of **Ust-Kamchatsk** (56˚13'N., 162˚26'E.) and two radiobeacons on the W side of Zaliv Olyutorskiy, near **Bukhta Lavrova** (60˚20'N., 167˚06'E.).

In the approach to **Anadyr** (64˚44'N., 177˚32'E.), there are radiobeacons on **Mys Barykova** (63˚03'N., 179˚28'E.) and on **Kosa Russkaya Koshka** (64˚34'N., 178˚33'E.).

Caution.—Caution is necessary as the radiobeacons and other radio aids to navigation along the Arctic coast of Russia between the Bering Strait and 90˚E are reported unreliable.

Seas

The North Polar Sea

The North Polar Sea is partly covered with sea ice at all times, the extent sea ice coverage range from about 10 to 90 per cent or 100 per cent depending on season and locality. One year old ice is seldom more than 2.5m thick but rafted ice can extend down to 12m or even more. After one winter sea ice has lost its salt by a leaching process, and therefore when it melts it dilutes the surface layer. The East Greenland and Canadian current carry both sea ice and icebergs, the latter from the Greenland ice cap, S to various latitudes but normally not farther than Newfoundland.

Although the Arctic is commonly thought to be largely ice covered, less than two fifths of its land surface apparently supports permanent ice. The remainder is ice free either because of relatively warm temperatures or scant snowfall. Glaciers are formed when the annual accumulation of snow, rime, and other forms of solid precipitation exceeds that of summer melting. The excess snow is converted slowly into glacier ice, the rate depending on the temperature and annual accumulation. In the Arctic, where most glaciers have temperatures far below freezing point, the snow changes into ice slowly. In NW Greenland, a hole 426m deep was made into the ice sheet without reaching glacier ice. The hole showed over 800 annual snow layers, from which it was possible to determine precipitation change for the last eight centuries.

Offshore in the Arctic Ocean N of Alaska the movement of ice indicates there is a large clockwise circulation of current.

The Barents Sea

The Barents Sea is bordered on the S by the coasts of N Norway and Russia, on the W and N by the archipelagos of Svalbard and Zemlya Frantsa Iosifa, respectively, and on the E by Novaya Zemlya and Ostrov Vaygach. It adjoins the Norwegian Sea between Norway and Svalbard, and the Kara Sea between Zemlya Frantsa Iosifa and Novaya Zemlya.

The SW part of the Barents Sea is kept from freezing by the comparatively warm water of the North Cape Current, thus permitting year round navigation. The remainder of the sea is encumbered with ice during part or all of the year.

The mainland coast of the Barents Sea is rocky and indented by numerous fjords in the W, and is low in the E. The S part of the Barents Sea cuts deeply inland to form a large body of water known as Beloye More (White Sea).

Barents Sea covers an area of 1,424,000 km^2 with a volume of 316,000 km^3. The greatest depths are in the W part of the sea. At this location a trough with the greatest depth of 600m (within the Barents Sea) enters the Norwegian Sea. The Barent Sea is characterized by extensive shallow areas where banks are crossed by gutters. The rugged bottom relief of the Barents Sea has a significant effect on its hydrology.

The position of the Barents Sea in the high latitudes goes beyond the Polar circle, and its connection with the Atlantic Ocean and Central Arctic Basin dictate the main climatic feature. The water circulation in the Barents Sea is generally counterclockwise. Yet, inflows from the neighboring basins and the rugged bottom relief cause a complicated system of currents to be formed. The E part of Barents Sea is entirely on the continental shelf. Depths vary from 100 to 350m with complicated bottom topography resulting from glacial action, producing many gentle rises and depressions. Bottom deposits at depths less than 100m consist mainly of sand with some boulders, gravel and shell. As depths increase, mud begins to mix with sand until, at maximum depth, mud predominates. In some shallow flat areas mud may replace the sand.

In the W, the sea is entered by the warm North Cape Current and it divides into the N and coastal current. The N periphery of the gyres is cold current. On merging, the cold current forms the Medvezhinskoye Current which is directed E to W. Further to the E, the North Cape Current falls into several legs.

The vertical structure of the Barents Sea waters is governed by several factors; a well-developed autumn-winter convection, inflow of Atlantic waters, wind mixing and summer warm-up. The Atlantic waters have an effect on the SW part of the sea. The temperature and salinity tend to change insignificantly with depth in this part. The horizontal distribution of the surface water temperature is characterized by a decrease from SW to NE. The highest salinity of 35‰ also occurs in the SW part of the sea receiving the Atlantic waters where the seasonal variations in salinity are clearly pronounced. In winter, the salinity across the sea rises to 35‰ except for the SE part in which it remains at 32.5-33‰. In summer, the river water goes far into the open sea and ice-melting makes surface water desalted even in the central and W parts.

The distribution of salinity with depths, as that of temperature, is not uniform across the sea. In summer, the desalted layer is 20 to 30m deep. At the lower boundary of the layer, a salinity discontinuity is formed which disappears in winter.

In winter, about 75 per cent of the Barents Sea is usually covered with ice. The warm North Cape Current maintains a temperature above 0˚C throughout the year in the SW part of the sea.

The entire S shore of the Barents Sea is bordered by a belt of barren country known as the tundra, the chief characteristic of which is the absence of forest vegetation. The greater part of the tundra is a gently undulating plain containing numerous lakes, rivers, swamps, and bogs.

The Barents Sea is navigable up to 75˚N and as far E as 50˚E by the middle of June. Towards the end of June the W coast of Novaya Zemlya, between Gusinaya Zemlya (71˚30'N., 51˚40'E.) and Poluostrov Admiralteystva (220 miles NNE), begins to clear of ice. The entire W coast of Novaya Zemlya is ice-free in early July, when the whole Barents Sea S of 77˚N is navigable.

In some years, the ice is so open that vessels may reach Zemlya Frantsa Iosifa, where the sea may be quite free of ice in August, while in other years the islands are quite inaccessible on account of ice. Zemlya Frantsa Iosifa was once reached in June, July, and August usually are most convenient for navigation, but navigation is not possible every year. On average, 50 per cent of the time a vessel has gotten through or the vessel has been free of ice right up to the island. Southward of Zemlya Frantsa Iosifa, much heavy pack ice surrounds it and young ice rapidly form in calm weather. Many of the narrower channels and fjords amongst the islands are perpetually ice-bound, but the larger ones are generally free, at some period, every season.

The Beaufort Sea

The Beaufort Sea forms a part of the Arctic Ocean and is a wedge shaped area bounded, on the S, by the N coasts of Alaska and Canada and, on the E, by the most westerly of the islands of the Canadian Arctic Archipelago.

The N limit of the Beaufort Sea is a line extended from Point Barrow, the N point of Alaska, then leading to Lands End (76˚22'N., 122˚36'W.) on Prince Patrick Island.

The E limit is formed by the coast of Prince Patrick Island from Lands End to Griffiths Point, then by a line leading to Cape Prince Alfred, the NW extremity of Banks Island, continuing by the W coast of Banks Island to Cape Kellett. Again, a line leading from Cape Kellett to Cape Bathurst (70˚ 35'N., 128˚01'W.) and continuing on to the mainland coast.

Amundsen Gulf extends E from the SE side of the Beaufort Sea. The deepest soundings obtained in the Beaufort Sea are in its W part, where depths over 3,658m have been measured about 130 miles N of the Alaskan coast. Further E the depths decrease and reach to the maximum at the SE end of the Beaufort Sea. Along half way between Banks Island and the mainland coast, the depth is about 457m. Off the Alaskan coast the continental shelf has an average width of about 30 miles and shoal water, with depths of less than 11m, extends from 5 to 10 miles offshore. Further E along the Canadian coast, between Herschel Island (69˚35'N., 139˚05'W.) and Cape Bathurst, a relatively shallow coastal shelf, with depths of under 54m, extends from 50 to 70 miles offshore and most of this coast is fringed with an extensive area of shoal water. To the W of Banks Island, it was found that the continental shelf was about 100 miles in width.

In the Beaufort Sea, the bottom sediments are generally poorly-sorted muds or sandy muds. On the continental shelf, gravels are frequently found, but only sporadically on the upper continental slope and never on the lower slope or abyssal plain. Towards the E, the sediments become relatively more fine-grained and better-sorted, being affected by the delta activity of the Mackenzie River.

The earth's magnetic field is disturbed by local anomalies at many places on the SE side of the Alaska Peninsula and in the off-lying islands; in the Aleutian Islands; and on the E side of Poluostrov Kamchatskiy, all of which are areas of volcanic activity.

Local magnetic anomalies also exist in the vicinity of St. George Island (56˚36'N., 169˚30'W.) and Bukhta Provideniya (64˚20'N., 173˚30'W.).

Large anomalies occur more frequently in shallow water near land and, in general, the effect diminishes rapidly with distance. In some localities an anomaly has multiple sources and the effect may be felt for many miles.

Details of the anomalies mentioned above are given later in the text.

The Beaufort Sea is covered with vast expanses of first year and multi year ice, 300 cm thick during most of the growth cycle. The first year ice is generally confined to an area within 100 miles of the N Alaskan coast. Some years it may extend more than 200 miles from the coast.

Activities related to the oil exploration and exploitation industry may be encountered in the coastal waters of the Beaufort Sea. Due to the continuing nature of the industry, mariners are advised to obtain the latest information regarding the disposition of drilling ships and rigs and the location of artificial islands, whether under construction, completed or dissipating after abandonment, before proceeding through this area. (See appropriate appendix applicable to the country in the text.)

Beloye More (White Sea)

The shores of the White Sea are usually covered with snow from November to May, inclusive, and the precipitous cliffs, which are scarcely noticeable in summer, stand out boldly from the white background; from June to October the shores appear brown, and the outlines of objects are concealed in the general dark mass, but the upper edge of the coast shows sharply. The appearance of the shores also changes with the height of the tide where the rise is considerable.

Timanskiy Bereg and the coast farther E, composed of sand or sandy clay, are only slightly above sea level, and the land has the character of a barren tundra, but at some distance inland there are high, flat topped hills.

Ostrov Kolguyev, lying off Timanskiy Bereg, is moderately high in its N part; it is either covered with peat or consists of bare sand ridges, intersected by gullies and enclosing small lakes or swamps. The S part of the island is low, flat, and composed of grass, bog, and peat.

The principal rivers are the Reka Onega, the Reka Severnaya Dvina, and the Reka Mezen, which flow into the White Sea, and the Reka Pechora, which into the Barents Sea.

The rivers flowing into the W side of the White Sea are generally mountain torrents and are not navigable, but those flowing into the E side are more or less navigable, and are of great industrial importance to Arkhangel'skaya Oblast.

The Bering Sea

The Bering Sea, a part of the Pacific Ocean, lies between the coasts of Alaska, Siberia, and N of the Aleutian Islands which extend about 900 miles WSW from the SW extremity of the Alaska Peninsula (54˚50'N., 163˚20'W.). The N limit of the sea is recognized by a line drawn to join Cape York (65˚24'N., 167˚30'W.) and Mys Kriguygun (Krigugon), about 90 miles W. It is named after Captain Vitus Bering, having previously been called the Bobr Sea, the Kamchatka Sea, the Aluska Sea, and the Aleut Sea. The Bering Strait leads from the N end of the Bering Sea into the Chukchi Sea.

There are few off-lying below-water dangers in the Bering Sea and along most of the W shore. There is also deep water close in where the sandy shoals and spits extend; these places are almost all steep-to. The tidal currents are mostly weak and, in general, passage can safely be made along the W side by following the coast at distances at which the navigational marks can be seen. On the E side there are extensive areas of shallow water and conditions for navigation of Bering Sea as a whole are often difficult because of the prevailing fog during the short summer season, and strong winds which influence the currents so that they are difficult to predict. In addition, as mentioned at the relevant places in the text, parts of the sea are not adequately surveyed and in some places the charts are inaccurate. Taken together all these factors, navigation in the region demands particular care.

The S portion of the ice covered area of the Bering Sea contains thin first year ice 30 to 71cm thick near the end of the growth cycle. The N portion and immediate coastal areas N of 62˚N attain medium first year growth 71 to 122cm.

In winter, much of the N part of Bering Sea is frozen over. In spring the ice breaks up and its movements are then dictated by the currents and winds. As the prevailing winds greatly affect the currents, mariners wishing to push N early in the season should be influenced by favorable movements.

Spring is generally considered the best season for navigation, although only slightly better than summer; in spring, winds have decreased from their winter maxima, the incidence of fog has not reached its peak, ice is beginning to thaw and sea conditions are as good as in any other season.

On the W side of the Bering Sea there are marine radiobeacons with ranges of 75 miles or more on all the salient points of the E coast of Poluostrov Kamchatskiy. These are grouped and together with a beacon on Mys Mayachnyy (52˚53'N., 158˚42'E.), in the approach to Petropavlovsk, they cover the recommended tracks of the S extension of the Northern Sea Route along this coast.

In addition, there is a radiobeacon situated close E of Ust-Kamchatsk (56˚13'N., 162˚26'E.) and two radiobeacons on the W side of Zaliv Olyutorskiy, near Bukhta Lavrova (60˚20'N., 167˚06'E.).

In the approach to Anadyr' (64˚44'N., 177˚32'E.) there are radiobeacons on Mys Barykova (63˚03'N., 179˚28'E.) and on Kosa Russkaya Koshka (64˚34'N., 178˚33'E.).

On Mys Lesovskogo, in the entrance to Bukhta Provideniya, an important stopping place for ships using the Northern Sea Route, there is a radiobeacon with a range of 200 miles. This beacon is grouped with another on Mys Chaplina (64˚24'N., 172˚13'W.), which is the S of a number of radiobeacons situated on the salient points of the coast on the W side of the approach to, and in Bering Strait. There is also a radiobeacon on the N end of Ostrov Ratmanova (65˚50'N., 169˚02'W.).

A number of radiobeacons are reported to transmit from positions on the NE coast of Siberia between the Bering Strait and 178˚E. Due to the prevailing low visibility they are considered to be important aids for vessels navigating the Northern Sea Route. However, due to lack of reliable information, no details of those situated W of 170˚W are given.

Caution.—The radiobeacons on the W side of the Bering Sea cannot be relied upon due to the possibility of changes being made without warning by the Russian authorities.

The W side of the Bering Sea is likely to be clear of ice a little earlier than the E side, and a vessel following the edge of the pack ice can reach Mys Navarin (62˚15'N., 179˚07'E.) about the middle of May. Heavy ice formed in Anadyrskiy Zaliv is met coming out of the gulf. The ice sets NE into the channel between Mys Chaplina (64˚24'N., 172˚15'W.) and St. Lawrence Island and then E onto the N side of the island.

In exceptionally good seasons, there may be a clear lead from Mys Navarin to Mys Chaplina or St. Lawrence Island as early as the 15th May; but after E winds flow, the ice may be found heavily packed in this vicinity. In this event it is advisable to follow the line of the pack ice E and try the E side of the sea. By so doing the ice edge will probably be found from 20 to 80 miles S of St. Matthew Island (60˚20'N., 172˚30'W.) and leading E close to the W coast of Nunivak Island. From there it should be possible to head N to St. Lawrence Island and along the S side of it to find clear water in the channel. The intent should be to get to the W of the island before the ice opens from Mys Navarin to Mys Beringa (65˚00'N., 175˚55'W.). It is useless to try to pass N of St. Lawrence Island, as the heavy ice from Anadyrskiy Zaliv remains there much later than the ice on the S side.

Along the N of St. Lawrence Island, ice clears much earlier than on the W side of thr Bering Sea, and vessels reaching Mys Chaplina find the ice broken into large flows around which they can work outside the fast ice as far as Mys Dezhneva (66˚05'N., 169˚38'W.).

After the Bering Sea has cleared of ice, it is recommended that vessels bound through Unimak Pass, the first ship channel W of Alaska Peninsula, for ports in the NE part of the sea, proceed as follows:

Unimak Pass to Norton Sound—

54˚36'N, 165˚04'W	off Cape Sarichef
60˚14'N, 168˚04'W	W of Nunivak Island
63˚00'N, 167˚40'W	E of St. Lawrence Island
63˚41'N, 165˚18'W	entrance to Norton Sound

Then, if bound for St. Michael on the S side of Norton Sound, proceed through 63˚41'N, 162˚21'W, N of Stuart Island.

Vessels bound for Golovnin Bay and Nome, on the N side of the sound, can proceed direct from the E of St. Lawrence Island.

Small vessels for which Isanotski Strait (64˚50'N., 163˚23'W), the first passage W of the Alaska Peninsula, is suitable, can use a route farther E.

Unimak Pass to Port Clarence—

From E of St. Lawrence Island proceed through:

64˚58'N, 167˚40'W	E of King Island
65˚19'N, 167˚40'W	SW of Cape York
65˚19'N, 166˚51'W	off Point Spencer
65˚17'N, 166˚25'W	Port Clarence

Unimak Pass to Bering Strait—

Proceed as above as far as King Island. Then pass through position 64˚58'N, 167˚40'W, E of Fairway Rock, into the strait.

The Chukchi Sea

The Chukchi Sea, formerly called the Chukotskoe Sea, is a part of the Arctic Ocean extending N from the Bering Sea between the coasts of Alaska and Siberia as far as a line joining Point Barrow (71˚22'N., 156˚23'W.) and the N side of Ostrov Vrangelya, about 445 miles W.

There is a counter-clockwise circulation of current in the Chukchi Sea. In the Chukchi Sea the tidal currents are little known, but they are considerable in some parts of it. During the navigation season, streams of a semdiurnal character are strongest in the vicinity of Ostrov Vrangelya (71˚10'N., 179˚00'W.). As the ice field develops across the sea, the tidal currents decrease in strength.

Vessels making a passage through the E part of Chukchi Sea to Beaufort Sea are recommended to proceed, as follows:

65˚38'N, 168˚31'W; E of Fairway Rock
68˚21'N, 167˚18'W; W of Point Hope
68˚58'N, 166˚40'W; NW of Cape Lisburne
70˚34'N, 162˚25'W; NW of Icy Cape
71˚20'N, 156˚55'W; W of Point Barrow

Ice conditions may hamper navigation N of Point Hope. Passage through the W part of the Chukchi Sea is normally made by the Northern Sea Route.

This route is part of the Northwest Passage, which connects the Pacific Ocean with the Atlantic Ocean N of the American Continent. A through passage is rarely attempted by any one vessel in a single season because of the shortness of the season and unpredictability of ice conditions.

North of the Bering Strait, in the Chukchi Sea, the ice cover is medium and thick first-year growth (greater than 122cm) during most of the growth cycle.

East Siberian Sea

The East Siberian Sea, lying between Ostrov Vrangelya (72˚N., 180˚E.) and Novosibirskiye Ostrova, about 100 miles NE, is a shallow basin that deepens gradually NE from gently sloping shores. The depths along the shore and within the East Siberian Sea vary considerably.

The W part of the sea, S of Novosibirskiye Ostrova, and the waters along its S shore as far E as the approaches of the Reka Kolyma are shallow with numerous shoals.

The central and E parts of the the East Siberian Sea and the waters adjacent to the coast are deeper and clear of known dangers. Except for Ostrova Medvezh'i, which lie N of the mouth of the Reka Kolyma between about 19 miles NE and 58 miles E of Mys Krestovyy, the islands off the coast are few and close to shore.

To the E of Novo Sibirskiye Ostrova, the shelf remains wide, but the continental slope becomes less steep than that bordering the Laptevykh Sea. The East Siberian Sea is very shallow, with depths of 10 to 20m in the W and 30 to 40m in the E.

In shallow water, the seabed consists mainly of sandy silt with pebbles and broken boulders. In deeper water, nearer the shelf edge, mud predominates.

In the W area of the East Siberian Sea, W of the Reka Kolyma (161˚E.), ice conditions are practically always favorable during the navigational period, unless a spell of onshore winds drives the ice back towards the coast. The E area of the East Siberian Sea, E of the Reka Kolyma, is the most difficult part of the Northern Sea Route, with the exception of the region of Proliv Borisa Vil'kitskogo.

The vegetation along the shores of the East Siberian Sea is uniform but poor. Except where there are rocky outcrops, there is the usual Arctic covering of tundra. The tundra is hummocky and in places patchy; in most places it is marshy and is covered, sometimes fairly dense with grass. Creeping willows and dwarf birches are found in a few places, and in the more elevated and drier parts there is reindeer moss. A variety of flowering plants bloom during the short Arctic summer in places sheltered from the wind.

The Kara Sea

The Kara Sea is located on the E of the Novaya Zemlya, N of the Polar circle. It is bounded on the S by the N coast of Siberia; on the W by Ostrov Vaygach, Novaya Zemlya, and a line drawn from the NE extremity of Novaya Zemlya to the E extremity of Zemlya Frantsa Iosifa; on the E by a line drawn from the E extremity of Zemlya Frantsa Iosifa to the N extremity of Severnaya Zemlya; and on the E by the W coasts of Severnaya Zemlya.

In addition to adjoining the Barents Sea between Novaya Zemlya and Zemlya Frantsa Iosifa, the Kara Sea is connected with it by Proliv Yugorskiy Shar, between the mainland and Ostrov Vaygach; by Proliv Karskiye Vorota, between Ostrov Vaygach and Novaya Zemlya; and by Proliv Matochkin Shar, which divides Novaya Zemlya into two islands.

The E part of the Kara Sea is connected with the Laptev Sea by Proliv Borisa Vil'kitskogo, Proliv Shokal'skogo, and Proliv Krasnoy Armii. The greater part of the Kara Sea is covered with ice throughout the year. The most favorable ice conditions during the navigation season are found in the region where the large Siberian rivers, bringing comparatively warm water, flow into the sea. Detailed exploration in the eastern part of the Kara Sea, formerly rendered impracticable by the constant ice, has in recent years been facilitated by the use of icebreakers and aircraft. A number of islands front the S shore of the Kara Sea, and several outlying islands are in the N and NE parts of the sea.

The sea covers an area of 993,000 km^2, having a volume of 101,000 km^3.

The Kara Sea has a diversified bottom relief; the average depth is 113m with the greatest depth being 620m. Its S and E parts are shallow, as 40 per cent of the area is less than 50m deep. Only 2 per cent of the sea area is deeper than 500m. The Kara shelf is divided N to S by two troughs, the St. Ann trough and Voronin. Along the E coast there are the Novaya Zemlya and Eastern-Novozemelal'sky troughs, with depths of 200 to 400m. The Kara Sea and the Barents Seas are connected by Yugorsky Shar, Kara Gate, and the Matochkin Shar. In the N part, the seas are connected by a broad passage between the Npoint of Novaya Zemlya and Franz Josef Land.

The Kara Sea is mostly shallow to medium depth and entirely on the continental shelf; in it are two areas of deeper water: A deep (600m) N to S rift which starts at the N end of Novaya Zemlya and runs N to the E of Zemlya Frantsa Iosifa; and the Novaya Zemlya Trough (300 to 400m), which lies close E of Novaya Zemlya.

Elsewhere, the Kara Sea is occupied by a series of platforms or broad terraces stepping down from the SE to N and W, where the continental slope edge lies at about 200m.

The seabed consists mainly of clay and mud in the shallower areas, with mud predominating in the deeper waters. The counter-clockwise current eddy favors the accumulation of mud at shallow depth in the SW part of the sea. Shallow deposits near river mouths are made up of sands and silty sands.

Although the proximity of the Atlantic Ocean makes the climatic conditions milder, the climate remains Arctic. The Atlantic effect, warm water develop air masses encountering the high mountains of Novaya Zemya, as a result making the Kara Sea climate more severe than that of the Barents Sea. The climatic features of the Kara Sea (monsoon, winter cooling and summer warm-up) also influence the formation of hydrological conditions of the sea.

Run-off from the Ob and Yenisey rivers influences the Kara Sea hydrology. The Kara Sea receives 1,290 km^3 of river waters annually. The Ob river discharges 450 km^3 and the Yenisey about 600 km^3. The Ob-Yenisey run-off causes a significant circulation in the Kara Sea.

On all the shores of the Kara Sea, the vegetation is poor and of a characteristic Arctic nature. In most places there is a covering of tundra, but in parts of Novaya Zemlya there are outcrops of sedimentary slate; in the W part of Poluostrov Taymyrskiy there are outcrops of gneisso-granite, and parts of N Novaya Zemlya and of Severnaya Zemlya are covered by glaciers. The tundra is lumpy and is covered with grass, which is sometimes thick as, for instance, in Poluostrov Yamal. In most places the tundra is marshy and in some places it is patchy. Here and there the ground is covered with creeping willow or dwarf birches. Iceland moss is sometimes seen in the higher, drier and sandy places. Many species of wild flowers grow in places sheltered from the wind and bloom in masses during the short Arctic summer.

Huge flocks of geese migrate to breed during the summer in the Kara Sea region. During the moulting season, which occurs about the end of July or beginning of August, these birds are unable to fly and are killed in large numbers. Besides geese there are ducks (including the eider-duck in Novaya Zemlya), loons and several species of snipe and gulls. The arctic owl is a resident. Eagles, gerfalcons and hawks are found on the mainland coast and on Ostrov Vaygach. Bird rookeries, some of great extent, are found in many places along the W coasts of Novaya Zemlya.

The Laptev Sea

The Laptev Sea lies between Severnaya Zemlya and Novosibirskiye Ostrova and the continental coast continued S. It consists of a shallow basin, with shifting off lying shoals and banks in the S part. The depths gradually increase to the N limit, which is the edge of the continental shelf extending SE from the N end of Severnaya Zemlya.

The meridian of 139˚E has been designated by the government of Russia as an arbitrary boundary separating the NE part of the Laptev Sea from the adjacent East Siberian Sea.

The SE part of the Laptev Sea is connected with the East Siberian Sea by Proliv Dmitriya Lapteva, Proliv Sannikova, and Proliv Eterikan, which are the straits of Novosibirskiye Ostrova. The S continental shores of the Laptev Sea are mostly low, barren, tundra indented by several large gulfs and bays into which the principal rivers flow.

The character of the continental shelf in the Laptev Sea differs markedly from that of the Kara Sea. Apart from some deep troughs around Severnaya Zemlya, the shelf is very flat and, on average, less than 75m in depth. Very shallow zones extend beyond the mouths of the large rivers. The shelf is narrow, seaward of Severnaya Zemlya, but widens to nearly 300m off the NE coast of Siberia. The continental slope begins at 200m and falls steeply to 1,000m. Bottom deposits in the shallower areas are mainly sand and mud, but some pebbles and broken boulders can also be found. In deeper water the seabed consists entirely of mud.

The low S shores of the sea are mostly composed of sand and clay with layers of buried ice, and are subject to constant erosion. Hills and some rock occur along the N coast of Poluostrov Taymyr. Farther N, Severnaya Zemlya, the archipelago comprising the NW boundary of the Laptev Sea, attains elevations of about 701m. The four main islands are ice capped and mostly steep-to.

Only the W islands of the archipelago of Novosibirskiye Ostrova lie entirely within the limits of the Laptev Sea. These are Ostrov Bel'kovskiy, Ostrov Stolbovoy, and Ostrov Semenovskiy. The latter, consisting of sand, clay, and imbedded ice, is rapidly eroding and may have disappeared entirely.

Navigation in the middle of the Laptev Sea is especially hazardous even when clear of ice because of the absence of seamarks, unknown permanent currents, irregular wind currents, and shifting shoals and banks. Poor visibility, overcast sky, abnormal refraction, and mirage are prevalent during the navigation season.

At the beginning of the navigational season, ice conditions are more favorable in the E part of the sea and less favorable in the W. The best conditions are found in the vicinity of the large rivers. The worst conditions are found in the E approaches to Proliv Borisa Vil'kitskogo and around Novo Sibirskiye Ostrova.

Along the shores of Laptev Sea the vegetation is fairly uniform and, except where there are rocky outcrops, there is a continuous but fairly narrow coastal belt of tundra. This tundra is mostly covered with dense layer of moss or lichen and is often swampy; in places where it is sheltered from the wind it is covered with grass, which is sometimes fairly thick, as, for instance, near the mouth of Reka Olenek. In some places there are creeping willows and dwarf birches, and on the most sheltered slopes of the hills there are considerable areas covered with several species of flowering plants. In Novo Sibirskiye Ostrova the tundra is almost barren, but there are isolated patches of several species of flowering plants.

The Lincoln Sea

The Lincoln Sea is the name applied to that part of the Arctic Ocean which lies off the NE end of Ellesmere Island and the NW end of Greenland; it extends from Cape Columbia, the N extremity of Ellesmere Island, on the W, to Kap Morris Jesup, the N extremity of Greenland, on the E; on the S, it is bounded by the coasts of Ellesmere Island and Greenland and by the N entrance of Robeson Channel.

The Norwegian Sea

The Norwegian Sea flows over the continental shelf off the Norwegian coast and has been eroded by the Norskerenna (Norwegian Trench). A glacial trough which follows the S and W coasts of Norway and terminates at the shelf edge in about 62˚N. Norskerenna is between 25 and 50 miles wide and has a maximum depth of 433m. The coast is indented with fjords, which often extend many miles inland and attain depths far exceeding those of the adjacent sea.

The S boundary of the Norwegian Sea is the Wyville Thompson Ridge, extending from Scotland to Iceland and with an extension between Iceland and east Greenland. In the deep waters of Norske Havet or Norwegian Sea, the main bottom constituent consists of ooze, clay, very fine sand, or a mixture of these materials.

On the continental shelf, which is narrow and deeply indented, rock predominates, overlaid with patches of sand and gravel. East of 25˚E, mud is also present. Off the continental shelf, the rock loses its dominance. In the west there is a narrow band of sand and gravel, and sand, mud and gravel merging at about 500 to 1,000m into an area of fine muds and oozes which occupy the deeper waters of the Norwegian Sea.

Along the parallel 72˚N, where the slope is less steep, areas of sand and mud predominate, gradually giving way to mud at about 350m.

Off the Norwegian coast, the continental shelf is of varying width, from 100 miles in 65˚N to 15 miles off Vesteralen, with extensive areas more than 200m in depth. The shelf is characterized by a series of straths, outer banks, and islands. The straths are broad, elongated depressions of glacial origin which generally form a pattern parallel and perpendicular to the coast. They cut deeply into the coast, are often deepest at their landward end, where they usually terminate in a sharp escarpment, and are not evident in the slope region. The largest bank in the area is **Sklinnabanken** (65˚20'N., 10˚15'E.), with a least depth of 120m.

On either side of the trough and within the trough itself are several banks, of which the more important are:

Little Fisher Bank	56˚55'N, 6˚20'E.
Great Fisher Bank	56˚45'N, 4˚10'E.
Eigersundbank	57˚45'N, 5˚25'E.
Revet	58˚05'N, 4˚35'E.
Ling Bank	58˚10'N, 2˚30'E.
Coral Bank	58˚30'N, 2˚55'E.
Klondyke Bank	58˚45'N, 3˚10'E.
Kalsmedgrunnen	58˚50'N, 5˚20'E.
Bergen Bank	60˚05'N, 2˚00'E.
Viking Bank	60˚35'N, 2˚30'E.

There is a marked variation in the character and distribution of the bottom sediments, which is related to the diverse sources of supply, conditions of deposition and bottom configuration. Fine sand and mud are the basic constituents of the shelf sediments, with gravel and rock freely dispersed among them. The coastal complex, which extends to the 100m depth contour, is extremely rocky with sand, stone and shingle edging the rocky patches. In the deep incursions through the shelf and in the deep waters of the fjords, the bottom is mainly one of mud overlying either glacial sediments or the rock floor.

Surface Temperatures

Surface temperatures in the Arctic Ocean system are always low, seldom rising above 4˚C or 5˚C even at the height of summer. Wherever there is ice the temperatures are close to 0˚C or lower (seawater of salinity 34 parts per thousand freezes at about -1.8˚C). There is an area known as the "north water," in northern Baffin Bay or southern Smith Sound, which remains unfrozen all winter, and in this region the summer temperatures are often above 5˚C. Hudson Bay, which in summer is subject to considerable surface dilution from land drainage, can be as warm as 10˚C in its S part for a brief period.

Traffic Separation Schemes

Traffic Separation Schemes (TSS) in the Arctic Ocean are listed below. Both IMO-adopted schemes and those established by local governments are listed with the originating authority.

The IMO-adopted schemes are not differentiated from local schemes on the charts. Russian northern coastal routes are not adopted by the IMO.

The White Sea (Beloye More)

Off Mys Zimnegorskiy (Government of Russia)
Off Ostrov Sosnovets (Government of Russia)
Off Ostrova Ponoyskiye Ludki (Government of Russia)
Off Tersko-Orlovskiy (Government of Russia)
Off Svyatonosskiy Poluostrov (Government of Russia)

The Barents Sea

Entrance to Kol'skiy Zaliv (Government of Russia)
Proliv Karskiye Vorota (Government of Russia)

A series of traffic separation schemes and recommended tracks are established in the approaches to Kol'skiy Zaliv and within that inlet from a position N of Mys Svyatoy Nos to the approaches to Arkhangel'sk. These traffic separation schemes and recommended tracks should, when appropriate, be followed by vessels on passage from a position N of Mys Svyatoy Nos to the approaches to Arkhangel'sk.

The most dangerous and narrowest part of the route is through Proliv Orlovskaya Salma, entered between Tersko-Orlovskiy Light (67˚12'N., 41˚20'E.) and the N end of Bol'shaya Orlovskaya Koshka. There are no prominent landmarks between Gorodetskiy and Tersko-Orlovskiy Light, except for Mys Ostraya Ludka Light (67˚25'N., 41˚06'E.).