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Northern Sea Route Handbook (Practical Edition) Volume I

The Japan Association of Marine Safety

Northern Sea Route Handbook, Practical (Volume One)
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Chapter I: Basic Knowledge about the Northern Sea Route

1. Basic knowledge about the geography, climate and hydrographic conditions of the Northern Sea Route

The first step in attaining a sufficient grasp of the specialized knowledge, technologies, skills, and so on, necessitated for the safe navigation of the Northern Sea Route, is to acquire basic knowledge pertaining to the Arctic Ocean and the Northern Sea Route itself. This chapter describes this basic knowledge, with regards to the geographic, climatic, and hydrographic conditions of the Arctic Ocean and Northern Sea Route.

1.1 Overview of the Northern Sea Route

In recent years, in the context of both intensified warming and ice recession in the Arctic Ocean, the increasing number of merchant vessels using the Northern Sea Route, in particular in summer, has become a global focus.

Below an overview of Northern Sea Route is given.

1.1.1 The Northeast Passage and Northwest Passage

In Europe the shipping route which navigates a passage through the Arctic Ocean along the Russian coastline of Eurasia was in the past known as the Northeast Passage, while in Russia it was referred to as the Northern Sea Route (NSR).

Meanwhile, the shipping route which navigates the Arctic Ocean along the Canadian coastline of the North American landmass was referred to as the Northwest Passage. However, use of the Northwestern Passage requires the navigation of the so-called Arctic Archipelago, which is made up of as much as 37,000 large and small islands. Passage of the Arctic Archipelago is treacherous and involves negotiating many complicated and labyrinthine straits. Moreover, as the danger and severity of ice conditions in the Northwest Passage often exceed those of Northeastern Passage, only a limited number of merchant vessels use this route. For this reason, when the Northern Sea Route is invoked, this usually indicates the Northeastern Passage.

In this book, excepting cases where it is indicated specifically, we will be dealing with the Northeastern Passage as the Northern Sea Route. However, in recent times the term Northern Sea Route is also used to refer to both the Northeastern Passage and the Northwestern Passage as a single whole.

In order to use the Northeastern Passage, in compliance with Russian law you must apply to and receive the permission of the Northern Sea Route Administration (NSRA) in advance. In addition, in accordance with provisions of Russian law, ships navigating the Northern Sea Route remain under control of the NSRA for the duration of their passage, and must consequently comply with their instructions. There are also a number of principles such as the obligation for navigating vessels to maintain wireless communications with the NSRA, in line with predetermined locations and schedules.

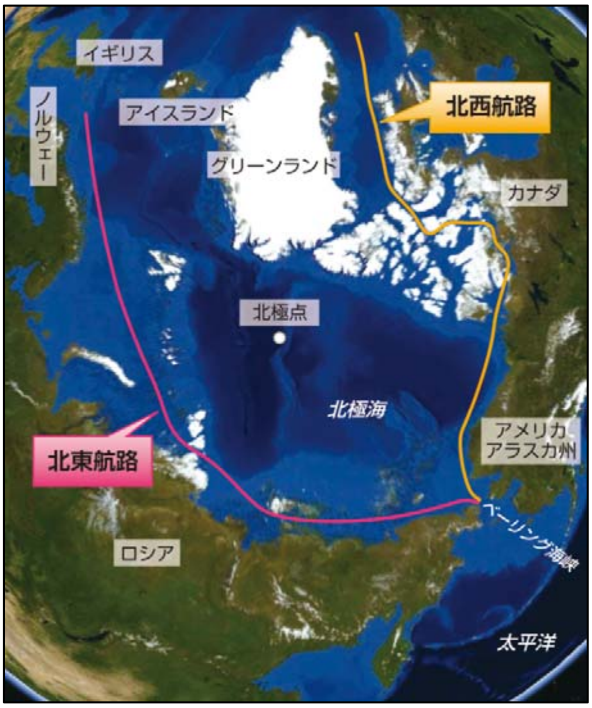


Fig. 1-1: Northern Sea Route

(NASA World Wind http://worldwind.arc.nasa.gov/java; Image depicts general conditions found in early summer)

1.1.2 History of the Northern Sea Route

Passages of the Arctic Ocean date back to the era of the Vikings, seeking to expand their dominions as far back as the 9th century, and take in Basque whale hunting expeditions in the 14th century.

When we enter the Age of Discovery in the 16th century, the maritime passage reaching from the Atlantic to the Pacific via the Arctic Ocean can be thought of as the shortest route connecting Europe and Asia, and expeditions for such passages become increasingly commonplace. However, the unrelentingly harsh conditions of the Arctic Ocean, combined with then-insufficient nautical instrumentation and shipbuilding techniques mean that ships experiencing difficulties remain rife through to the successful opening up of a sea course by the SS Vega at the end of the 19th century.

Ultimately we enter the 20th century when, as a result of innovations to facilitate more comfortable passage of the Arctic Oceans, such as icebreakers and the birth of wireless communications, the navigation route along the Russian coast of Eurasia is established. This route is then referred to in Europe as the Northeast Passage and in Russia as the Northern Sea Route. However, the political circumstances following the birth of the Soviet Union after the Russian Revolution of 1917 lead to a long period during which merchant vessels from other countries cannot use the Northern Sea Route. At its prime during the 1980s the Soviet Union exported more than 6 million tons of cargo via the Northern Sea Route per year.

In 1987, following the end of the Cold War, the strategic value of the Northern Sea Route declined, and the Soviet Union again allowed its use by merchant vessels from other countries. However, the dissolution of the Soviet Union, and the economic turmoil of the newly emerged Russia, meant that in the immediate aftermath there was little progress in the use by merchant vessels from other countries, and Russian use of the Northern Sea Route also declined drastically. The average volumes of cargo transported annually thus stagnates at around 2 million tons after the year 2000.

Eventually in 2009, with the background of increasing recession of ice in the Arctic Ocean, and the development of an administrative infrastructure for passages on the Russian side, two German-registered ice-strengthened cargo ships are loaded with power plant components at Ulsan Port in South Korea, and transport these from the Bering Strait to a Russian harbor via the Northern Sea Route. This was the first case of a non-Russian registered merchant vessel using the Northern Sea Route. With this as the departure point, we have now reached the present era of increased use of the Northern Sea Route by merchant vessels.

1.1.3 Merits and demerits of the Northern Sea Route

Use of the Northern Sea Route shortens the maritime transport distance between Europe and Asia by 30 to 40 percent when compared with passage via the Suez Canal, previously the default global east-west transport route in both directions. The merits accompanying this shortened passage include savings in both transport time and fuel costs.

The results of a shortened passage are remarkable for Asia, as you travel both northwards and eastwards on the Northern Sea Route. Consequently, the countries of Far Eastern Asia (including Japan, South Korea, China, Russia, and North Korea) are those with the most to gain. For example, if you are navigating from Rotterdam to Yokohama, you can shorten distances by 3,750 miles, or 33%, by using the Northern Sea Route as opposed to the Suez Canal. Maintaining the same speed, this equates to arriving in Yokohama a total of 13 days earlier. An additional merit is in facilitating the circumvention of territorial waters in which there is political instability or in which there is a chance of a pirate presence.

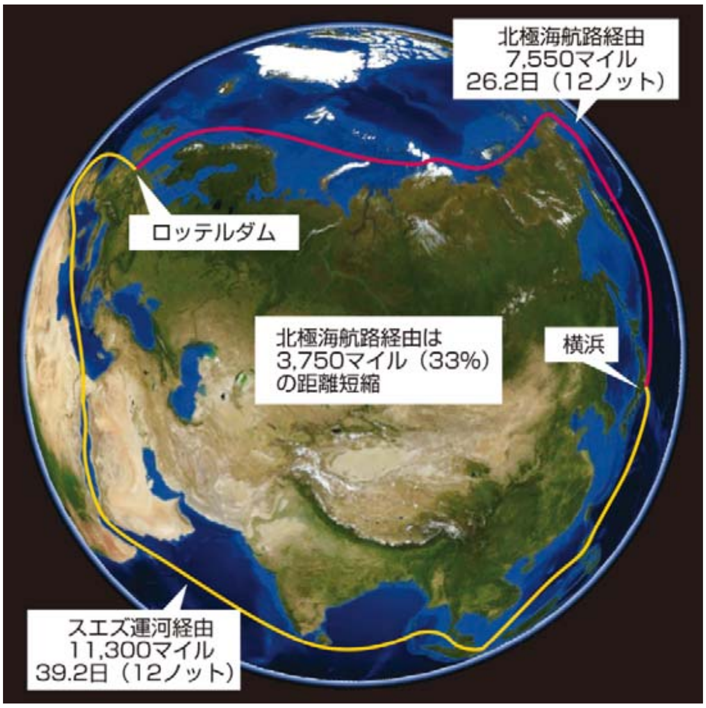


Fig. 1.2: Comparison of passages via the Northern Sea Route and the Suez Canal
(Based on NASA World Wind http://worldwind.arc.nasa.gov/java)

On the other hand, operational demerits also accompany use of the Northern Sea Route, such as the comparatively higher shipbuilding costs and additional insurance levies incurred in order to acquire ice class to navigate through sea ice. Moreover, as the possibility of passage depends greatly on the environmental factors including ice conditions, unavoidable delays, including reduced transit speeds during passage or time spent waiting for improved ice conditions must also be factored in.

In addition to the emergence of issues such as consolidation of water depth data; strengthening of search and rescue operations and communications; provision of systems for evacuation ports at times of emergency and systems for the replenishment of water, fuel and food, there are also increasing voices of concern concerning the marine pollution in the Arctic Ocean which accompanies accidents at sea.

1.2 Basic geographical knowledge

The Arctic Ocean is surrounded by the many small islands of the Eurasian and North American landmass, and Greenland, among others, and the Northern Sea Route is located on the continental shelf around the Russian coastline of Eurasia.

Below, the basic geographical knowledge pertaining to the Arctic Ocean and Northern Sea Route is elucidated.

1.2.1 Total area of the Arctic Ocean

The Arctic Ocean is one of the world’s seven Oceans, surrounded by the many small islands of Eurasia, North American, and Greenland, with a total area of approximately 12 million square kilometers (around 31.5 times the area of Japan). However, it is a small ocean, which represents only about 3% of the total area of the world’s seas.

On the other hand, at the opposite extreme of the globe, the area of Antarctica is approximate to this, at 14 million square kilometers; with the area of the Antarctic Ocean enclosing Antarctica around 1.7 times that of the Arctic Ocean, at 20 million square kilometers.

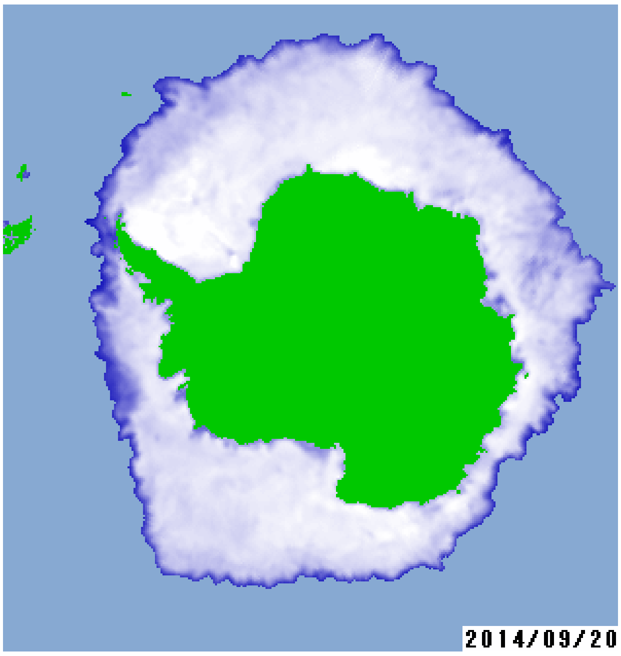


Fig. 1-3: Distributions of sea ice in the Arctic and Antarctic regions, September 20, 2014
(Source: Japan Meteorological Agency website)

1.2.2 Water depths in the Arctic Ocean

The Arctic Ocean is almost entirely surrounded by land. For this reason, ice movement is less pronounced when compared to the Antarctic Ocean and it is of a form which means that ice does not easily flow into the adjacent Atlantic or Pacific Oceans.

A submarine plain with a water depth of around 4,000 meters diffuses in the central part of the Arctic Ocean, which is 5,440 meters at its deepest. The Arctic Ocean is made up of 70% relatively deep waters in excess of 1,000 meters depth, with the remaining 30% being made up of relatively shallow waters of less than 1,000 meters.

1.2.3 Water depths on the Northern Sea Route

In recent years, ice in the Arctic Ocean has declined, particularly in summer. However, ice thawing in the Arctic Ocean has a tendency to be centered on the coastal areas, and the further we head offshore the less ice tends to thaw, even in summer. For this reason, it is either impossible or difficult for vessels to navigate the deep waters in the central part of the Arctic Ocean even in summer.

Accordingly, the course of the Northern Sea Route is located along the continental shelf surrounding Eurasia, where ice either thaws in summer, or where little ice is found. This also means that, while ice conditions are favorable, because this course is close to Eurasia or the islands in its vicinity, water depths remain within 200m at their deepest, with the shallowest areas of depths under 20 meters. Many areas of shallows of less than 10 meters depth and areas of sunken rocks mean that it is necessary to navigate a number of sea straits for passage either between islands and land or islands and islands.

1.2.4 Rivers of the Arctic Ocean

Many large rivers flow into the Arctic Ocean. Of these, the Lena River, the Yenisei River and the Ob River, entering from Eurasia, and the Mackenzie River from North America are known as the four great rivers of the Arctic Ocean.

The combined volume of water from the rivers which flow into the Arctic Ocean is equivalent to around 10% of the total volume of the world’s rivers. For this reason, the average saline content of the Arctic Ocean is strikingly lower than that of the other great oceans, and it is distinguished by stratified saline densities, while the chilled surface waters do not deeply penetrate the ocean. Accordingly, as the concentration of chilled water remains on the surface, sea ice can easily form due to freezing water. In addition, the abundant nutrients washed out from forests in the mid-latitudes of the upper reaches of the great rivers which feed it, have a large influence on the creation of the rich ecosystems of the Arctic Ocean.

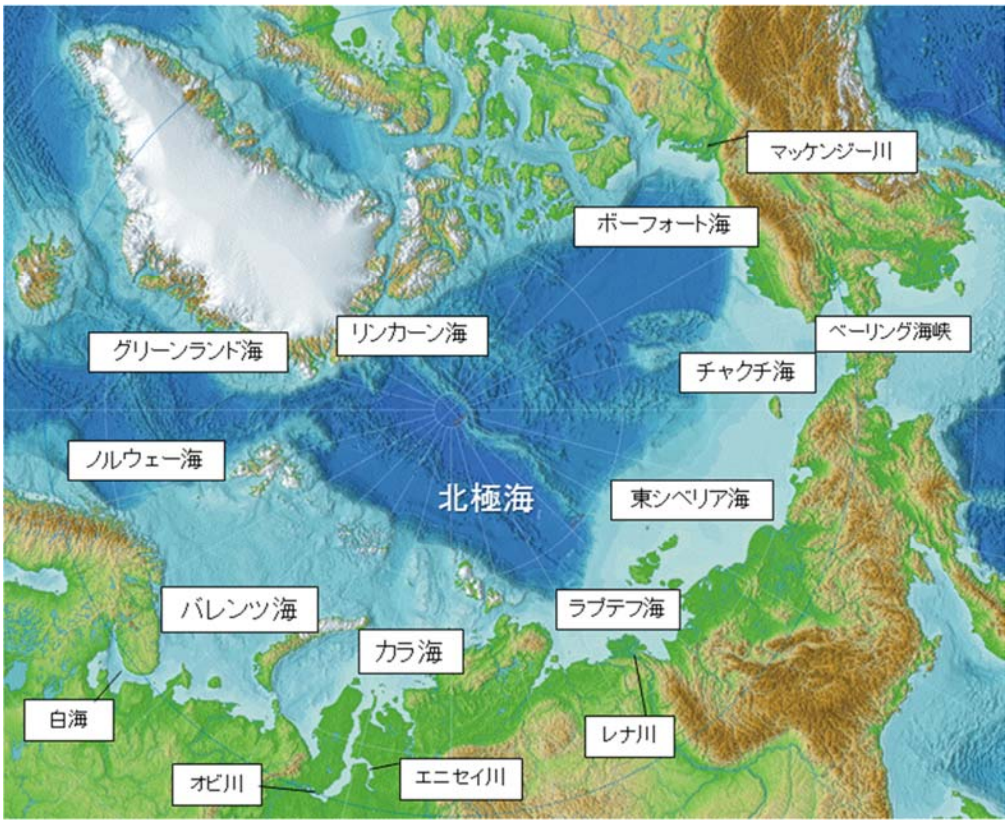


Fig. 1-4: Rivers and seas of the Northern Sea Route

(Source: Based on the National Institute of Polar Research “Arctic Region” map)

1.2.5 Seas of the Northern Sea Route

Within the Arctic Ocean, there are a number of Seas in the vicinity of the continental shelf along Eurasia, where the Northern Sea Route is located. Heading east from Europe towards the Bering Strait, these have names such as the Barents Sea, the Kara Sea, the Laptev Sea, the East Siberian Sea, and the Chukchi Sea.

[Barents Sea]

The Barents Sea has average depths of approximately 200 meters in its western part, 100 meters in its eastern part, and an overall average depth of 230 meters, with its deepest part reaching approximately 600 meters depth. In normal circumstances for vessels using the Northern Sea Route on the Barents Sea, passage is most often set on the continental shelf at depths from approximately 50 to approximately 250 meters depth.

The western and northern sides are connected to the comparatively deep Norwegian and Greenland Seas, while the eastern side is connected to the comparatively shallow Kara Sea. It also has a large gulf referred to as the White Sea (Beloye More) in its southwestern part, located on the western side of the Kola Peninsula.

[Kara Sea]

The Kara Sea has an average depth of around 120 meters, with many parts being less than 100 meters deep. It has extreme depth variations, and shallows of a few meters to 20 meters depth are common. In the western part of the Kara Sea, at the extreme northeast of Novaya Zemlya, offshore from Cape Zhelaniya, comparatively deep water depths up to approximately 600 meters are found.

In normal circumstances for vessels using the Northern Sea Route on the Kara Sea, passage is most often set on the continental shelf at depths from approximately 20 to approximately 200 meters depth. However, vessels ordered to navigate offshore from Cape Zhelaniya may do so at water depths which can sometimes exceed as much as 500 meters, representing one of the comparatively deepest sections on the Northern Sea Route.

The western side of the Kara Sea is connected to the Barents Sea and the eastern side with the Laptev Sea. Of the four great rivers of the Arctic Ocean, the Yenisei and the Ob Rivers enter the Kara Sea. Due to the influence of a warm current flowing from the North Atlantic Ocean, the Barents Sea and part of the territory covered by the Kara Sea is warmed, meaning that despite being part of the Arctic Ocean, there is no ice year round.

[Laptev Sea]

As most of the Laptev Sea is located on the continental shelf, it has comparatively mild variations in depth, with depths of approximately 50 meters to less than 25 meters closer to land. However, the northern part of the Laptev Sea is not on the continental shelf, connecting with the deep central part of the Arctic Ocean, meaning that depths exceed 3,000 meters.

In normal circumstances for vessels using Northern Sea Route on the Laptev Sea, a course is most often set on the continental shelf at depths from approximately 20 to approximately 80 meters depth. However, when vessels are ordered to navigate offshore, off the continental shelf, they may do so at water depths which can sometimes exceed 1,000 meters, representing the deepest section on the Northern Sea Route.

The western side of the Laptev Sea is connected to the Kara Sea and the eastern side to the East Siberian Sea. Of the four great rivers of the Arctic Ocean, the Lena River enters the Laptev Sea.

The territory from the Kara Sea to the Laptev Sea as far as the East Siberian Sea has comparatively cold weather conditions, with large volumes of river water entering from Eurasia meaning that ice forms easily.

[East Siberian Sea]

The western side of the East Siberian Sea is connected to the Laptev Sea and the eastern side to the Chukchi Sea.

The territory of the East Siberian Sea broadly coincides with the continental shelf, having comparatively mild depth variations, with the majority at water depths of less than approximately 50 meters and with depths of less than approximately 25 meters in the vicinity of land. The course of the Northern Sea Route on the East Siberian Sea is the shallowest passage.

In normal circumstances for vessels using Northern Sea Route on the East Siberian Sea, a course is most often set on the continental shelf at depths from approximately 12 to approximately 40 meters depth. However, off the continental shelf the northern part of the East Siberian Sea is connected to the deep waters in the central part of the Arctic Ocean with depths in excess of 1,000 meters. Nevertheless, as ice in this area does not thaw even in summer, there are no instances in which navigation of this area is indicated.

[Chukchi Sea]

The western side of the Chukchi Sea is connected to the East Siberian Sea and the eastern side with the Bering Strait.

Like the East Siberian Sea, the Chukchi Sea is in comparatively shallow territory with mild depth variation, of mostly less than 50 meters in depth.

In normal circumstances for vessels using the Northern Sea Route on the Chukchi Sea, a course is most often set on the continental shelf at depths from approximately 30 to approximately 50 meters.

Due to the influence of a warm current entering from the North Atlantic Ocean, the Chukchi Sea is warmed, meaning that there are long periods with no ice.

[Other Seas]

The Arctic Ocean around the continental shelf off the Canadian coastline of the North American continent is called the Beaufort Sea. The area covered by the continental shelf spreading out from the Arctic Ocean coastline in the northwest of Greenland is referred to as the Lincoln Sea.

When compared to the courses along Eurasia, the Northern Sea Route along the continental shelf of North America is extremely narrow, and offshore regions of the Arctic Archipelago or Greenland are directly connected to the deep waters in the central part of the Arctic Ocean.

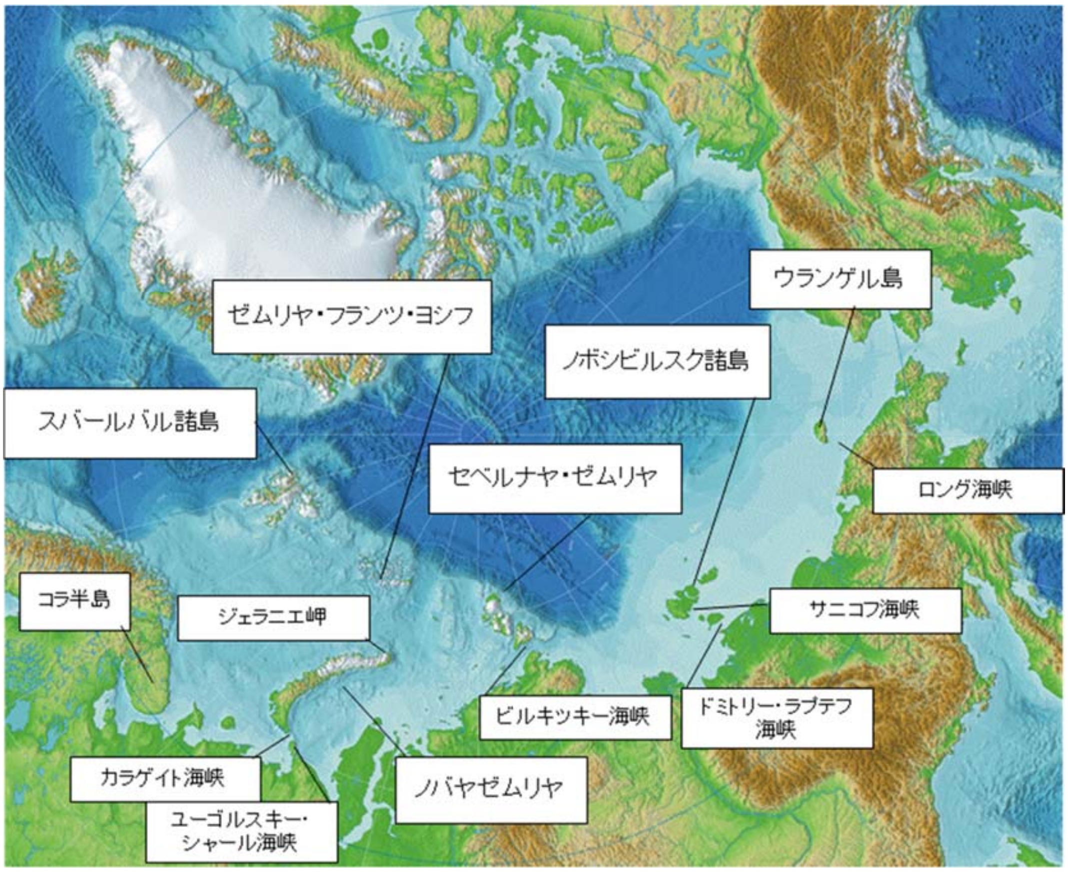


Fig. 1-5: Islands, straits, etc. around the Northern Sea Route

(Source: Based on the National Institute of Polar Research "Arctic Region" map)

1.2.6 Islands around the Northern Sea Route

Among the islands of the Arctic Ocean around the continental shelf along the Eurasia Continent where the Northern Sea Route is located are in eastwards order travelling from Europe towards the Bering Strait, Svalbard Archipelago, Novaya Zemlya, Franz Josef Land, Severnaya Zemlya, the New Siberian Islands (Novosiriskiye Ostrova) and Wrangel Island (Otrov Vrangelya).

1.2.7 Straits of the Northern Sea Route

There are many straits on the Arctic Ocean around the continental shelf along Eurasia where the Northern Sea Route is located, either between islands and land or islands and islands. Navigation of several of these straits may be indicated to vessels using the

Northern Sea Route according to permissions issued by the NSRA or by a service control station commissioned by the NSRA.

An order to navigate by particular straits is decided based on an integrated evaluation by the NSRA or its designated authority, taking into account such factors as the navigating vessel port of embarkation and port of destination, the latest weather information, and ice conditions.

As some of these straights are of shallow depth, there are restrictions on the drafts of the vessels permitted to navigate them. The main navigation straits for which permissions may be indicated are given below.

[Kara Strait (Proliv Karskiye Vorota)]

The Kara Strait connects the Barents Sea and the Kara Sea, between Novaya Zemlya and Vaygach Island. Within the strait, oncoming transit is conducted by “traffic separation schemes” based on “route designations” adopted and determined by the International Maritime Organization (IMO).There are depth variations of between approximately 20 and 200 meters. For tides, strong winds can reach as much as 3 knots or higher.

If the port of embarkation is Arkhangelsk on the coast of the White Sea, in the southwest of the Barents Sea, from the Barents Sea through to the Kara Sea, and the port of destination is Sabetta on the Yamal Peninsula (Poluostrov Yamal), the distance involved in navigating the Kara Strait rather than offshore of Cape Zhelaniya at the northeastern extreme of Novaya Zemlya is considerably shorter. In these cases, if ice conditions allow, there is a high possibility that the order will be given to navigate the Kara Strait.

Meanwhile, if the port of embarkation is Murmansk, from the Barents Sea through to the Kara Sea, the distance involved in a passage of the Kara Strait or offshore of Cape Zhelaniya at the northeastern extreme of Novaya Zemlya is largely the same. Nevertheless there are times when fast ice or drift ice does not thaw and remains present through summer in the southwest of the Kara Sea, where the Kara Strait is located. In such cases, there is a high possibility that an order will be given to navigate Cape Zhelaniya at the northeastern point of Novaya Zemlya rather than the Kara Strait.

[Yugorsky Strait (Proliv Yugorskiy Shar)]

Yugorsky Strait, like the Kara Strait, connects the Barents Sea and the Kara Sea between Vaygach Island and the mainland. It is located around 70 miles southeast from the Kara Strait. It is not as wide as the Kara Strait, being less than 6 miles wide at its narrowest. With water depths of 13 to 17 meters, there are restrictions on navigating vessel drafts. There are times when fast ice and drift ice do not thaw and remain even in summer. For tides, strong winds can reach as much as 3 knots at the narrowest point of the strait.

For these reasons, ocean-going merchant vessels using the Northern Sea Route from the Barents Sea through to the Kara Sea are often ordered to navigate either the Kara Strait or Cape Zhelaniya at the northeastern point of Novaya Zemlya, rather than Yugorsky Strait.

[Vilkitsky Strait (Proliv Vil'kitskogo)]

Vilkitsky Strait connects the Kara Sea and the Laptev Sea, between Bolshevik Island (Ostrov Bol'shevik), one of the islands of Severnaya Zemlya, and the mainland. It has water depths generally between 20 and 200 meters, but there are also shallow points of less than 10 meters deep, with the strait being about 4.5 miles wide at its narrowest point.

Of the straits for which an order to navigate may be indicated, ice remains the longest through summer in its territory, and may not thaw even then, making it the most treacherous passage on the Northern Sea Route.

When going from the Kara Sea through to the Laptev Sea on the Northern Sea Route, the passage offshore from the northern point of Severnaya Zemlya has long been used. However, ice remains in the territory around this sea even until late in summer, and often ice does not thaw even then. For these reasons, ocean-going merchant vessels using the Northern Sea Route from the Kara Sea through to the Laptev Sea are often ordered to navigate Vilkitsky Strait even given that it is the most treacherous passage on the Northern Sea Route. Vessels such as research ships or tourist cruise ships, sometimes navigate offshore of the northern point of Severnaya Zemlya.

[Laptev Strait (Proliv Dimitrya Lapteva)]

Laptev Strait connects the Laptev Sea and the East Siberian Sea, and is located between the New Siberian Islands and the mainland. It is about 30 miles wide at its narrowest point, and an average depth of 12 to 15 meters, with shallows of less than 10 meters at points, meaning that there are limits on the drafts of navigating vessels.

For these reasons, ocean-going merchant vessels using the Northern Sea Route from the Laptev Sea through to the East Siberian Sea are often ordered to navigate straits other than the Laptev Strait.

[Sannikov Strait (Proliv Sannikova)]

Sannikov Strait, like the Laptev Strait, connects the Laptev Sea and the East Siberian Sea, and is located within the area of the New Siberian Islands. It has a navigable width of about 20 miles, and the overall depths are shallow with some shallow areas of 13 meters depth, meaning that there are draft limitations for navigating vessels of 12.5 meters.

From the Laptev Sea through to the East Siberian Sea on the Northern Sea Route, the route offshore from the northern point of the New Siberian Islands, called the Tikhonov Route was long in use. Nevertheless, as surveys of that route are insufficient, and for other reasons, such as the fact that ice does not thaw even in summer, ocean-going vessels using the Northern Sea Route were often instructed to navigate by the Sannikov Strait. Recently, ships may be ordered to use either the Sannikov Strait or the Tikhonov Route depending on ice conditions.

[De Long Strait (Proliv Longa)]

De Long Strait connects the East Siberian Sea and the Chukchi Sea, and is located between Wrangel Island and the mainland, with widths reaching about 60 miles. The average water depth is approximately 40 meters.

From the East Siberian Sea through to the Chukchi Sea, the route passing offshore from the northern point of Wrangel Island has long been used. However, at present, ocean-going merchant vessels using Northern Sea Route are often ordered to navigate by De Long Strait.

1.2.8 Ports around the Northern Sea Route

The number of ports around the Northern Sea Route is not substantial, with the major ports as given below.

[Port of Kirkenes]

Kirkenes is a port at the most northern point of Norway on the coastline of the Barents Sea, which does not freeze year-round. It is near the Russian border, where iron ore excavated from Bjørnevatn mines and other resources are handled.

The largest vessel types which can enter port are tankers with a deadweight capacity of 20,000 tons and drafts of 10.06 meters, or bulk carriers with a deadweight capacity of 12,000 tons and drafts of 15.54 meters. Refueling and freshwater replenishing, equipment repair, as well as medical facilities such as hospitals, and waste receiving services are available.

[Port of Murmansk]

Murmansk is a Russian port in the north of the Kola Peninsula on the coastline of the Barents Sea, which does not freeze year-round. It has long been one of the hub ports of the Northern Sea Route. It handles coal, apatite (raw material of chemical fertilizer containing phosphate), gas condensate (a light petroleum extracted with natural gas), iron ore, fertilizers, and marine produce, among others.

The largest vessel types which can enter port are tankers of 160 meters overall length and drafts of 7.5 meters, or bulk carriers with deadweight capacity of 16,000 tons, overall length of 300 meters and drafts of 15.55 meters. Refueling and freshwater replenishing, all types of equipment repair, as well as medical facilities such as hospitals and waste receiving services are available.

[Port of Arkhangelsk]

Arkhangelsk is a Russian port facing onto the White Sea, which connects to the Barents Sea, and it freezes. It has long been one of the hub ports of the Northern Sea Route after Murmansk. It handles pulp, lumber, coal and petroleum, among other items.

When there is no ice, the largest vessel type which can enter port is 190 meters overall length, and with ice-cover, 165 meters overall length and 30 meters beam.

There is a draft limit of 9.2 meters, which can change depending on, for example, seasonal conditions throughout the year.

Refueling and freshwater replenishing, all types of equipment repair, as well as medical facilities such as hospitals, and waste receiving services, including oleaginous waste, are available.

[Port of Amderma]

Armderma is a Russian port near Yugorsky Strait in the south of the Kara Sea, which freezes. It is used for material supplies for resource development of the Pechora Sea. There are no berths for pier-docking of large vessels, and loading and unloading uses barges, etc. at anchorage. There is a hospital in the town.

[Port of Sabetta]

Sabetta is a Russian port facing the Gulf of Ob which connects to the Kara Sea, and it freezes. As well as being used for material supplies for resource development of the Yamal Peninsula, it is used for shipments of liquefied natural gas (LNG). It is one of the new hub ports of the Northern Sea Route.

[Port of Dikson]

Dikson is a Russian port at the mouth of the Yenisei River in the south part of the Kara Sea, which freezes. The largest draft permitted, depending on the route taken to enter port, is limited to 10 or 11 meters. Refueling and freshwater replenishing, equipment repair, as well as medical facilities such as hospitals are available.

[Port of Dudinka]

Dudinka is a Russian port 215 miles upstream from the mouth of the Yenisei River in the south part of the Kara Sea, and it freezes. It has berths of 40 meters water depth, and the largest vessel types which can enter port are those with a deadweight capacity rank of 10,000 tons. It is used for material supplies for resource development of Northern Siberia, and is also one of the hub ports of the Northern Sea Route. It is used year-round by ice-strengthened cargo ships for transport, as a transport hub for nickel, etc. produced in the outskirts of Norilsk. Refueling and freshwater replenishing, equipment repair, as well as medical facilities such as hospitals are available.

[Port of Khatanga]

Khatanga is a Russian port 115 miles upstream from the mouth of the Khatanga River which enters the Laptev Sea, and it freezes. It handles among others coal, gravel and sand, lumber, commodities, and various types of petroleum.

It has berths which allow for pier-docking of vessels with drafts of up to 5.2 meters. Refueling and freshwater replenishing, equipment repair, as well as medical facilities such as hospitals and waste receiving services excluding oleaginous waste are available.

[Port of Tiksi]

Tiksi is a Russian port at the mouth of the Lena River in the south part of the Laptev Sea, and it freezes. It handles timber, various types of petroleum and fuels. It has depths of around 5 to 10 meters within the harbor, and has many berths including those for vessel ranks of 200 meters overall length.

Refueling and freshwater replenishing, equipment repair, as well as medical facilities such as hospitals are available.

[Port of Pevek]

Pevek is a Russian port on the coast of the East Siberian Sea, which does not freeze year-round. It has various berths of approximately 12 to 25 meters depth, and a maximum berth rank of 150 meters.

Refueling and freshwater replenishing, all types of equipment repair, as well as medical facilities such as hospitals are available.

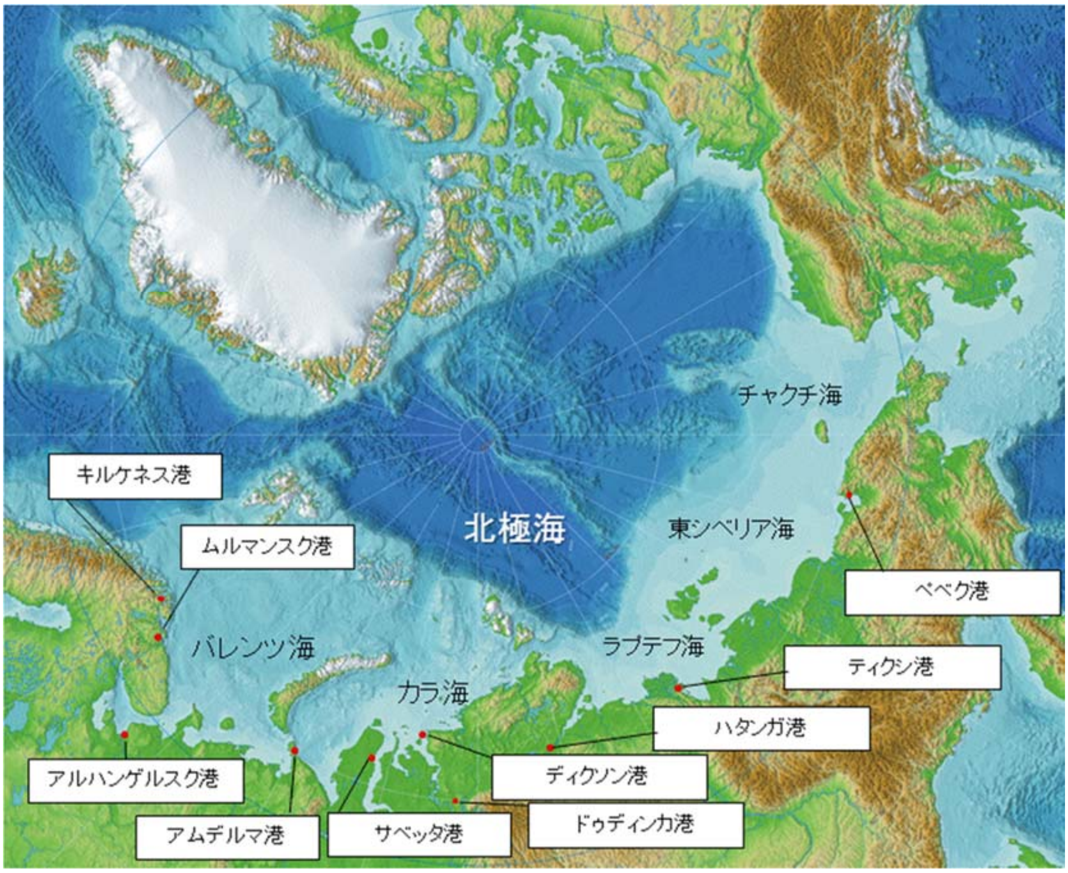


Fig. 1.6: Ports around the Northern Sea Route

(Source: Based on the National Institute of Polar Research “Arctic Region” map)

1.2.9 Navigation routes of the Northern Sea Route

The Northern Sea Route is a word used to indicate the entire route used to navigate the Arctic Ocean along the Russian coast of the Eurasia. This does not mean that distinct shipping lines divided by different aids to navigation exist. The actual route to be used by navigating vessels is indicated by the NSRA or a service control station commissioned by the NSRA on a case-by-case basis.

The NSRA, etc., will come to a decision on the navigation route by integrated consideration of the navigating vessel ice class, vessel type, draft, capacity and steering capacity, port of embarkation and destination port, the latest weather information, ice conditions, and so on. Accordingly, even if a vessel may be navigating the Northern Sea Route in the same direction at the same time, it is possible that there will be divergences in the route indicated to particular navigating vessels.

[Northern passage]

Navigation routes of the Northern Sea Route can be broadly divided into northern and the southern passages. The northern passage stretches from the Barents Sea, through the northeast point of Novaya Zemlya, offshore from Cape Zhelaniya, the sea areas at the northern side of Severnaya Zemlya, the northern point of the New Siberian Islands (Tikhonov Route) to the Bering Strait via the De Long Strait. The northern passage is approximately 230 miles shorter than the southern passage. However, as ice often does not thaw on the northern passage even in summer, this means that it cannot always be used.

[Southern passage]

The southern passage stretches from the Barents Sea, through the Kara Strait on the southern side of Novaya Zemlya, Vilkitsky Strait on the southern side of Severnaya Zemlya, Sannikov Strait on the southern side of the New Siberian Islands to the Bering Strait via the De Long Strait.

[Mixed route]

Recently, a mixed route with an appropriate combination of the northern passage and the southern passage is often indicated, depending on factors such as ice conditions. For example, a route from the Barents Sea through offshore of Cape Zhelaniya at the northeast point of Novaya Zemlya, Virkitsky Strait on the southern side of Severnaya Zemlya, Sannikov Strait on the southern side of the New Siberian Islands to the Bering Strait via the De Long Strait may often be indicated. This route takes in a combination of the northern passage as far as the Kara Sea, with points eastward of the Kara Sea using the southern passage.

Alternatively, a route from the Barents Sea through the Kara Strait on the southern side of Novaya Zemlya, Virkitsky Strait on the southern side of Severnaya Zemlya, the northern point of Novaya Zemlya (Tikhonov Route) to the Bering Strait via the De Long Strait may be indicated. This route takes in a combination of the southern passage as far as the Laptev Sea, with points eastward of the Laptev Sea using the northern passage.

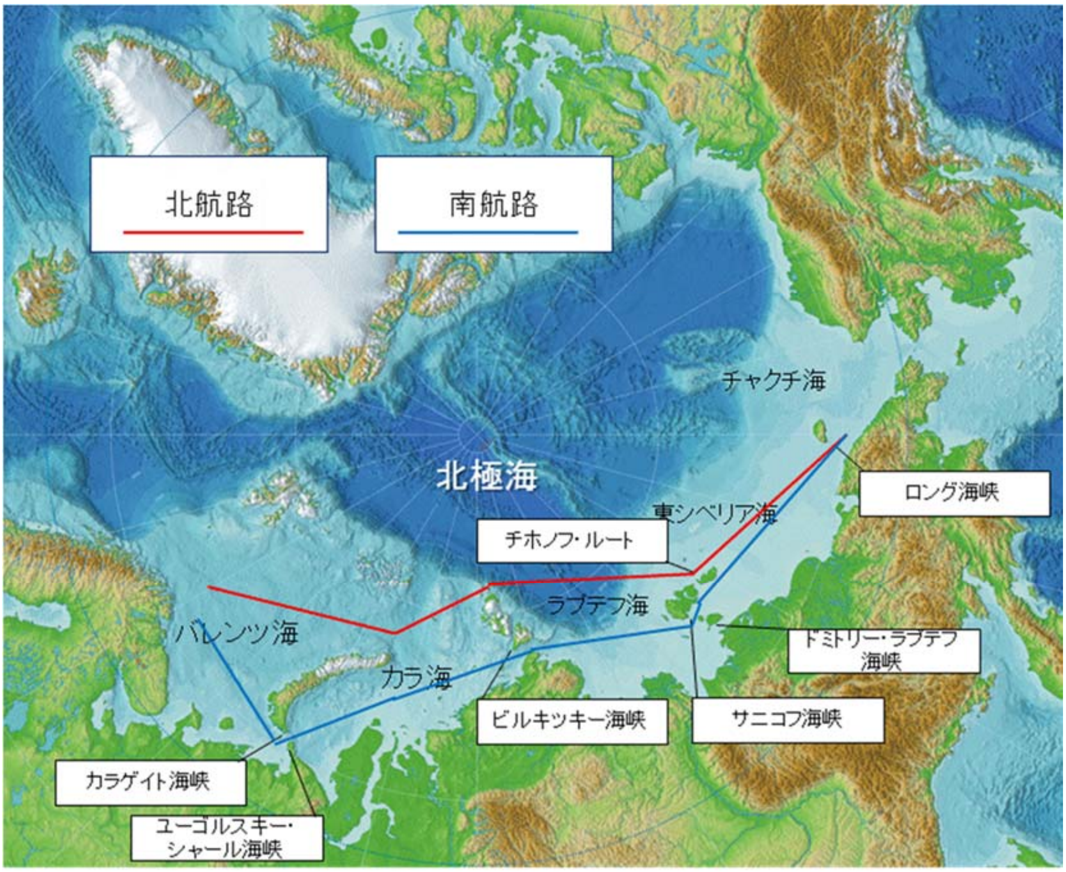


Fig. 1-7: Navigation routes of the Northern Sea Route

(Source: Based on the National Institute of Polar Research “Arctic Region” map)

1.3 Basic knowledge about climate and hydrographic conditions

In recent years, amidst the concern over global scale climate change, the scale and severity of warming and recession of ice in the Arctic Ocean has been accelerating. The degree of rising of temperatures over the last 30 years in the Arctic Ocean is 2 to 3 times as large as those on the globe as a whole, which means that the Arctic region is one of the areas in which the impact of climate change on a global scale has been most conspicuously evident. At the same time, weather phenomenon unique to the Polar Regions which cannot be seen in any other sea territories habitually occur in the Arctic Ocean.

Below, some of the basic knowledge about climate and hydrographic conditions in the Arctic Ocean and on the Northern Sea Route will be elucidated.

1.3.1 Temperature

While the North and South Poles are both Polar Regions, there are considerable temperature differences between them. The South Pole is a continent covered by an ice sheet with an average thickness of 2,000 meters, and has a plateau with an average elevation above sea level which reaches 2,300 meters. For this reason the South Pole has lower temperatures than the North Pole. Temperatures as low as −89.2°C in July 1983 and −93.2°C in August 2010 are observed at the South Pole.

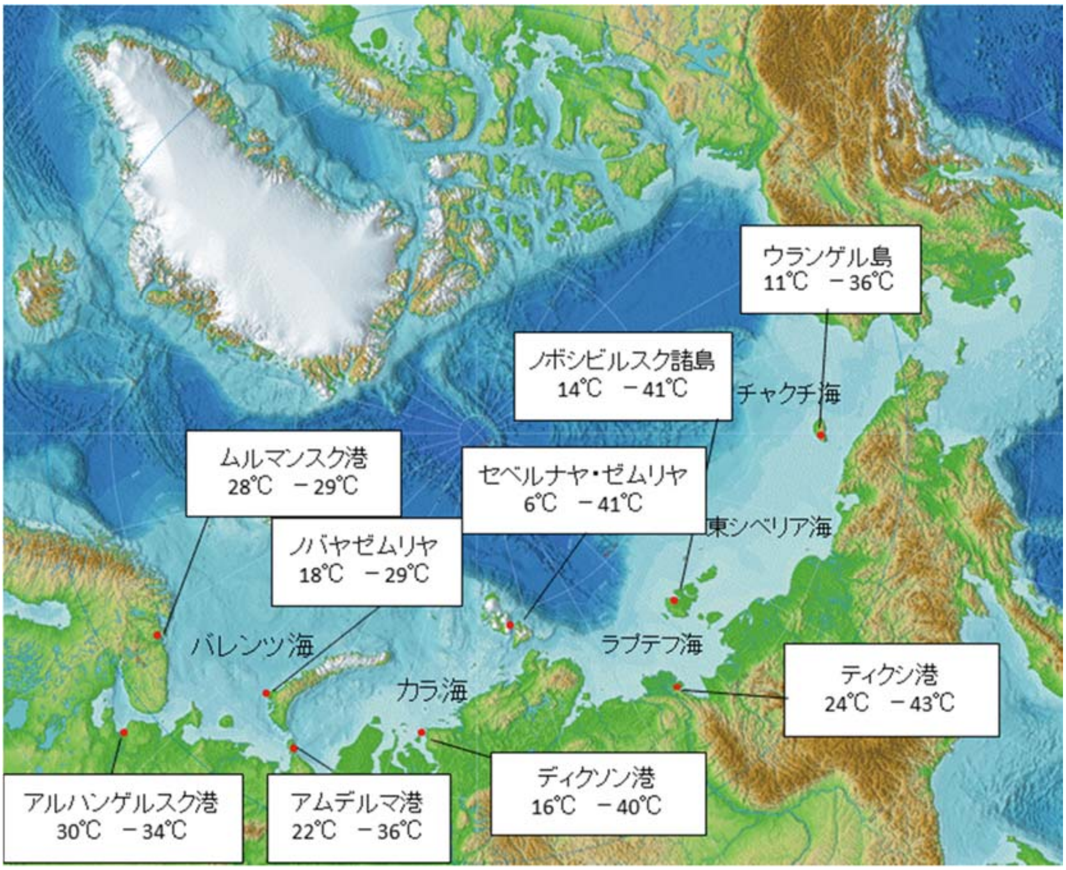


Fig. 1-8: Mean values for highest and lowest temperature in the ports and islands of the Northern Sea Route

(Source: Based on the National Institute of Polar Research “Arctic Region” map. Data from the World Meteorological Organization (WMO) database)

The North Pole meanwhile is comprised of ocean, meaning it has an elevation of 0 meters. Also, the thickness of the ice on the sea surface averages two meters, with even thicker areas within three to four meters. Moreover, the temperature of the seawater beneath the ice is over −2°C even at its coldest and acts as an insulator. Accordingly, North Pole temperatures do not become particularly low when compared to those at the South Pole. In the coldest months of winter in January and February, even in the central part of the Arctic Ocean, the average temperatures remain within −30°C to −35°C. In addition, the summer months when temperatures reach their highest and the traffic of ocean-going merchant vessels begins to increase, in July and August, the temperatures around the Northern Sea Route reach approximately +5°C to +10°C. Temperatures exceeding +20°C, which are usually associated with warmer climates, may also be observed.

According to data of the World Meteorological Organization (WMO), average yearly temperature highs observed in Murmansk Port on the coast of the Barents Sea are +28 °C, with average yearly temperature lows of −29°C (yearly means for 1974-2009). Similarly, average yearly temperature highs observed in Arkhangelsk Port on the coast of the Barents Sea are +30°C, with average yearly temperature lows of −34°C (yearly means for 1984-2009).

Average yearly temperature highs observed on the west coast of Novaya Zemlya are +18°C, with average yearly temperature lows of −29°C (yearly means for 1984-2010).

Average yearly temperature highs observed at Amderma Port on the coast of the Kara Sea are +22°C, with average yearly temperature lows of − 36°C (yearly means for 1984-2010). Similarly, average yearly temperature highs observed at Dikson Port on the coast of the Kara Sea are +16°C, with average yearly temperature lows of −40°C (yearly means for 1984-2010).

Average yearly temperature highs observed on the west coast of the Severnaya Zemlya are +6°C, with average yearly temperature lows of −41°C (yearly means for 1984-2010).

Average yearly temperature highs observed at Tiksi Port on the coast of the Laptev Sea are +24°C, with average yearly temperature lows of −43°C (yearly means for 1984-2010).

Average yearly temperature highs observed at the north coast of the New Siberian Islands are +14°C, with average yearly temperature lows of −41°C (yearly means for 1984-2010).

Average yearly temperature highs observed on the south coast of Wrangel Island are +11°C, with average yearly temperature lows of −36°C (yearly means for 1984-2010).

1.3.2 Polar night and polar day

On the Northern Sea Route in winter (the period between Autumnal and Vernal Equinoxes), there are days when the sun does not appear (polar night) or days during which the night is drastically longer than the day. On the other hand, in summer (the period between Vernal and Autumnal Equinoxes) there are days when the sun does not set (polar day or midnight sun) or days during which the day is drastically longer than the night.

The number of continuous days of polar nights and polar days increase as latitudes increase. At northern latitudes of around 73°, there are approximately 80 days of polar night and 90 days of polar days in a year, while at latitudes of around 80° there are approximately 125 days of polar night and 140 days of polar days. At the most northerly latitude of 90°, there are approximately 175 days of polar night and 190 days of polar days. There are more total days of polar day than total days of polar night, due to the apparent radius of the sun, namely it maintaining a certain size, and the refraction of the sun in atmospheric light, meaning that the sun can still be visually perceived even when approximately 0.5° beneath the horizon.

Polar nights and polar days occur because the earth's axis is tilted at an angle of 23.5° from the orbital plane of the sun. They do not occur anywhere other than within the Arctic Circle (the area within a circle drawn at latitude 66° 33′ north) and the Antarctic Circle (the area within a circle drawn at latitude 66° 33′ south). The Northern Sea Route excluding part of the sea area around the Bering Strait is all within the Arctic Circle.

1.3.3 Precipitation

Precipitation around the Northern Sea Route is of a low level comparable to that found in deserts or the countries of the Middle East with yearly averages within 100 to 400 millimeters. The area around the Northern Sea Route is characterized by precipitation in summer exceeding that in winter. The average yearly precipitation in

Tokyo is around 1,500 millimeters, meaning that the precipitation in the Northern Sea Route area is as little as between 7% and 26% of that level. In the comparatively warmer months of the summer, rain falls rather than snow.

The low precipitation levels around the Northern Sea Route have their cause in the low amounts of saturated water levels as a result of comparatively low temperatures. In addition, it is said that causes such as soot and smoke occurring in Europe contribute to atmospheric pollution which reaches as far as Alaska due to the low levels of precipitation in the Arctic Ocean, which means that this soot and smoke is not brought down with snow or rainfall.

According to World Meteorological Organization data, average yearly precipitation observed at Murmansk Port on the coast of the Barents Sea is 420 millimeters, with a yearly average of 195 days with precipitation (defined as days with 0.1 millimeters or more of precipitation), and there is more precipitation in summer than in winter, with marginally less days with precipitation in summer than in winter (yearly means for 1986-2009). Similarly yearly average precipitation observed at Arkhangelsk Port on the coast of the Barents Sea is 484 millimeters, with a yearly average of 168 days with precipitation, and there is marginally more precipitation in summer than in winter, with less days with precipitation in summer than in winter (yearly means for 1986-2009).

Average yearly precipitation observed on the south coast of Novaya Zemlya is 259 millimeters, with a yearly average of 164 days with precipitation, and there is more precipitation in summer than in winter, with marginally more days with precipitation in summer than in winter (yearly means for 1995-2010).

Average yearly precipitation observed at Amderma Port on the coast of the Kara Sea is 435 millimeters, with a yearly average of 211 days with precipitation, and there is more precipitation in summer than in winter, with marginally less days with precipitation in summer than in winter (yearly means for 1984-2010). Similarly, average yearly precipitation observed at Dikson Port on the coast of the Kara Sea is 379 millimeters, with a yearly average of 190 days with precipitation, and there is roughly the same amount of precipitation in summer as winter, and roughly the same amount of days with precipitation in summer as winter (yearly means for 1984-2010).

Average yearly precipitation observed on the west coast of Severnaya Zemlya is 166 millimeters, with a yearly average of 130 days with precipitation, and there is more precipitation in summer than in winter, and roughly the same amount of days with precipitation in summer as winter (yearly means for 1984-2010).

Average yearly precipitation observed at Tiksi Port on the coast of the Laptev Sea is 328 millimeters, with a yearly average of 146 days with precipitation, and there is marginally more precipitation in summer than in winter, and roughly the same amount of days with precipitation in summer as winter (yearly means for 1984-2010).

Average yearly precipitation observed on the north coast of the New Siberian Islands is 219 millimeters, with a yearly average of 147 days with precipitation, and there is more precipitation in summer than in winter, and roughly the same amount of days with precipitation in summer as winter (yearly means for 1984-2010).

Average yearly precipitation observed on the south coast of Wrangel Island is 183 millimeters, with a yearly average of 93 days with precipitation, and there is marginally less precipitation in summer than in winter, and roughly the same amount of days with precipitation in summer as winter (yearly means for 1984-2010).

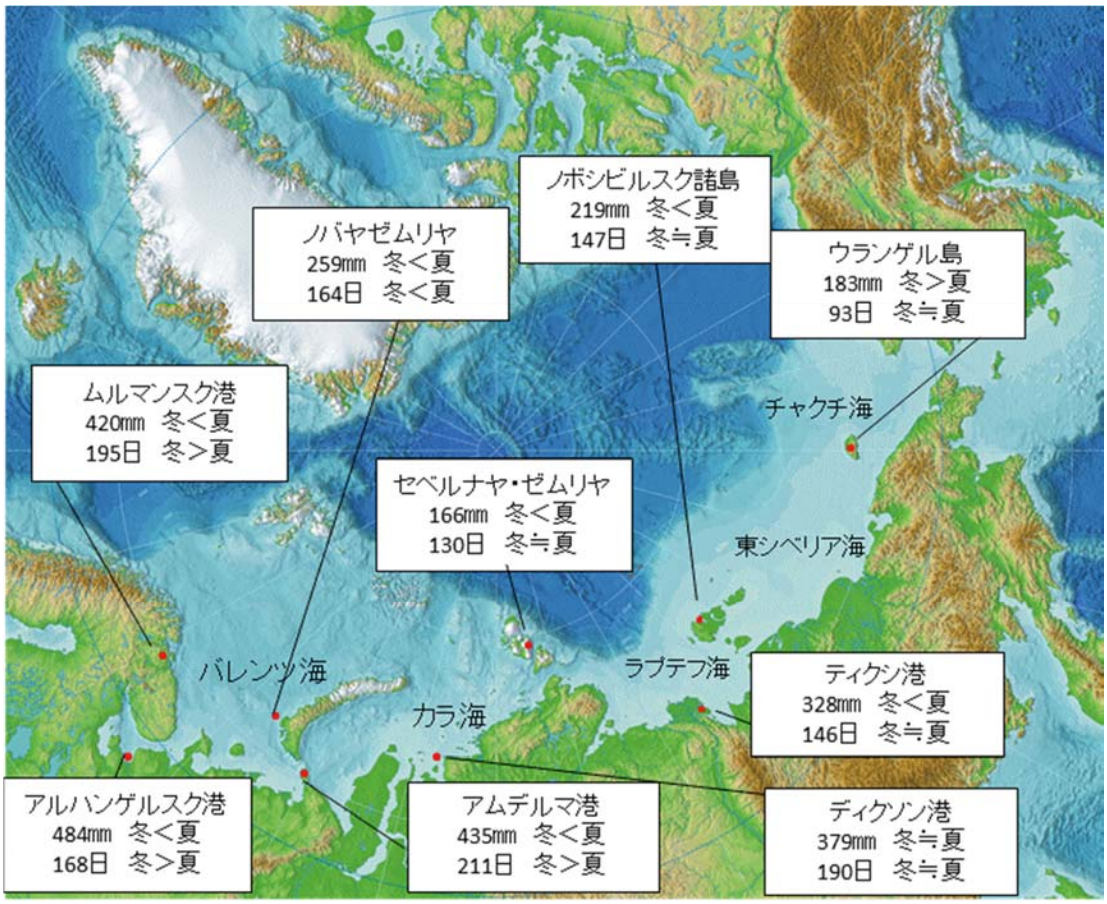


Fig. 1-9: Mean values for yearly precipitation levels and days with precipitation for the ports and islands of the Northern Sea Route

(Source: Based on the National Institute of Polar Research “Arctic Region” map. Data from the World Meteorological Organization (WMO) database)

1.3.4 Amount of snow

Snowfall on ice increases the ice-breaking resistance for icebreakers, and becomes an obstacle to effective ice-breaking capacity. In worst case scenarios vessels may be rendered immobile due to the failure to break ice. Also, snow accumulated on ice is one of the largest factors impacting on the formation and thawing of ice.

Snow accumulation on ice in the surroundings of the Northern Sea Route is within 0 to 10 centimeters for first-year ice, while for second-year ice it is within 12 to 18 centimeters. However, hummocks caused by separate bodies of ice pushed against and overlapping with each other, or ridges along the swells of hummocks, can result in normal levels of 60-100 centimeters, and at times reach to levels of 200 centimeters, as accumulations of snow tend to increase when blizzards cause buildups in the surrounding snow.

1.3.5 Arctic stratus clouds and fog

Around the Northern Sea Route, warm air from land meets ice, and forms so-called Arctic stratus clouds which are characterized by clouds with ceilings of less than 500 meters or fog. Particularly in summer there are almost no cloudless days, and there is generally a 70% to 80% chance that there will be continual turbid weather with a cover of arctic stratus clouds or fog. Meanwhile, the chance of these phenomena occurring during winter drops to between 20% and 40%. Around the boundaries of areas of open water and sea ice, severe fog densities may be encountered, meaning particular caution should be observed.

Recent reductions of ice levels in summer leading to temperature differentiations between the sea surface and the cold ice in the Arctic Ocean, have meant that rather than Arctic stratus clouds or fog, convective clouds with high ceilings are becoming more commonplace, due to the large supply of heat and water vapor from the sea surface to the atmosphere.

According to WMO data, at the Port of Murmansk on the coast of the Barents Sea, a yearly mean of 17 days with fog were observed, with occurrences most common from spring through summer (yearly means for 1974-2009). At the Port of Arkhangelsk on the coast of the Barents Sea, a yearly mean of 20 days with fog were observed, with occurrences most common from spring through summer (yearly means for 1984-2009).

On the west coast of Novaya Zemlya, a yearly mean of 24 days with fog were observed, with occurrences most common from spring through summer (yearly means for 1984-2010).

At the Port of Amderma on the Kara Sea, a yearly mean of 60 days with fog were observed, with occurrences most common from spring through summer (yearly means for 1984-2010). At the Port of Dikson on the Kara Sea, a yearly mean of 45 days with fog were observed, with occurrences most common from summer through autumn (yearly means for 1984-2010).

On the west coast of Severnaya Zemlya, a yearly mean of 25 days with fog were observed, with occurrences most common in summer (yearly means for 1984-2010).

At the Port of Tiksi on the Laptev Sea, a yearly mean of 20 days with fog were observed, with occurrences most common in summer (yearly means for 1984-2010).

At the north coast of the New Siberian Islands, a yearly mean of 19 days with fog were observed, with occurrences most common in summer (yearly means for 1984-2010).

At the south coast of Wrangel Island, a yearly mean of 34 days with fog were observed, with occurrences most common from summer through autumn (yearly means for 1984-2010).

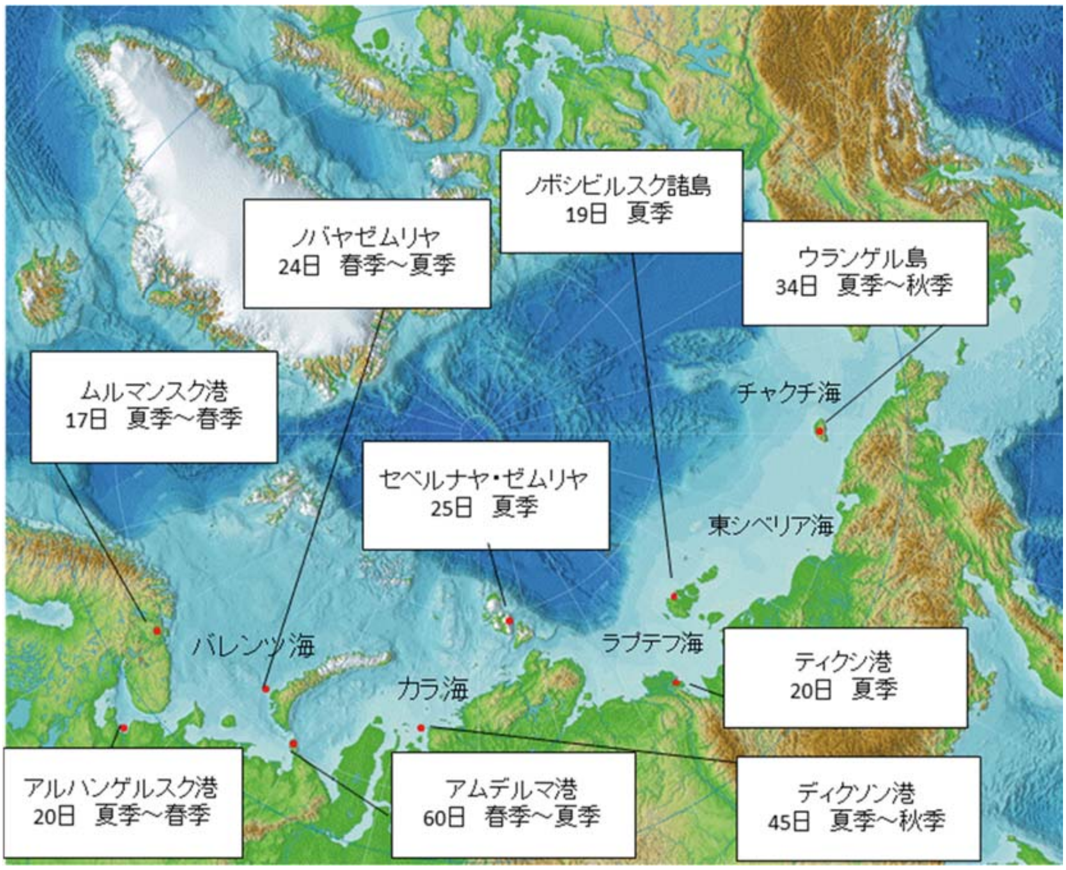


Fig. 1-10: Mean days with fog for the ports or islands of the Northern Sea Route

(Source: Based on the National Institute of Polar Research “Arctic Region” map. Data from the World Meteorological Organization (WMO) database)

1.3.6 Arctic haze

Misty smog often occurs in early spring around the Northern Sea Route, and this is referred to as Arctic haze. When Arctic haze occurs, visibility is reduced to a few miles.

Generally, smog is a result of atmospheric pollutants suspended in the atmosphere, and in recent years it has been occurring in cities of China, Brazil and India, becoming a serious social issue. In Japan, during the period of rapid economic development of the Showa Period (1926-1989), it occurred in industrial zones and resulted in pollution issues which impacted on human health and people's living environments.

It is said that the reason that Arctic haze occurs is gas fumes and soot and smoke emissions in the northern hemisphere.

Pic. 1-1: Arctic haze (Source: National Institute of Polar Research)

1.3.7 Low pressure fronts

A characteristic course for a low pressure fronts in the Arctic Ocean in winter would be to enter from the direction of Iceland or the White Sea, move through the Barents Sea, the Kara Sea and the Laptev Sea, and then travel through as far as the East Siberian Sea and the Chukchi Sea direction. Other examples would be low pressure fronts entering from the direction of the Norwegian Sea through the Svalbard

Archipelago; those moving northward in the direction of the Chukchi Sea after entering from the Bering Straits; or those entering from the Laptev Sea.

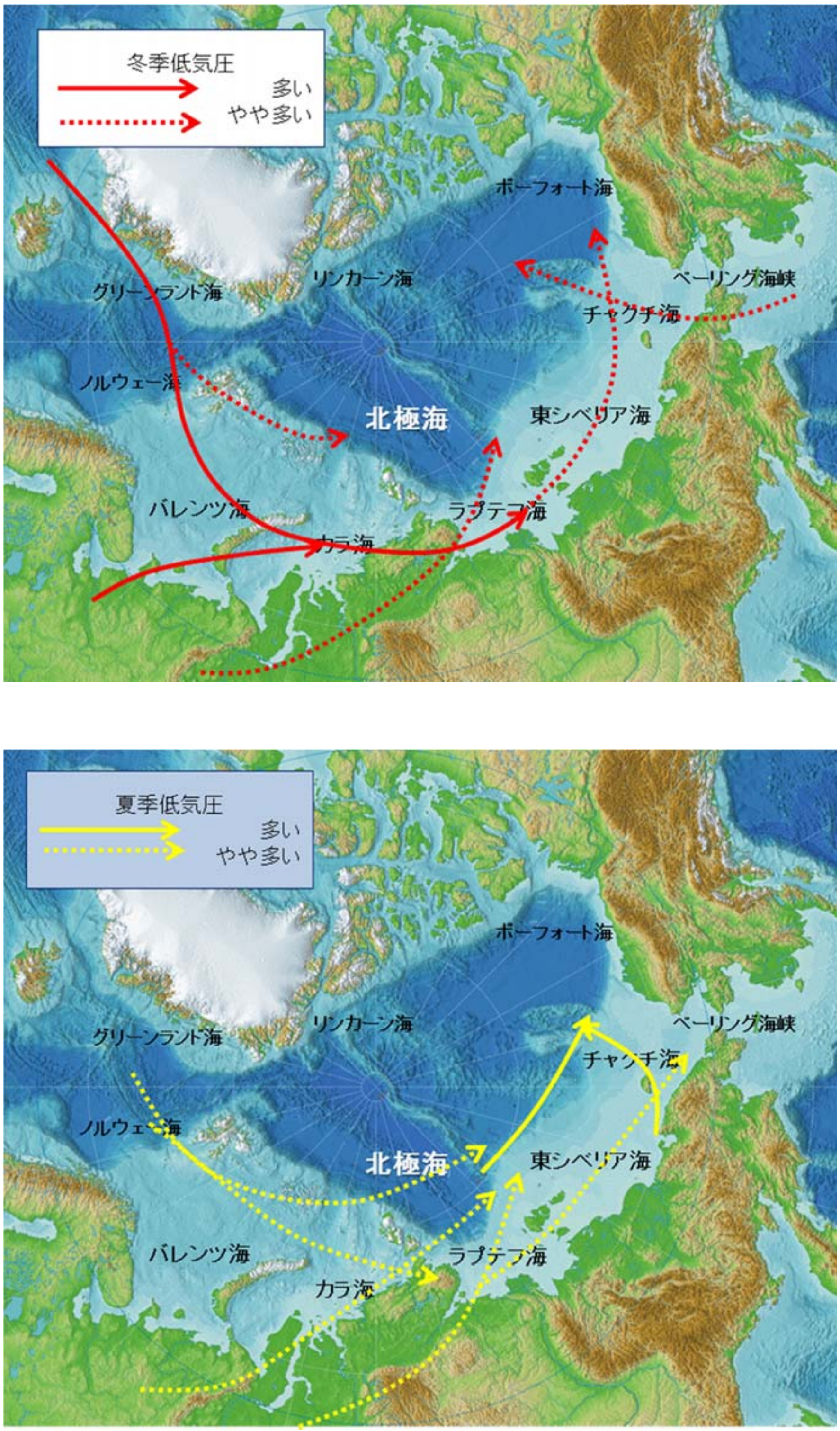
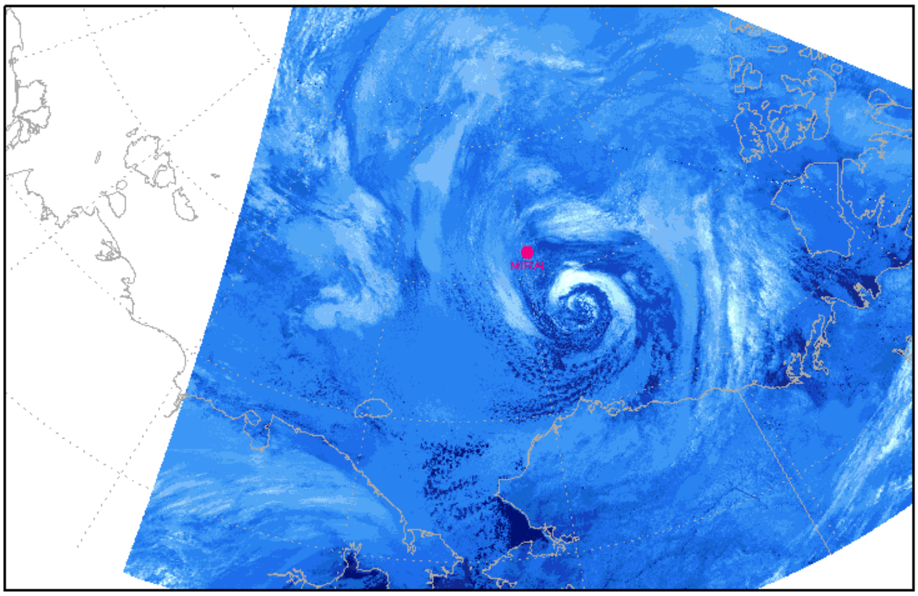


Fig.1-11: Typical course of Arctic Ocean low pressure fronts

(Source: Based on the National Institute of Polar Research "Arctic Region" map. Data from Arctic Ocean publication, United Kingdom Hydrographic Office)

Characteristic courses for low pressure fronts in the Arctic Ocean in summer would be to enter from in the Laptev Sea or the northern part of the East Siberian Sea and move eastwards; or occur on the coastline of Siberia and move northwards towards the Chukchi Sea. Other examples would be those entering from the Greenland Sea or the Norwegian Sea direction and moving through the Kara Sea or the Laptev Sea direction via the Svalbard Archipelago; or entering from the coast of Russia and proceeding in an easterly direction in the direction of the Kara Sea, the Laptev Sea or the East Siberian Sea.

The Arctic Ocean in summer was previously characterized by continuous mild days with light breezes while having few cloudless days. However, in recent years the convection clouds which have occurred alongside the reduction of ice have developed in a vertical direction, meaning that low pressure fronts are more easily formed. Low pressure systems become particularly active during years marked by the pronounced reduction of ice. These kinds of low pressure fronts which, rather than entering the Arctic Ocean after forming at middle latitudes, are formed at the boundaries of polar fronts in the Arctic Ocean, namely the low pressure systems which occur around the edges of the sea territory, are referred to as polar low pressures or "polar low". Polar lows are characterized by their small scales of within 400-600 kilometers diameter; they are exclusively cold-core, with no front; are spiral-forming, and generate, develop and disappear rapidly. Polar lows are accompanied by violent blizzards and rain, bringing unsettled weather to the Arctic Ocean, and obstructing vessel navigation. At times they develop on the level of typhoons, and ships using the Northern Sea Route should pay due heed to polar lows.



Pic. 1-2: Satellite image of a polar low captured by JAMSTEC Japanese oceanographic research vessel “RV Mirai”, September 25, 2010 (courtesy of Jun Inoue)

It should be noted that strong winds from generated low pressure systems, are said to be contributing to the increasing reduction of ice by pushing and transporting ice outside the Arctic Ocean. The movement of ice by polar lows also has impacts on global scale climate change.

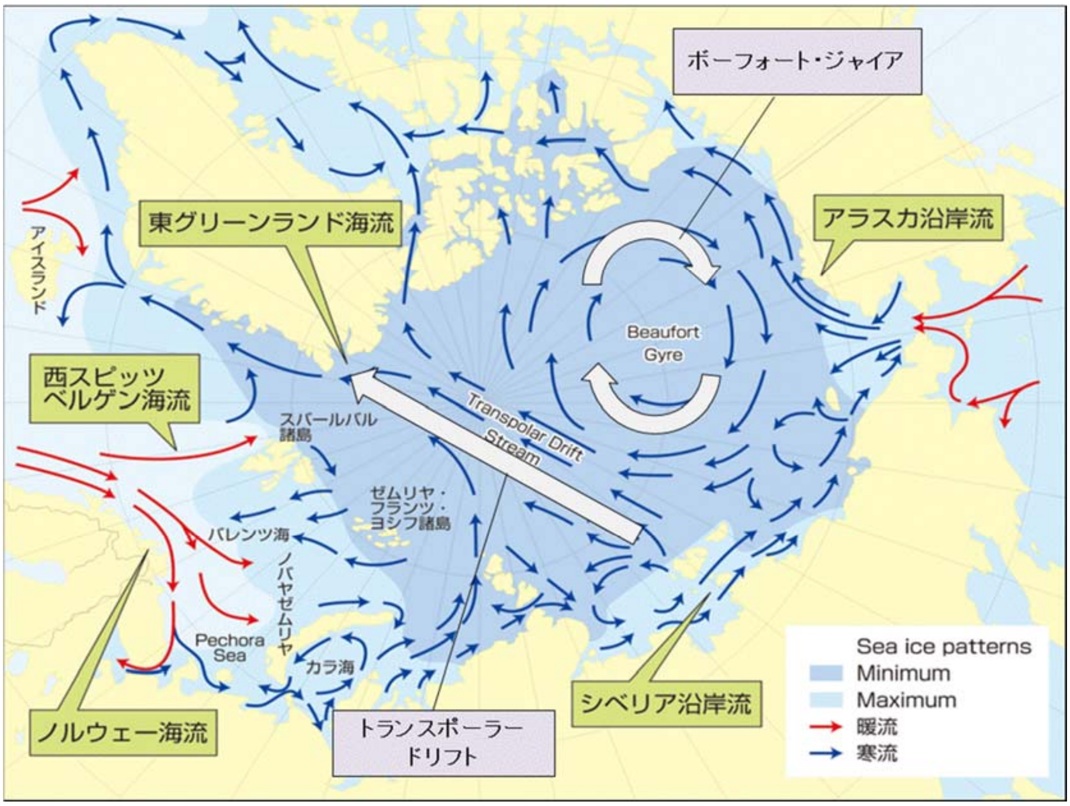


Fig. 1-12: Arctic Ocean ice movement and surface currents

(Source: Map based on CraftMAP http://www.craftmap.box-i.net/, created with reference to “Arctic Ocean currents and sea ice extent. Map courtesy of Phillippe Rekacewicz, UNEP/GRID-Arendal”)

1.3.8 Ice movement and surface currents

There are two major movements of ice in the Arctic Ocean. The first is the clockwise rotation which can be seen in the Canada Basin off the North American continent, known as the Beaufort Gyre. The second is called Transpolar Drift, and is a straight movement from the direction of the Laptev Sea and the East Siberian Sea on the Russian coast, which, after heading towards the North Pole in a northerly direction, travels through towards the direction of the Fram Strait in the northeast part of Greenland.

The surface currents of the Arctic Ocean can be divided into those driven by the ice movement as described above and littoral currents which flow along the coastline or continental shelf. The currents of the former category share certain affinities and coincide with the movement of ice. Namely, they circulate slowly in a clockwise direction off the coast of North America in the Canada Basin, like the Beaufort Gyre. The speed of the currents is fast on the south and west sides of the rotational center and gentler on the north and east sides.

Representatives of the latter littoral currents include: the Norwegian current, a warm current entering the Barents sea along the Scandinavian peninsula having come northerly from the North Atlantic; the West Spitsbergen Current which separates from the Scandinavian peninsula and heads northwards to enters the Arctic Ocean through the east channel of the Fram Strait; the East Greenland Current which feeds into the Greenland Sea along the Eastern seaboard of Greenland from the Arctic Ocean; Alaska Coastal Current which brings warm Pacific water northward along the Alaskan Coast of the Chukchi Sea; and the Siberian Coastal Current which moves towards the Bering Strait along the Siberian Coastline of the Chukchi Sea.

When navigating the Northern Sea Route eastwards from the direction of Europe, from the Barents Sea to the Kara Sea, Laptev Sea and East Siberian Sea, you generally proceed along the line of the surface currents. However, pay due caution that, as you proceed over the comparatively shallow water depths extending across the continental shelf from Eurasia on the Northern Sea Route, you can expect to experience complex tides changes in these vicinities, depending on the season, wind direction, and other factors. Current speeds around the Northern Sea Route, excluding the narrow channels of the straits, etc. are not particularly rapid overall, being within 0.5 to 1 knots at their strongest.

1.3.9 Water temperatures

In summer, the water temperatures around the Northern Sea Route generally exceed 5°C and even at their lowest never drop below zero. In the Barents Sea, due to the influence of the warm current flowing in from the North Atlantic, temperatures of as high as 10°C or more are also experienced.

In winter, from the Kara Sea over wide areas as far as the Laptev Sea, the East Siberian Sea and the Chukchi Sea, sea temperatures drop below zero and reach as low as −2°C. In the Barents Sea (and part of the Kara Sea), due to the influence of a warm current, water temperatures are generally above zero and can exceed 5°C at most.

1.3.10 Swells

In the sea area around the Northern Sea Route, excluding circumstances where low pressure systems occur or develop, it is generally relatively placid, meaning that swells are comparatively small. Also, a feature of this area is that, even when low pressures are encountered and strong winds rise, the offshore ice becomes an obstacle to wind fetch distances, meaning it is difficult for large swells to be generated.

Swells and waves pulverize ice floes and fast ice, or contribute to their thawing. Habituation to swells will allow you to estimate the distance to the ice edge or the proximity of the ice to the ice bound seas by observing factors such as the conditions of their progress.

1.3.11 Wind

According to World Meteorological Organization (WMO) data, there is a yearly mean of 7 days in which strong wind, that is to say wind in excess of Beaufort Scale 7 (equivalent to wind speeds of 28 to 33 knots: 13.9 to 17.1 m/s), is observed at the Port of Murmansk on the Barents Sea coast, with there being more such days in winter than in summer. The direction of strong winds in winter is generally southerly, and the direction of strong winds in summer is generally southerly or northerly (yearly means for 1974-2009). There is a yearly mean of under one day of strong winds, observed at the Port of Arkhangelsk on the Barents Sea coast (yearly means for 1984-2009).

There is a yearly mean of 75 days in which strong wind is observed on the west coast of Novaya Zemlya, with there being more such days in winter than in summer. In winter, the direction of strong winds is generally easterly or southerly, and the direction of strong winds in summer is generally easterly or northerly (yearly means for 1984-2010). There is a yearly mean of 20 days in which strong wind is observed at the Port of Amderma on the coast of the Kara Sea, with there being more such days in winter than in summer. In winter, the direction of strong winds is generally southerly, and the direction of strong winds in summer is generally easterly or southerly (yearly means for 1984-2010). There is a yearly mean of 16 days in which strong wind is observed at the Port of Dikson on the coast of the Kara Sea, with there being more such days in winter than in summer. In winter, the direction of strong winds is generally southerly, and the direction of strong winds in summer is generally northeasterly or southerly (yearly means for 1984-2010).

There is a yearly mean of 4 days in which strong wind is observed at the west coast of Severnaya Zemlya, with there being more such days in winter than in summer. In winter, the direction of strong winds is generally easterly, and the direction of strong winds in summer is generally northeasterly (yearly means for 1984-2010).

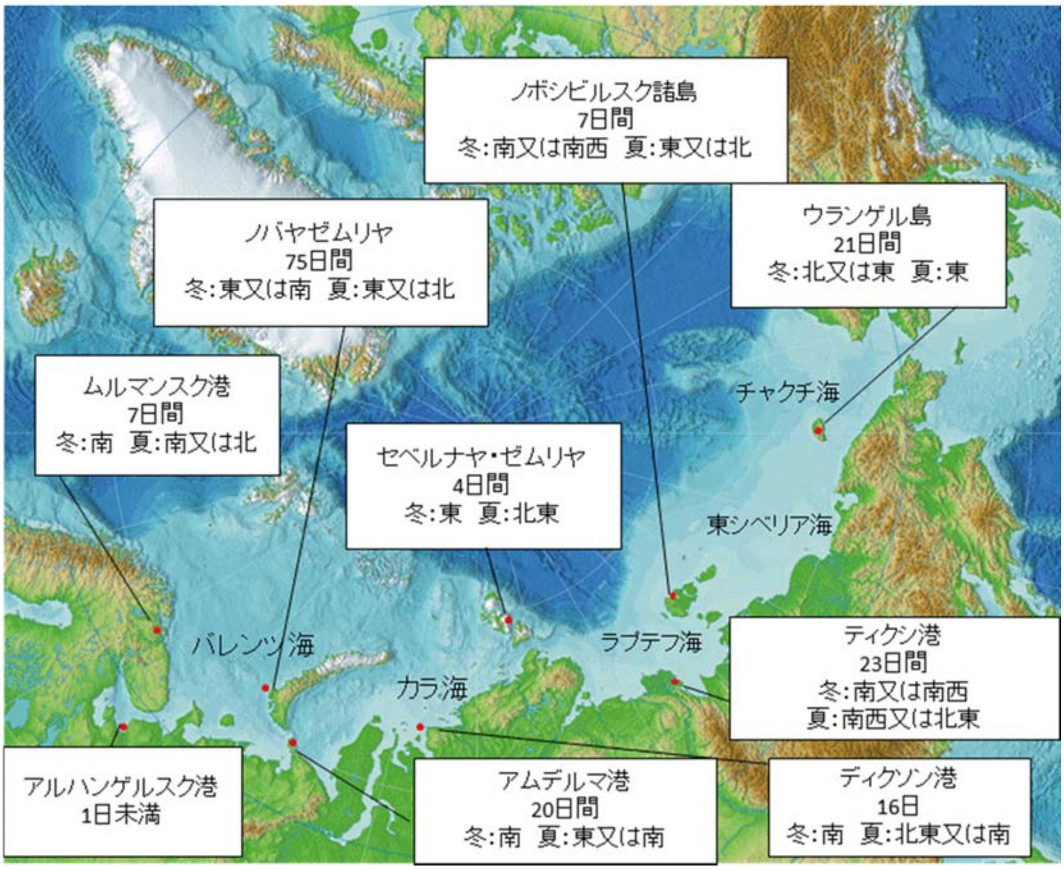


Fig. 1-13: Annual means for days with strong winds and their direction for the ports and islands of the Northern Sea Route

(Source: Based on the National Institute of Polar Research “Arctic Region” map. Data from the World Meteorological Organization (WMO) database)

There is a yearly mean of 23 days in which strong wind is observed at the Port of Tiksi on the coast of the Laptev Sea, with there being more such days in winter than in summer. In winter, the direction of strong winds is generally southerly or southwesterly, and the direction of strong winds in summer is generally southwesterly or northeasterly (yearly means for 1984-2010).

There is a yearly mean of 7 days in which strong wind is observed at the north coast of the New Siberian Islands, with there being roughly the same number of such days in winter and summer. In winter, the direction of strong winds is generally southerly or southwesterly, and the direction of strong winds in summer is generally easterly or northerly (yearly means for 1984-2010).

There is a yearly mean of 21 days in which strong wind is observed at the south coast of Wrangel Island, with there being more such days in winter than in summer. In winter, the direction of strong winds is generally northerly or easterly, and the direction of strong winds in summer is generally easterly (yearly means for 1984-2010).

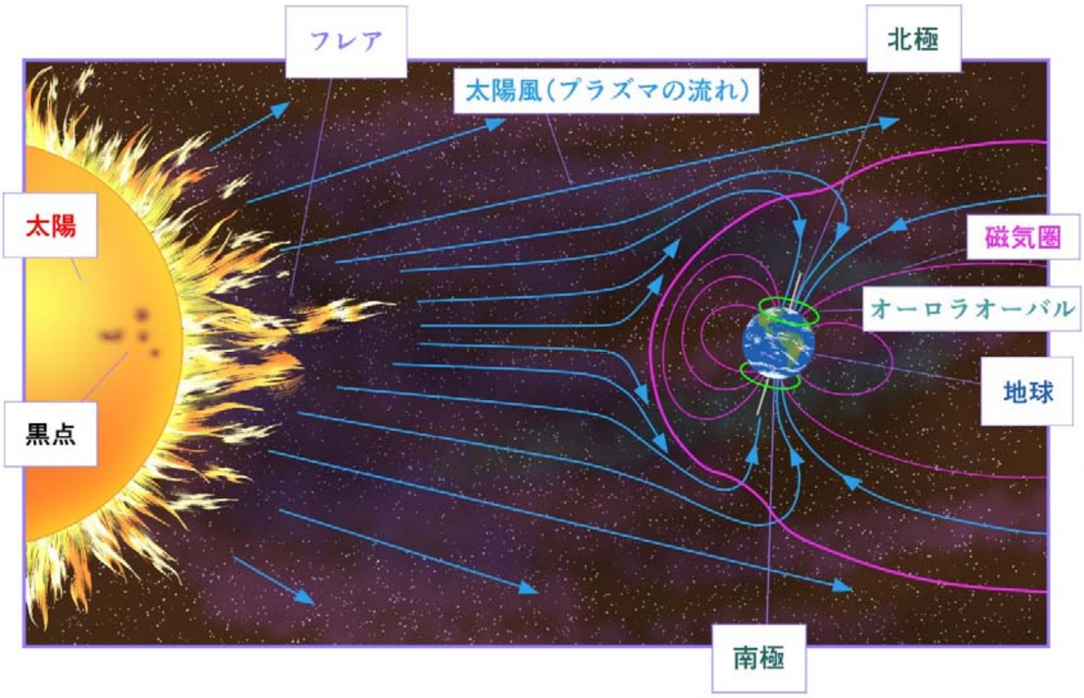


Fig. 1-14: Aurora occurrence mechanism

1.3.12 Aurora

The magnificent sight of the Aurora, also referred to as the Aurora Borealis or Northern Lights, flickering fantastically in the sky, is a natural phenomenon which can only be observed in the polar regions. When a surface eruption of the sun, known as a solar flare, or a large scale ejection of the sun's surface air referred to as a corona occurs, ionized particles (plasma) are released at high speeds, and this is called a solar wind. When this plasma reaches the Earth's magnetosphere, the magnetic field causes it to be carried to the Polar Regions as these regions are a lattice of the lines of magnetic force. At a height of 100 to 500 meters above ground of the Polar Regions, the plasma collides with atoms and particles in the atmosphere, to produce a luminescence known as the aurora. This is the same principle which produces luminescence in a cathode ray tube, fluorescent lamp, neon sign, and so on. Plasma collides with atmospheric oxygen atoms to produce green or red light, while collision with nitrogen atoms or ions produces purple or blue light.

While the Aurora does not often occur around the North Pole, it does often occur in what is known as the auroral zone, an area which elliptically surrounds the Earth's magnetic poles. The auroral zone is located from around latitudes 65° to 70°, and includes: Kiruna in Sweden; Tromsø in Norway; Fairbanks in Alaska; and Yellowknife in Canada, with these areas all being famous worldwide as locations where the aurora can be observed, and which are thus visited by tourists from throughout the world.It is said that the aurora generally occurs at a high rate of around 100 times per year within the auroral zone. Nearly the entire course of the Northern Sea Route is within the auroral zone. When the Earth is observed from space, the location when the aurora occurs at the moment is called the aurora oval. This does not mean that the auroral zone and the aurora oval are the same.

It should be noted that, when the aurora is at its most turbulent and spreading around haphazardly, electromagnetic disturbances are often induced and magnetic storms may occur. This phenomenon is known as an auroral storm, and due caution should be paid to these storms, as they are accompanied by the release of high currents reaching from 100,000 to 1 million amperes into the atmosphere, then cause disturbances to the terrestrial magnetic field, and can have a negative effect on a vessels communications or measurement instrumentation.

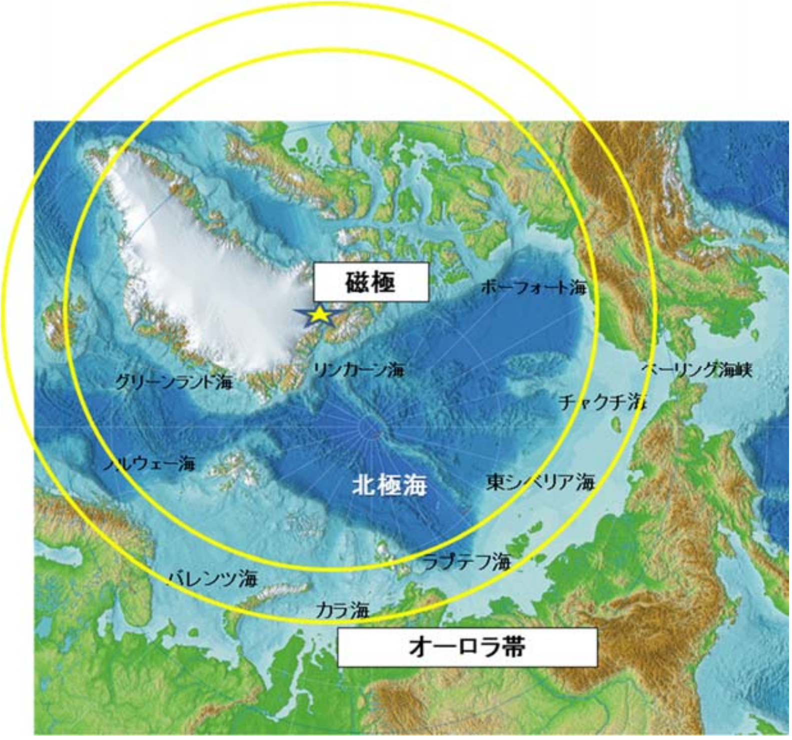


Fig. 1-15: North Pole auroral zone

(Source: Based on the National Institute of Polar Research “Arctic Region” map.)

2. Basic knowledge about sea ice

Approximately 90% of all of the ice which exists on the surface of the Earth is found in the Antarctic ice sheet, and an approximately further 9% is in the Greenland ice sheet. The remaining 1% is ice and snow found in sea ice or on high mountains. This means that the total volume of sea ice is a practically negligible amount of less than 1% of the total volume of ice which can be found on the Earth’s surface. Nevertheless, the actual area covered by sea ice is roughly equivalent to the area of the terrestrial ice (ice of land origin) found in, for example, the Antarctic and Greenland ice sheets. Around 10% of the world’s seas freeze, but compared to ice of land origin, this ice is extremely thin, and a major characteristic is its high susceptibility to global warming.

For crew persons with little or no experience with sea ice, the ice found floating in seas is one of the most troublesome obstacles, and its presence or the likelihood of its presence, represents a major threat. Nevertheless, in order to acquire and apply the specialized knowledge and skills appropriate for the safe navigation of the Northern Sea

Route, you must have an accurate grasp of the nature of your foe; that is to say it is essential that you acquire knowledge of the basic facts with regards to ice. Below we elucidate this basic knowledge with regards to sea ice.

2.1 Sea ice of the Arctic Ocean

In winter, the ice of the Arctic Ocean is at its height every year around March. Excluding the Barents Sea, which is fed by a warm current, nearly all regions of the Arctic Ocean will have ice. As spring arrives around May the ice begins to thaw. Passing into summer, by around September, heading towards the central part of the Arctic Ocean, the ice reaches its furthest point of recession, and the area of the ice is at its lowest. Around the Northern Sea Route, depending on the location, there are areas which are entirely free of ice, and this heralds the high season for passages. Subsequently, in October and November, the ice again begins to freeze and the cycle begins again.

The thickness of ice most frequently encountered in the Northern Sea Route, is around 2.0 meters in winter and around 0.5 meters in summer. However, one should always be on guard for encounters with multi-year ice such as small icebergs which have grown above 5 meters thickness.

Of the sea territories around the Northern Sea Route, the region from the Barents Sea to the southwest of the Kara Sea is ice-free throughout the year, due to the influence of the warm current entering from the North Atlantic. Meanwhile, the sea region from the Kara Sea to the Laptev Sea and as far as the East Siberian Sea, has comparatively colder climates, and is also fed by large volumes of freshwater from the large rivers of the Russian coast, contributing to the development of sea ice. Specifically, the ice conditions in the sea territory between the Kara Sea and the Laptev Sea, the area around the islands of Severnya Zemlya, and the sea region in the west of the East Siberian Sea are the most severe, and there are times when ice does not thaw and remains through summer. Also, in the Chukchi Sea, to the east of the East Siberian Sea, due to the influence of the warm current entering from the North Atlantic, the period where there is no sea ice is becoming longer.

As shown in Fig. 1-16, the trend first observed by satellite in around 1979 of reductions in the sea ice of the Arctic Ocean has continued, and has been accelerating since 1998. The temperature rises in the Arctic Region are on average 2 to 3 times those of the globe as whole. Initially, the reduction of ice in summer was most conspicuous, but since 2004, winter ice has also been receding significantly.

In the summer of 2007, the ice around the Northern Sea Route almost entirely disappeared. Also, as shown in Fig. 1-17, on September 16, 2012, the area of sea ice in the Arctic Region had its lowest record since satellite observation began in 1978 of $3.44 \times 10^6 km^2$. The area of sea ice in the summer of 1980 was 7.89×10^6 km^2, meaning that in roughly 30 years, it has been reduced to less than half of this level.

Ongoing research is being implemented into the causes for these reductions of ice, and in addition to global warming, warming seas due to changes in Arctic Ocean currents, and increasing incidence and severity of stronger low pressure systems have been implicated. The reduction of ice in the Arctic Ocean has a great impact on the global heat balance, causing abnormal fluctuations in prevailing westerlies, and is thought of as being a source of strange weather phenomenon in every region of the globe.

With this is mind, in order to safely navigate the Northern Sea Route, it is essential that information combining climate and hydrographic forecasts, as well as sea ice forecast be gathered. There are three types of sea ice forecast for different purposes, and the most commonly used by crew of vessels are the short- and medium-term forecasts.

[Short-term forecast]

The sea ice forecast for between a few days and a week is necessary for choosing the daily course, etc. when navigating the Northern Sea Route. This forecast is based on, for example, calculations using the numerical weather forecast and the ocean and sea ice numerical models.

[Medium-term forecast]

This is a sea ice forecast for coming several months. This is necessary to facilitate early decisions on the ease of navigation of the Arctic Ocean in a given year, and propose a ship allocation schedule.

Calculations, such as those using the numerical weather forecast, are imprecise and difficult to apply, so predictions based on, for example, procedures which combine precision analysis of satellite remote sensing data, and experiential or statistical methods for sea ice in winter are used.

[Long-term forecast]

This is a sea ice forecast for between 1 and 10 years ahead. This is necessary for decision making with regards to construction planning of ships which use the North Sea Route or harbor improvements, and so on. This forecast is achieved by means of calibration and optimization of climate models used in projections of climate change.

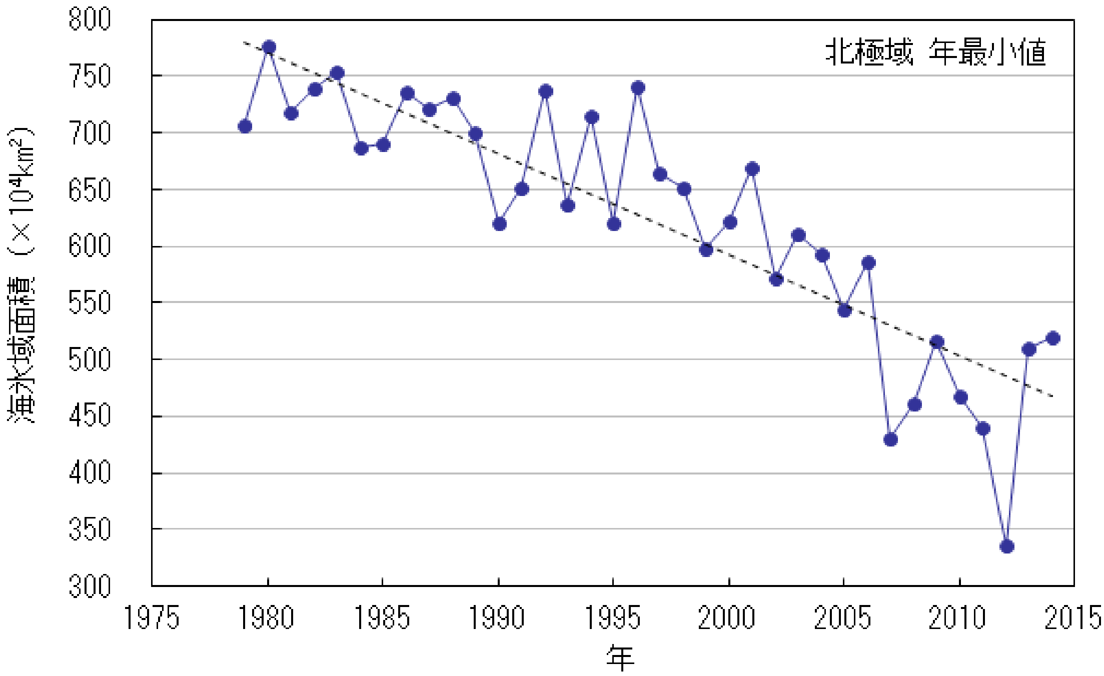


Fig. 1-16: Changes in lowest yearly values of sea ice area in the Arctic Region/1979-2014 (Source: Japan Meteorological Agency website)

* Sea ice area means the area of the sea territory where the ice concentration exceeds 15%. The zig-zag blue line shows the yearly change of the lowest value of annual sea ice area in the Arctic Region. The dotted line is the change trend.

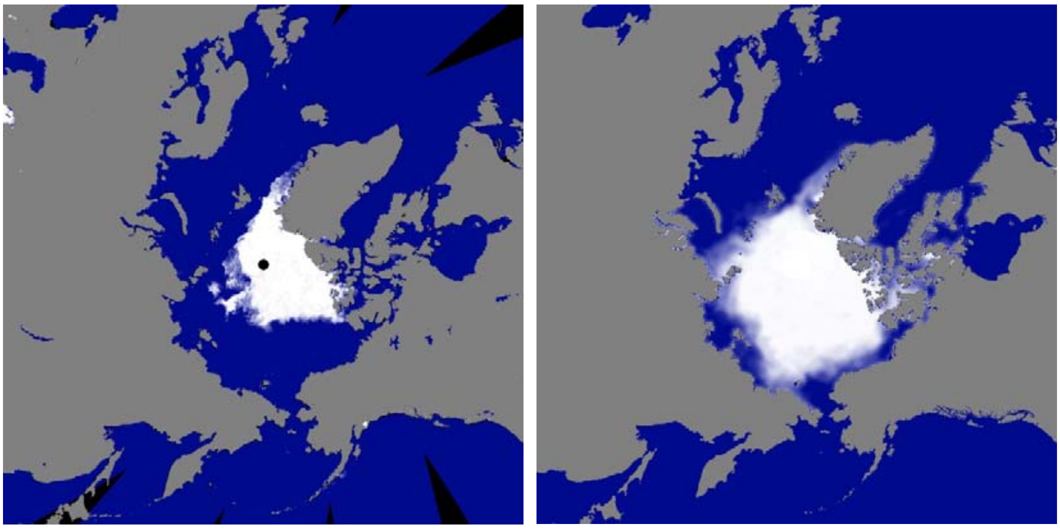


Fig. 1-17: Comparison of the sea ice area for the Arctic Ocean in summer
(left: September 16, 2012 / right: lowest mean distributions during September in the 1980s)
Credit: Japan Aerospace Exploration Agency (JAXA) (Source: website with satellite project latest information details, September 20, 2012 "Arctic Ocean sea ice area, update of lowest historically observed levels"

2.2 Ice types and terminology

The World Meteorological Organization (WMO) and other bodies have stipulated a number of technical terms with regards to ice. When navigating the Northern Sea Route, there is a possibility that these will be used in communications with icebreakers or service control stations, so it would be advantageous to commit them to memory.

2.2.1 Terms relating to ice type

Ice of various forms which floats on water is called "floating ice". Floating ice includes "sea ice" which can be seen on the sea formed from frozen sea water, "ice of land origin" which is made up of ice which is formed of ice from land or ice shelf; "lake ice" formed on lakes regardless of where it is observed; and "river ice" formed on rivers regardless of where it is observed. Ice of land origin includes ice which runs ashore in the shallows, or land, or ice which comes ashore.

Sea ice which has affixed to the sea shore, etc. is called "fast ice" and sea ice other than fast ice is called "drift ice" or "pack ice". In this case drift ice is the academic term, and differs from the term in general spoken use in Japan (which includes not only sea ice but also lake ice and river ice. The academic term is equivalent to floating ice).

Most of the ice encountered in the Northern Sea Route and the surrounding sea area comes under the academic term of floating ice. However, while it is rare there is a possibility that ice of land origin, such as icebergs which have separated from glaciers, lake ice which has washed out from lakes on the coast, and river ice which has washed out from large rivers such as the Lena River may also be encountered.

For this point, in order to allay any possible confusion, the use of the term floating ice to its academic sense is limited to this chapter. Also, in chapters two and three, we uniformly refer to the ice present on the Northern Sea Route and surrounding sea territory as sea ice, regardless of its origin.

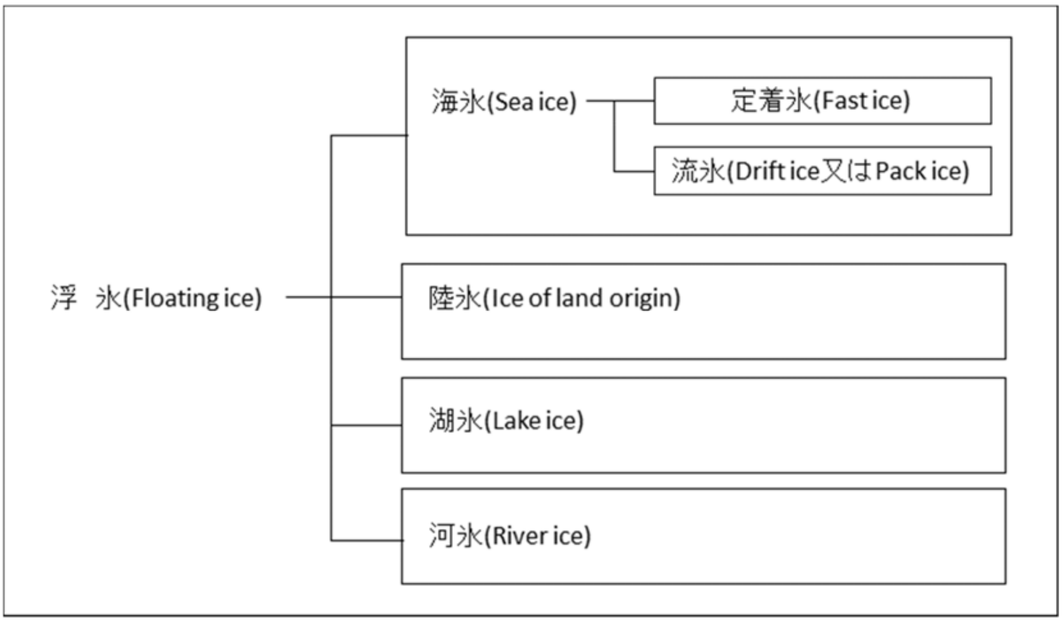


Fig. 1-18: Classification of terms relating to ice type

2.2.2 Terms relating to the development process of sea ice

Terms such as the below are used in relation to the development process of sea ice.

[New ice]

Generic term for newly formed ice, which includes among others frazil ice, grease ice, slush, and shuga. While this type of ice is frozen, it is made up of hairsbreadth ice crystals and is not hard enough to assume a shape. It only assumes a certain form when floating.

- Frazil ice: Ice crystals which consist of plates or spicules of ice suspended in water. Frazil ice occurs when sea water cools to reach temperatures below freezing.
- Grease ice: Ice at the stage of freezing following frazil ice. Ice forms groups of crystals which clump together and float on the sea surface, the state of forming a soupy layer. As it does not reflect the light, the sea surface assumes a dull and pasty appearance.
- Slush: Moisture heavy snow on the land or on ice, or lumps of viscous snow suspended in the water following a large snowfall.
- Shuga: Clumps of spongy white ice of a few centimeters diameter. Formed when grease ice or slush floats to the sea surface. Crystal groups with increased consistency are agitated between waves and accumulate in repeated clumps, which at times look just like shoals of small fish such as sardines.

[Nilas]

Filmy groups of crystals which have grown to assume a plate-like state. The surface becomes hard and elasticity is present, with a thickness under 10 centimeters. The surface lacks luster and appears grey. Easily formed by the action of waves or swells. When strong lateral pressure is exerted, they assume the shape of interlaced fingers. Nilas is subdivided as below according to degree of brightness.

- Dark nilas: under 5 centimeters thickness. Ice thickness remains thin, and seawater penetrates giving them a dark appearance.
- Light nilas: Over 5 centimeters thickness. Ice thickness is slightly increased giving it a bright white appearance.

[Ice rind]

Ice formed due to the direct freezing of calm sea surfaces, or formed from grease ice. Surface has a hard luster giving it a bright appearance. Thickness of around 5 centimeters. Easily broken up by the action of the wind or swells, often then becoming rectangular ice cakes. Normally formed from seawater with low saline content around river mouths, etc.

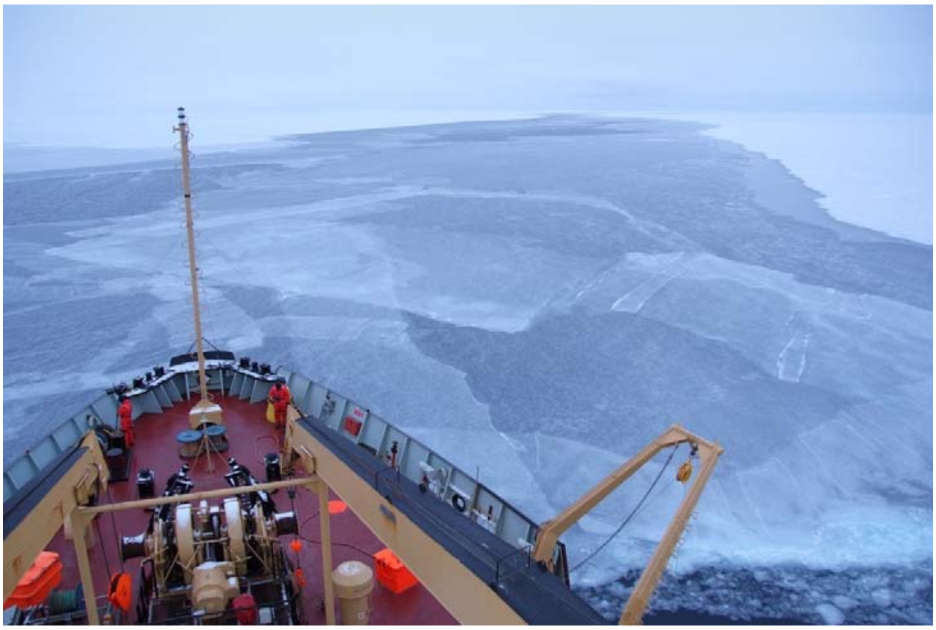
[Rafted Ice]

Formed when nilas overrides with other nilas to create ice sheets of even greater thickness. Referred to as rafted ice because the vertical movement of swell action or horizontal movement by wind action creates a shape which resembles an interlocked “raft”.

[Pancake Ice]

Ice collides with other ice, and the rims turn up to resemble lotus leaves, to form roughly disk-like ice. Assumes a diameter of between 30 centimeters and 3 meters, with an ice thickness of around 10 centimeters. White or grey in color.

May be formed by the weak action of swells from grease ice, slush, sponge ice or new ice, or the breaking up of rind ice or nilas, or when the action of waves or swells is extreme by the breaking up of thin young ice. Also, often it is of a constant thickness and it is formed at the boundary side between water masses of differing physical properties, at times floating to the surface and rapidly covering wide areas of the sea surface.



Pic. 1-3: Rafted ice created by the deformative action of an external force (courtesy of Koji Shimada)

[Young Ice]

Transitional stage between nilas and first-year ice, with a thickness of 10 to 30 centimeters. Formed when pancake or other ice rubs against other such ice and lotus like rims heave, which then overlap with each other and increase their thickness. Classified as follows according to ice thickness.

- <Grey ice>: Young ice of 10 to 15 centimeters thickness; grey in color. Less elasticity than nilas and broken up by the action of swells. Often piles up due to lateral pressure.
- <Grey-white ice>: Young ice of 15 to 30 centimeters thickness; greyish white in color. Rather than piling up due to lateral pressure, it will often bulge to form ridges (piled or walled portion of ice formed and broken by pressure).

Pic. 1-4: Pancake ice resembling lotus leaves (courtesy of Koji Shimada)

[First-year ice]

Ice which has grown beyond young ice, over a period of no more than a single winter is called first-year ice. Generally white with a thickness within 30 to 200 centimeters. Classified as follows according to ice thickness.

- <Thin first-year ice>: First-year ice of 30 to 70 centimeters thickness.
- <Medium first-year ice>: First-year ice of 70 to 120 centimeters thickness.
- <Thick first-year ice>: First-year ice of over 120 centimeters thickness.

Note that most of the ice which ocean-going merchant vessels using the Northern Sea Route will encounter will be first-year ice. On the passages of the Russian coast along Eurasia, encounters with ice which has grown more than this are not particularly common.

Pic. 1-5: Young ice with increased thickness (courtesy of Kazutaka Tateyama)

[Old ice]

Old ice refers to first-year ice which has survived at least a single summer without melting. Reaches a thickness of from 2.5 to over 3 meters. Classified as follows according to age.

- <Second-year ice>: Ice which has survived a single summer and remains on the sea surface. Thickness of within 2.5 meters. Has many orderly “puddles” on its surface formed when ice has melted due to summer temperature rises, etc. Parts with snowfall are white, parts without or puddles are aquamarine.
- <Multi-year ice>: Ice which remains on the sea surface without melting for at least two summers. Thickness reaches over 3 meters. Surface puddles become large and irregularly shaped. Parts with snowfall are white, parts without or puddles are blue.

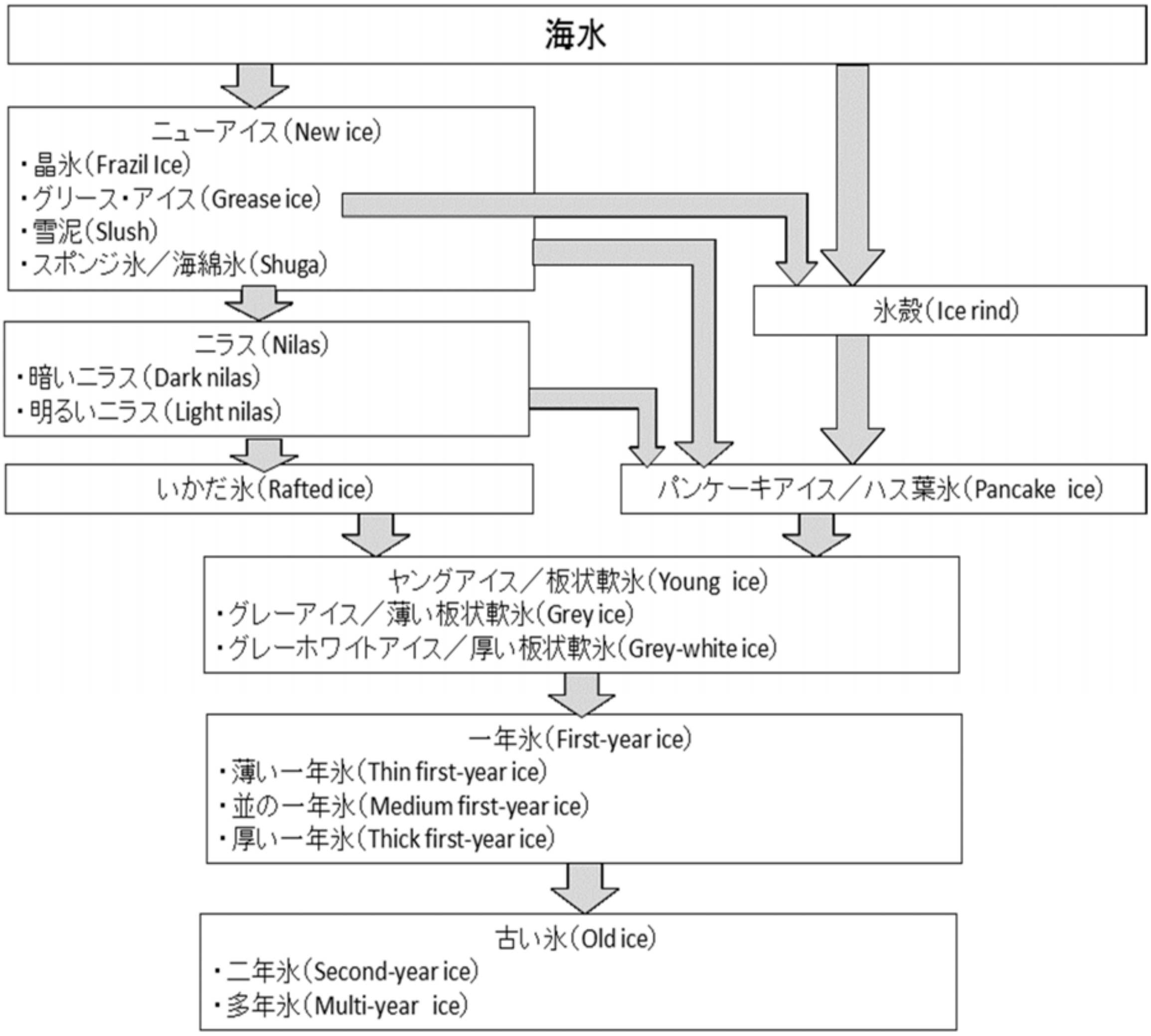


Fig. 1-19: Classification of terms relating to sea ice development process

2.2.3 Terms relating to fast ice formations

Sea ice is classified into the two varieties of fast ice, affixed, for example, to coastlines, or drift ice.

Fast ice is sea ice which connects with and becomes affixed to coastlines, glaciers, ice floe walls, and so on, and includes sea ice which is buried and immobile between grounded icebergs. Fast ice is formed either when seawater freezes where it is or as drift ice adheres to the coastline, and vertical fluctuations can be seen due to changes in sea level. Fast ice of narrow width reaches from a few meters from shore, with wider fast ice reaching to several 100 kilometers from shore. The following terms are also used in relation to fast ice.

[Young coastal ice]

Initial stage of fast ice formed from nilas or young ice. Width is from a few meters reaching to 100 to 200 meters from shoreline.

[Ice foot]

Narrow and long belts of ice affixed along the shoreline. Follows the shore line and extends with a long and slender appearance strongly resembling a wall of ice. An ice foot is not displaced by the tide. The part which is left behind and does not thaw even when fast ice has retreated.

[Anchor ice]

Ice which is found below the water surface in contact with or attached to the seabed.

[Grounded ice]

Floating ice which has grounded in shallows.

[Stranded ice]

Floating ice which continues to remain on the coast after end of full tides.

[Grounded hummock]

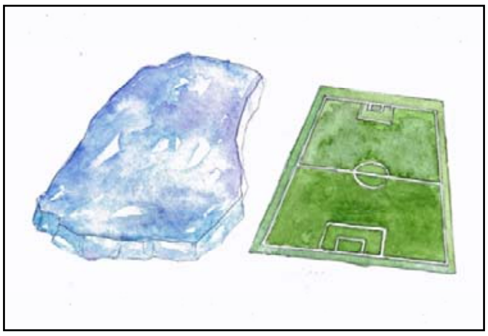
Ice which has grounded and become hummocked. There may be individual or lines (or chains) of grounded hummocks.

2.2.4 Terms relating to drift ice formations

All sea ice besides fast ice is referred to as drift ice in academic terminology. This is not affected by the shape, placement, and so on, of that ice. In English, if the ice concentration is 7/10 or more, it is acceptable to refer to it as “pack ice” instead of “drift ice”. Below are some of terms used in relation to drift ice formations.

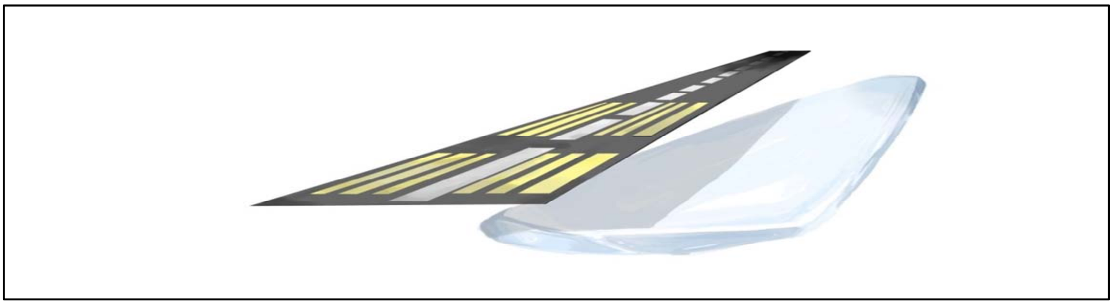
[Pancake ice]

One of the aforementioned sea ice development processes. Floating drift ice formed when ice collides with other ice and the rims turn up to resemble lotus leaves, to form ice with an approximately disk-like shape. Have a diameter from 30 centimeters to 3 meters, with ice thickness of around 10 centimeters.

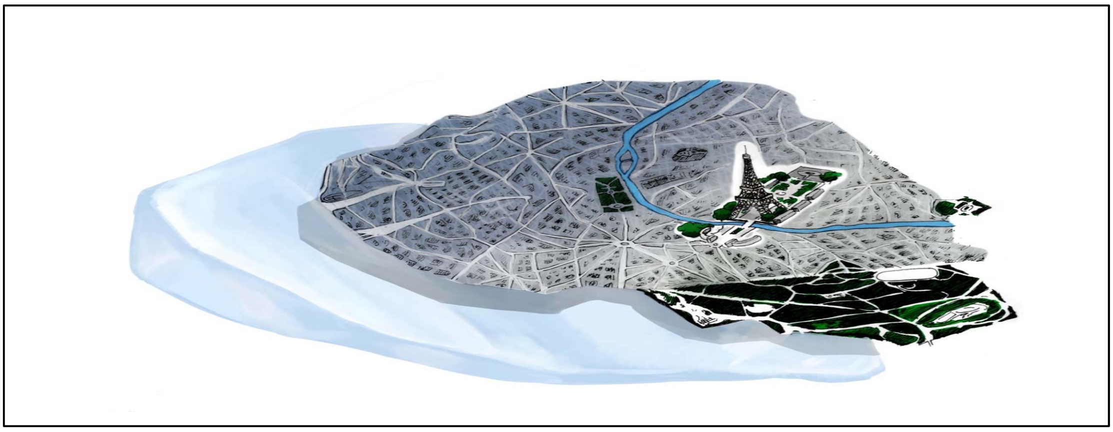


Soccer pitch sized small ice floe (between 20-100 meters diameter)

University campus sized medium ice floe (between 100-500 meters diameter)



Aircraft landing strip sized big ice floe (between 500-2,000 meters diameter)



Giant flow the size of the city of Paris (over 10 kilometers diameter)

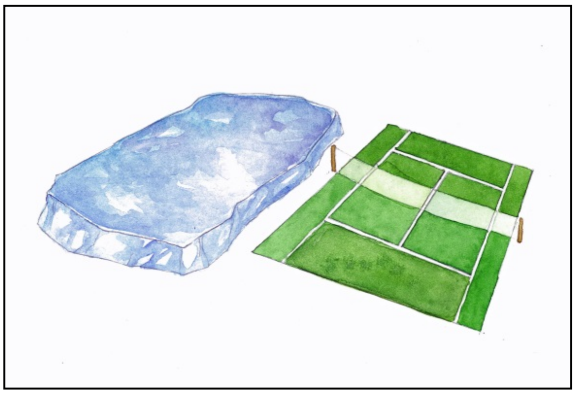
Fig. 1-20: Comparison of ice floe sizes

[Floe]

Drift ice formations comprised of comparatively flat bodies of sea ice above 20 meters in diameter are called floes. Classified as follows according to their width.

- <Small ice floe>: Flat surface sea ice formations with a diameter of between 20 to 100 meters
- <Medium ice floe>: Flat surface sea ice formations with a diameter of between 100 to 500 meters
- <Big ice floe>: Flat surface sea ice formations with a diameter of between 500 to 2,000 meters
- <Vast ice floe>: Flat surface sea ice formations with a diameter of between 2 to 10 kilometers.
- <Giant ice floe>: Flat surface sea ice formations with a diameter of over 10 kilometers.

Ping pong table-sized small ice cake
(under 2 meters diameter)



Tennis court-sized ice cake
(between 2 and 20 meters diameter)

Fig. 1-21: Comparison of ice cake sizes

[Ice cake]

Drift ice formations comprised of comparatively even bodies of sea ice under 20 meters in diameter are called ice cakes. Classified as follows according to their size.

- <Small ice cake>: Comparatively flat sea ice formations with a diameter under 2 meters.
- <Ice cake or ice shard>: Comparatively flat sea ice formations with a

diameter of between 2 and 20 meters.

Table 1-1: Size classifications of ice cakes or floes

名　称	大きさ
小板氷又は小氷片(Small ice cake)	直径2メートル未満
板氷又は氷片(Ice cake)	直径2～20メートル未満
小氷盤又は小氷原(Small ice floe)	直径20～100メートル未満
中氷盤又は中氷原(Medium ice floe)	直径100～500メートル未満
大氷盤又は大氷原(Big ice floe)	直径500～2,000メートル未満
巨氷盤又は巨氷原(Vast ice floe)	直径2～10キロメートル未満
巨大氷盤又は巨大氷原(Giant floe)	直径10キロメートル以上

[Floeberg]

Drift ice which consists of individual or multiple hummocks which have frozen to create large bodies of ice, separated from surrounding sea ice. May reach heights of up to 5 meters above the sea surface.

[Ice breccia]

Drift ice which consists of ice with various development processes, which have frozen together into lumps of ice.

[Brash ice]

Drift ice which consists of small ice cakes which have crumbled and accumulated into various shapes with less than 2 meters diameter. Brash ice is also formed by the passage of icebreakers through sea ice areas. A passage (lead) covered with ice cakes of sizes of around 30 centimeters diameter is called a brash ice channel.

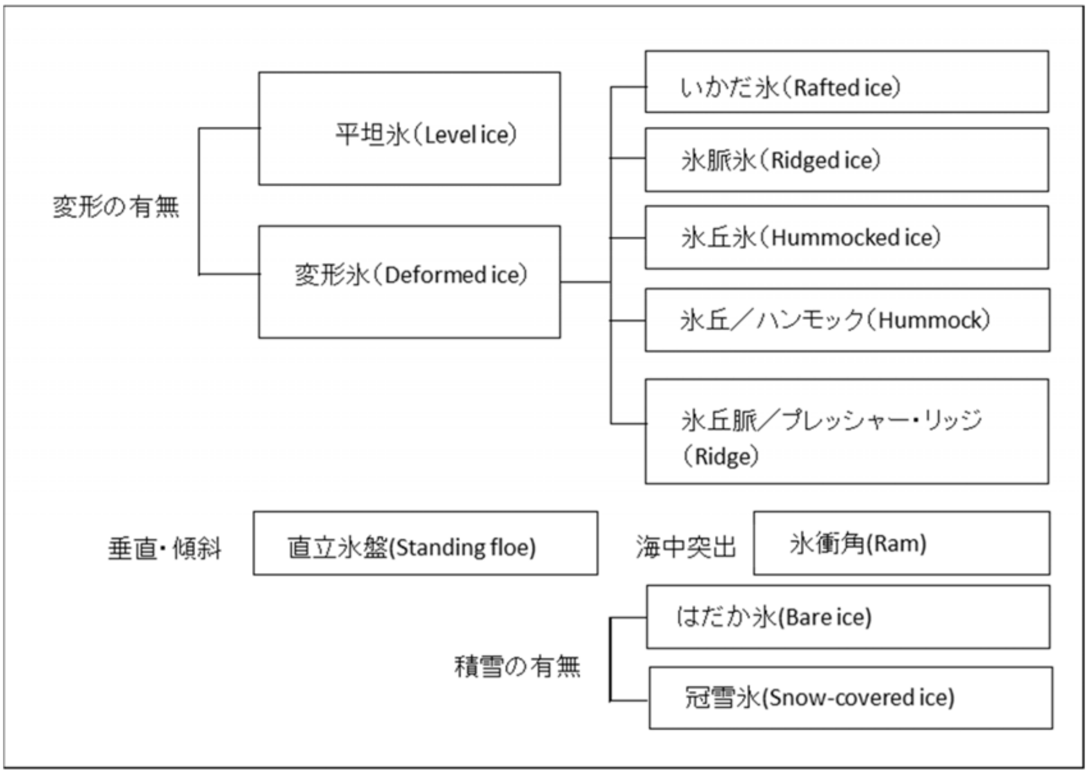


Fig. 1-22: Classification of terms relating to characteristics of sea ice surfaces

2.2.5 Terms relating to characteristics of sea ice surfaces

Below are some of the terms used with regards to characteristics of sea ice surfaces.

[Level ice]

Ice which is level and has no deformities is called level ice.

[Deformed ice]

Ice is constantly subject to the effects of external forces, such as wind on the surface of the ice and seawater on the underside of the ice. For this reason, fields of ice become compacted, dispersed or diffused; added to which ice jostles against other ice, both of which can at times result in deformities as ice is either pushed up or down. Deformed ice is the generic term for ice which has undergone deformation. Deformed ice is classified as below.

- <Rafted ice>: As previously described, deformed ice which has become rafted as a result of ice overlapping with other ice.
- <Ridged ice>: Deformed ice which, as a result of ice irregularly overlapping over other ice, forms a mountain or walled (piled) shape. In normal

circumstances this is seen with first-year ice, but may also be seen with old ice.

- <Hummocked ice>: Deformed ice with undulations formed as a result of ice irregularly overlapping with other ice. Assumes a smoothed hill shape with weathering.
- <Hummock>: A hummock of ice formed as a result of ice jostling and overlapping with other ice. Both new and weathered examples are seen. As they are pushed downwards as a result of pressure, the submerged part counterpart of the hummock formed from the ice block projecting below the water on its underside is called a bummock.
- <Ridge>: A hummock which has assumed a swell shape. May also be seen in lakes, etc. The submerged part of the ridge which has been pushed down from pressure is called an ice keel. Many ridges are often hard and are a source of difficulty for navigating vessels.

[Standing floe]

A single floe which is standing either vertically or at a slant. Surrounded by comparatively flat ice.

[Ram]

Protruding part of ice formed under the sea surface. Juts out from ice fronts, icebergs, ice walls, and so on. In normal circumstances formed by pronounced thawing or erosion of the surface part of the ice on such formations. There may be a chance that a ram is projecting between two ice floes with traces of pronounced thawing or erosion on their surfaces, meaning that they are a danger to navigating vessels.

[Bare ice]

Ice with no snow-cover on its surface.

[Snow-covered ice]

Ice with snow-cover on its surface.

Fig. 1-6: Cluster of pressure ridges occurring due to repeated formation of hummocks (courtesy of Koji Shimada)

Fig. 1-7: Dangerous ram protrudes below the sea surface (courtesy of Seiji Shigehara)

2.2.6 Terms relating to sea ice thawing process

Below are terms used in relation to the sea ice thawing process.

[Puddle (or melt pond)]

Water which has accumulated on the top of ice. Refers to water which has formed puddles due to summer temperature rises etc., melting, for example, snowfall, mainly on top of ice. As this process progresses, the ice itself melts and puddles are formed. At its initial stage, speckles of the thawing snow can be created.

[Thaw holes]

Vertical holes in the sea ice formed by progressive puddling and which penetrate through to the sea water below the ice.

[Rotten ice]

Ice which has become honeycombed from advanced thawing and disintegration.

[Dried ice]

Ice from which the surface water has melted and disappeared due to the formation of fractures or thaw holes. During the drying period the surface becomes whitish.

[Flooded ice]

Ice which has become weighted down due to flooding from water or wet snow.

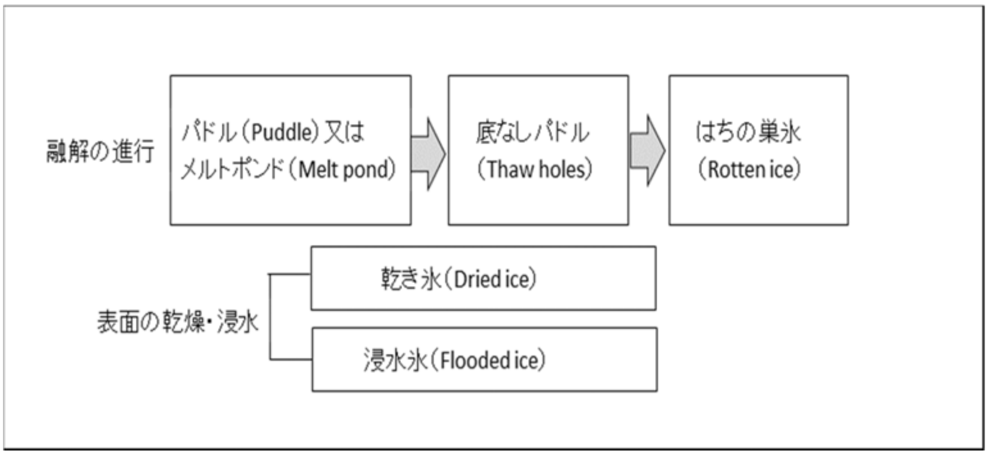
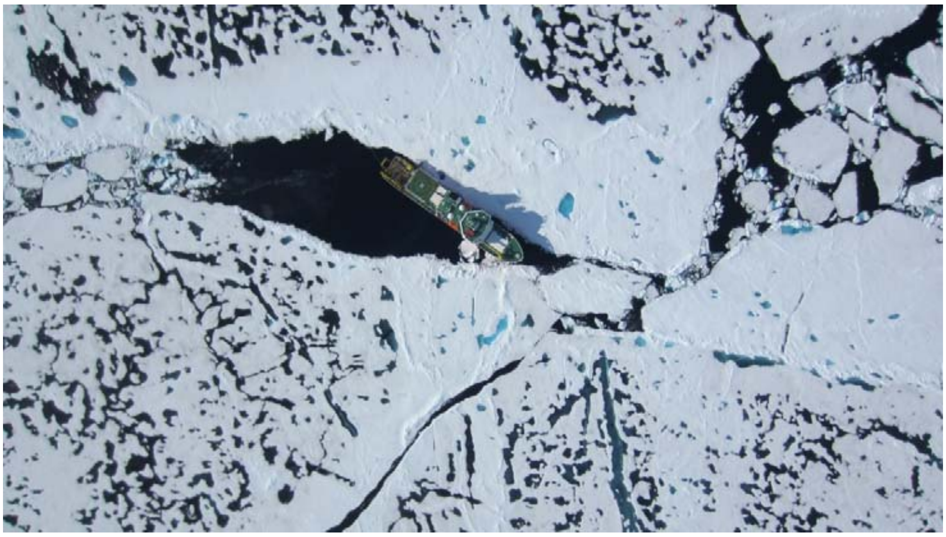


Fig. 1-23: Classification of terms relating to thawing process of sea ice



Pic. 1-8: Puddles or melt ponds as seen from above (courtesy of Korea Polar Research Institute)

Pic. 1-9: Puddles or melt pond as seen from the ice (courtesy of Koji Shimada)

2.2.7 Terms relating to sea ice volume or concentration

Below are some of the terms used in relation to sea ice volume or concentration.

[Ice cover]

The ratio taken up by sea ice concentrated on either all the seas of the vast areas of sea over the entire globe or in the hemispheres, or particular seas or bays, etc. Example use: “The present ice cover of the East Siberian Sea is 6/10”.

[Concentration]

The percentage taken up by sea ice on the surface of a particular sea territory, expressed in deciles, percentiles, etc. For example, when half of the sea surface is covered by ice, the ice concentration is indicated as 5/10 (0.5), fifth decile, or 50%. The concentration of all ice on the sea surface is called the total concentration; while that of a certain part of ice is called the partial concentration. Sea surface conditions are expressed in the following ways according to their ice concentration.

- <Ice free>: 0/10 (0.0) concentration; sea area where neither any sea ice nor ice of land origin has any presence whatsoever. If any ice whatsoever is present, regardless of the ice type, this expression is not used.
- <Bergy water>: Freely navigable sea area in which there is no sea ice but some ice of land origin (icebergs, etc.)
- <Open water>: 1/10 (0.1) concentration or less; sea area which is open and freely navigable by vessels. If the concentration is less than 1/10, the presence of sea ice or ice of land origin is not a problem.
- <Very open ice>: 1/10 (0.1) - 3/10 (0.3) concentration; ice presence but with considerably more open sea than ice.
- <Open ice>: 4/10 (0.4) - 6/10 (0.6) concentration; ice presence where there is roughly the same amount of ice as open sea. There are many leads or polynya and ice bodies are generally not in contact with each other.
- <Close ice>: 7/10 (0.7) - 8/10 (0.8) concentration; ice presence where ice is usually in contact with other ice.
- <Very close ice>: 9/10 (0.9) - 10/10 (1.0) concentration.
- <Compact ice>: 10/10 (1.0) concentration; ice presence where entirety of the sea surface is covered with ice, meaning the sea cannot be seen.
- <Consolidated ice>: 10/10 (1.0) concentration; ice presence where ice is frozen together with other ice.

Pic. 1-10: Compact ice (courtesy of Kazutaka Tateyama)

Table 1-2: Ice concentration

名称	密接度	海面と氷域の割合
無氷海面（Ice-free）	0/10（0.0）	
氷山海面(Bergy water)	陸氷（氷山等）のみが存在	
開放水面（Open water）	1/10（0.1）以下	
分離氷域（Very open ice）	1/10(0.1)～3/10（0.3）	
疎氷域（Open ice）	4/10（0.4）～6/10（0.6）	
密氷域（Close ice）	7/10（0.7）～8/10（0.8）	
最密氷域（Very close ice）	9/10（0.9）～10/10(1.0)	
全密接氷域（Compact ice）	10/10（1.0）	
凍結密氷域（Consolidated ice）	10/10（1.0）	

2.2.8 Terms relating to sea ice distributions

Below are some of the terms used in relation to sea ice distribution.

[Ice field]

Drift ice area with a diameter in excess of 10 kilometers, made up of ice floes of various sizes, and classified as follows according to size.

- <Small ice field>: Drift ice area of between 10 and 15 kilometers in diameter.
- <Medium ice field>: Drift ice area of between 15 and 20 kilometers in diameter.
- <Large ice field>: Drift ice area of over 20 kilometers in diameter.

[Ice patch]

Drift ice area of under 10 kilometers in diameter, made up of clusters of floes of various sizes.

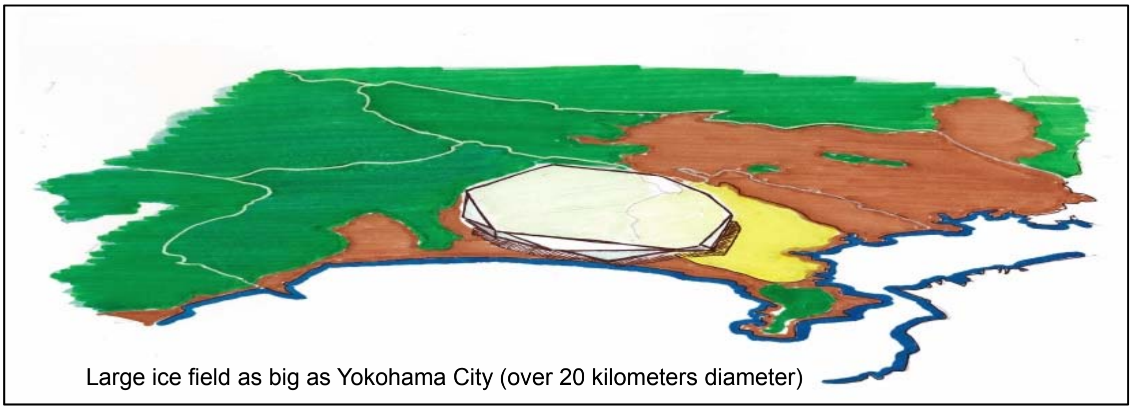


Fig. 1-24: Scale of a large ice field

Table 1-3: Size classification of ice patches and ice fields

名　称	大きさ
流氷原（Ice patch）	直径10キロメートル未満
小流氷野（Small ice field）	直径10～15キロメートル
中流氷野（Medium ice field）	直径15～20キロメートル
大流氷野（Large ice field）	直径20キロメートル超

[Belt]

A feature (belt) of drift ice which stretches long and slender, of a width between 1 and over 100 kilometers.

[Tongue]

Tongue-like projection of ice edge to a length of a few kilometers caused by wind or sea currents.

[Strip]

Small ice cakes separated from the main body of drift ice with a long and streaky shape of less than 1 kilometer in width. They move under the influence of the wind, or swells and sea currents, etc.

[Bight]

Broad and crescent-like indentation in the ice edge. Formed by the wind or sea currents.

[Ice jam]

Strait or narrow channel, or river water which has become blocked by brash ice, etc. where the ice has assumed a dam-like state.

[Ice edge]

Boundary of sea ice area with open water. The position of the ice edge undergoes temporal changes. In normal circumstances, a distinct ice edge is formed on the windward side of the drift ice, with a broken ice edge formed on the leeward side.

[Ice boundary]

Boundary between fast ice and drift ice, or between drift ice areas of different concentrations at arbitrary times.

Pic. 1-11: Broken ice edge on leeward side (courtesy of Kazutaka Tateyama)

2.2.9 Terms relating to the sea surface in ice areas

Below are some of the terms used in relation to the sea surface in ice areas.

[Fracture]

Breaks or rips due to the formation action of ice, in very close ice, compact ice, consolidated ice, fast ice or individual floes, and classified as follows according to size.

- <Very small fracture>: Fractures of between 1 to 50 meters width.
- <Small fracture>: Fractures of between 50 to 200 meters width.
- <Medium fracture>: Fractures of between 200 to 500 meters width.
- <Large fracture>: Fractures of over 500 meters width.

[Crack]

Rifts in ice which do not cause the ice body to separate, of a few centimeters to a meter width.

Table 1-4: Size classification of cracks and fractures

名　称	大きさ
クラック（Crack）	幅数センチメートルから1メートル
微小割れ目（Very small fracture）	幅1～50メートル
小割れ目（Small fracture）	幅50～200メートル
中割れ目（Medium fracture）	幅200～500メートル
大割れ目（Large fracture）	幅500メートル超

[Tide crack]

Crack which occurs at the juncture of an immobile ice foot or a glacier front and fast ice. Rise and fall with the tide.

[Flaw]

Narrow rift between drift ice and fast ice. Ice shards within the flaw are in a chaotic state. Formed when drift ice is sheared along the boundary of fast ice, due to the effect of strong winds or sea currents.

[Fracture zone]

Ice area, etc. with many fractures.

[Lead]

A fracture or narrow passage in a sea ice area which is navigable by vessels.

[Polynya]

Irregularly shaped sea surface surrounded by ice which looks like a lake in the sea. There is brash ice in the polynya, or it may be covered by new ice, nilas, young ice, etc. When one side of the polynya is connected to the shore or to fast ice, it is called a shore lead or a flaw lead. If it occurs in the same area each year, it is called a recurring polynya.

2.2.10 Terms relating to atmospheric phenomena of sea ice areas

Below are some of the terms used in relation to atmospheric phenomena of sea ice areas.

[Water sky]

The phenomenon whereby the underneath of clouds in skies above sea surface with no ice presence appear to have dark grey striations. This occurs because the light of the sun is not reflected on the surface of open water without ice presence. During fog, clouds with a black speckled appearance may be seen above the open water.

[Ice blink]

An ice blink is a phenomenon which appears in the sky above sea areas with ice presence, occurring because the sunlight reflected on the ice surface is projected onto the clouds in the sky above. Generally, the underneath of clouds on the horizon appear a white or yellowish-white color.

[Frost smoke]

Fog which occurs around the sea surface or the leeward of ice edge of a sea ice area. It occurs when cold weather which has moved over the ice, meets the warmer sea surface. When the cold weather is particularly severe, it can freeze and become “ice fog”.

[Mirage of ice]

A phenomenon whereby it appears that the ice has floated up near the horizon, or appears as a magnified virtual image. Occurs due to an abnormal refraction of sunlight in air of different concentrations. It is one of the mirage phenomenon, and occurs when, for example, the sea water is abnormally cold.

2.2.11 Terms relating to ship operating

Below are some of the terms which are used in relation to ship operating in sea ice areas.

[Beset]

When a vessel has become surrounded by ice and is unable to move.

[Ice bound]

When a vessel is unable to operate without the escort of an icebreaker due to ice effects, etc. in a bay or an inlet, and so on.

[Nip]

A forcible load against a vessel from the surrounding ice, after it has run into a beset, etc. Even if the vessel is not damaged, it is said to have been nipped.

[Ice under pressure]

Ice which is actively changing state. This can prove an obstacle to navigating vessels, and is potentially dangerous.

[Difficult area]

Sea area in which ice conditions are severe, to the point that they pose difficulties for the navigation of vessels.

[Easy area]

Sea area with mild ice conditions, in which vessels can operate without difficulty.

[Ice port]

An ice shelf, etc. where vessels can directly moor, unload, and so on. In most cases these are temporary.

2.2.12 Terms relating to ice of land origin

Below are some of the terms used in relation to ice of land origin.

[Ice sheet]

A broad expanse of land which is covered by thick snow and ice. This can include an ice shelf which is protruding and floating on the sea surface. Currently there are two ice sheets, the Antarctic ice sheet in Antarctica, and the Greenland ice sheet.

[Glacier ice]

The ice in a glacier or ice which originates in a glacier. There is no distinction made if such ice is on land or ice which is floating on the sea, such as an iceberg.

[Ice shelf]

An ice sheet which has slid down land, and protruded into the sea, with its tip affixed or suspended on the shore. Two to 50 meters above sea surface, or considerably thicker, affixed or suspended on the shore. Occurs by annual snow accumulation or when a glacier extends to the sea. In normal circumstances, spreads expansively in a horizontal direction, with a level or mildly undulating surface. Part of the ice may also reach the bottom. The horizontal wall of the seaward edge is called the ice front.

[Iceberg]

Glacier ice which has broken from a glacier or ice shelf and been washed to sea. Refers to features more than 5 meters above the sea surface. Can be either floating or grounded.

Most of the icebergs seen in the Northern Hemisphere have separated from the Greenland glacier and been washed out to the North Atlantic. Rarely seen around the Northern Sea Route on the Russian coast.

Classified as tabular, dome, wedge, pinnacle, weathered or glacier bergs according to their formation. Features which are less than 5 meters above the sea surface are classified according to their size as follows.

- <Bergy bit>: A bergy bit refers to glacier ice floating on the sea surface. Within 1 to 5 meters above the sea surface, with an area of around 100 to 300 square meters.
- <Growler>: A growler refers to glacier ice which is also floating on the sea surface, which is smaller than a bergy bit or a floeberg. Frequently appear transparent or sometimes green or mainly blackish. Less than 1 meter above the sea surface in height, with an area of around 20 square meters.

Table 1-5: Size classifications of glacier ice on the sea surface

名　称	大きさ
氷山（Iceberg）	海面上高さ5メートル以上 面積約300平方メートル以上
氷山片(Bergy bit)	海面上高さ1～5メートル 面積約100～300平方メートル
氷岩(Growler)	海面上高さ1メートル未満 面積約20平方メートル

Pic. 1-12: Tabular berg (courtesy of Hajime Yamaguchi)

Pic. 1-13: Glacier berg (courtesy of Hiroki Shibata)

[Glacier berg]

A berg which has separated from a glacier. Irregularly shaped.

[Tabular berg]

A berg with a flat summit. Most have been formed after breaking off from an ice shelf. Horizontal striations (stripes) can be seen on the surface.

[Ice island]

Large floating ice over 5 meters above the sea surface made from broken off Arctic Ocean ice shelf. Have a thickness of 30 to 50 meters, and reach an area of between several square kilometers to 500 square kilometers, or more.

Generally surface has regular undulations and has a rib-like appearance when seen from an aircraft. As they have their source in land of ice origin, the surface ice is covered in sand and grit or lichens, etc. meaning that they can be mistaken for actual islands.

In the past manned meteorological stations called drifting stations were established on top of Arctic Ocean ice islands, and carried out monitoring at the mercy of the wind and waves.

[Iceberg tongue]

A large gathering of berg clusters which have protruded out to sea. May be grounded or frozen fast ice.

2.3 Formation of sea ice

When the sea surface cools, there is a vertical reversal of concentrations and convection occurs. When salinity is uniform, the seawater becomes heavy as the temperature drops and it sinks down. The cooled seawater at the sea surface sinks and mixes with the warmer seawater beneath the sea surface which encourages further cooling. Finally when the seawater temperature above and below reaches -1.7°C, vertical convection decreases.

Further, even when the seawater reaches the temperature for ice formation of -1.7°C to -1.8°C and cooling continues, and as latent heat is expelled, seawater begins to freeze as part of it becomes crystals consisting of needle-like spicules or plates. However, while the freezing temperature of freshwater is 0°C, the freezing point of seawater changes according to the salinity or pressure.

Salinity of seawater is expressed in parts per thousand or part per thousand (ppt/‰). For example, if seawater has a salinity of 32ppt, this means that 32 grams of salts are dissolved in a single kilogram.

The freezing temperature of seawater T (°C) can be expressed by the following formula, as a function of seawater salinity S (‰) and pressure P (bar, 1 bar = 10^5 Pa), (Millero, 1978).That is to say, seawater freezing temperature falls in inverse proportion to salinity.

$$\mathrm{T} = -0.0575S + 1.710523 \times 10^{-3} S^{\frac{3}{2}} - 2.154996 \times 10^{-4} S^2 - 7.53 \times 10^{-3} P$$

Seawater freezing temperature T (°C) can also be approximated using the following formula (Maykut, 1985).

$$\mathrm{T} = -0.055 \times \mathrm{S}$$

Table 1-6: Relationship of freezing temperature and salinity by approximate equation

塩分S‰	20	25	30	32	33	34	35
結氷温度T℃	−1.100	−1.375	−1.655	−1.760	−1.815	−1.870	−1.925

In normal circumstances, as seawater has a salinity of within 30-33ppt, its freezing temperature is -1.7°C to -1.8°C as shown in table 1-6. Also, as the only part of seawater that actually freezes is its freshwater component, high saltwater concentration is either discharged in an unfrozen state within seawater or remains locked within frozen seawater. This high concentration saltwater is called brine. As the cooling of seawater progresses, with the further freezing of the freshwater component in brine, brine increases its salinity while in turn decreasing its volume. Sea ice growth will increase as the freshwater component is frozen and brine is expelled. As the expelled brine has high concentrations of saltwater, it is denser than seawater and sinks into the sea.

After this, as long as sea surface waves, swells, and so on, are gentle, frazil will begin to slowly grow as it freezes together with other frazil, eventually becoming nilas or ice rind, and gradually increasing thickness as it spreads over the sea surface.

If there is a relative degree of sea surface waves or swells, frazil will combine as it collides and fragments, to become a soup-like pasty layer called grease ice, and continue its growth while covering the sea surface.

Eventually, with the action of waves or swells, grease ice will collide and the rims will turn up to resemble lotus leaves, to form ice with a largely disk-like state called pancake ice.

Once it has reached the stage of pancake ice, the waves or swells gradually subside due to the effect of friction of ice on other ice. As a result, the growth of sea ice and freezing of different bodies of ice progress, and ice will increase in thickness and hardness. Subsequently, its growth proceeds to a sea ice formation called young ice or grey ice with a thickness in excess of around 10 centimeters.

2.4 Structure of sea ice

Sea ice is mainly made up of clumps of thin ice plate crystals from frozen freshwater in the seawater. When we examine a magnified vertical cross-section of sea ice under a microscope, we see that the ice crystals in the upper layer have a larger wedge than those in the lower layer.

When we examine a magnified horizontal cross-section of sea ice under a microscope, we see that the brine is cylindrical or spherical and fills the gap between ice crystals. These are called brine cells or concentrated saline cells. High concentration saltwater or bubbles are locked within brine cells. Brine cells are greatly implicated in the relative strength of sea ice.

Pic. 1-14: Vertical cross-section (left) and horizontal cross-section (right) of sea ice (courtesy of Hiroyuki Enomoto)

2.5 Sea ice strength

The gaps between ice crystals within sea ice are filled by cylindrical or spherical brine cells. The brine cells are at average intervals within 0.5 millimeters, and increase with the increase of ice thickness. As the internal brine cells function as a buffer seawater, when compared with ice formed from freshwater with almost no gaps, sea ice is quite pliable and is about 1/3 as strong. Besides the crystal structure, sea ice strength is dependent on the ice temperature, salinity, and volume of bubble content. That is to say, the strength and hardness of sea ice increases as the temperature, salinity and volume of bubble content decreases. The salinity in sea ice will increase with the degree of salinity of sea ice when freezing occurs, and in line with the rapidity with which sea ice grows.

Meanwhile, when the internal brine is mostly expelled, and ice salinity rapidly decreases, sea ice can sometimes become as hard as ice formed from freshwater. While the salinity of seawater before freezing is 30 to 33 grams per kilogram, when one kilogram of sea ice is thawed directly after freezing, the thawed water will only have 10 to 12 grams per kilogram. Moreover, if we thaw 1 kilogram of sea ice which has grown to over a meter of thickness, there will only be around 5 to 6 grams of salt content in the thawed water. This is because internal seawater brine is with time pushed underneath the sea ice by gravity, and eventually extricated from seawater, to be expelled into the sea. Sea ice which has grown and been desalinized in this way often increases in strength and hardness much as with the formation of ridges, etc. from ice compressing together, and may prove an obstacle or danger to navigating vessels, meaning that due heed should be paid.

As an iceberg is made from freshwater of land of ice origin, it lacks the buffering effect of brine cells. Moreover, as it originates in a glacier formed by the long-term compression of ice and snow, it is said to be exponentially stronger than other ice, around twice that of ice made from freshwater, and around 6 times as strong as newly formed sea ice.

2.6 Composition of sea ice

Many salts such as sodium chloride are dissolved in seawater. The salt content of seawater varies according to particular sea areas, but is normally over 30 ppt. However, in the case of the Arctic Ocean, due to the inflow of large volumes of river water from the great rivers, and accompanying the thawing of sea ice in summer, the salt content of surface layer seawater is lower when compared to other sea areas, with concentration of less than 25ppt centered around the coastal areas. Salts are dissolved in seawater in the form of various ions etc., with no large variation between percentage compositions in any given sea area, being made up of concentrations of chlorine (around 55.0%), sodium (30.6%), sulfuric acid (7.7%), magnesium (3.7%), calcium (1.2%), potassium (1.1%), and so on.

Sea ice formed from the freezing of seawater is composed of pure ice from frozen freshwater, brine and solid state salts. As cooling progresses, part of the freshwater in brine freezes further and is separated out from the brine. With this process, as the brine volume is reduced, brine salt content increases. The brine volume fraction v (‰) can be expressed by the following formula, as a function of sea ice saline content S (‰) and absolute value of ice temperature t (°C) (Frankenstein and Garner, 1969).

$$\mathrm{v} = \mathrm{S}\left({}^{49.185}/_{t} + 0.532\right)$$

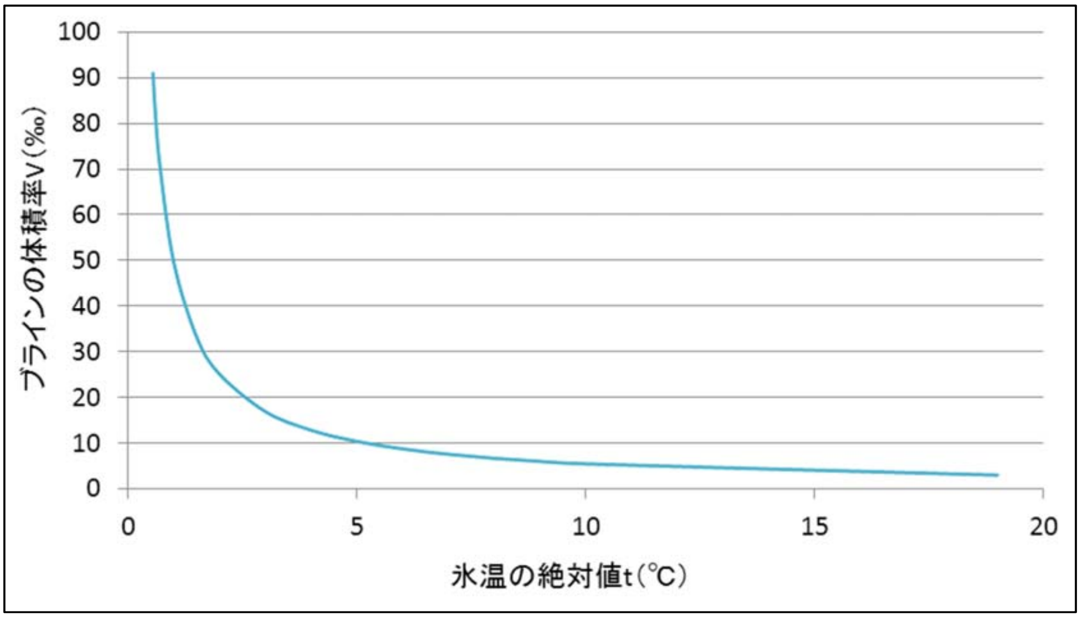


Fig. 1-25: Relationship between brine volume fraction and absolute value of ice temperature (with salinity of 1ppt)

Fig. 1-25 shows the relationship between the brine volume fraction and absolute value of ice temperature, when the salinity of seawater is 1ppt.

As freezing progresses further, the salt content begins to be expelled from the brine. For sea ice which has been formed from so called standard seawater with a salinity of 34.33ppt, sodium sulfate ($\mathrm{Na_2SO_4 \cdot 10H_2O}$) and sodium chloride ($\mathrm{NaCl \cdot 2H_2O}$) are separated at -8.2°C and at -22.9 °C, respectively. At -44 °C, magnesium chloride ($\mathrm{MgCl_2 \cdot 12H_2O}$) is separated. At -55 °C, brine largely disappears from sea ice, and the sea ice is composed of pure ice made up of freshwater and solid state salts.

3. Basic knowledge about ice class ships

The presence or potential presence of ice is a characteristic of the Northern Sea Route, and can result in danger leading to accidents for navigators such as damage to the ship hull. To safely and efficiently navigate in such sea areas, in addition to navigators acquiring specialized knowledge and techniques, it is also necessary to prepare special navigating vessels by means of reinforcement, etc. appropriate to icebound seas. Such vessels are generally referred to as ice class ships, and are usually divided into icebreakers and ice-strengthened (ice-worthy) ships. Below the basic knowledge about icebreakers and ice-strengthened ships is elucidated.

3.1 Ice class

In order for a vessel to safely and efficiently navigate frozen waters, the ship body and propulsion systems must be reinforced so that even if they collide or come into contact with ice they will not be damaged. A ship bow shape modified to break or push through ice, as well as a stern shape to make the broken ice come to the water surface quickly, are also necessary. Further, it is necessary for the vessel to be fitted with a powerful propulsion capacity when compared with equivalent vessels constructed for navigation in general sea areas; facility to protect propeller or rudder against ice; and equipment to protect ship body, instrumentation, and so on against low temperatures or encroaching ice. In addition, it is also important to have a hardware strategy with regards to equipment and instrumentation, etc. which will conserve the delicate environment of polar seas from pollution from oil and waste, etc.

Vessels navigating icebound seas, giving due consideration to the specific dangers associated with operating in icebound seas, are required to satisfy certain conditions above certain standards with regards to ship structure, engine, instrumentation, equipment, and so on. Ice class is an official class meaning that a ship is certified by all classification societies as having means above these standards of vessel icebreaking and ice-strengthened capacity, to ensure safe navigation in icebound seas and the protection of the environment.

3.1.1 Dangers specific to icebound seas

The dangers which may be encountered and should be considered by vessels navigating in icebound seas such as the Arctic Ocean when making decisions on standards for ship structure, engine, equipment and instruments are as follows.

[Ice load]

There is a risk that ice load from collision or contact with ice can increase the ship hull resistance and have effects such as damage to the body of the ship. Also, should the propeller comes into contact with ice, there is a danger of a sudden torque increase occurring. Moreover, a ship may be enclosed by ice and become unnavigable, and in the worst case scenario, there is a danger of crushing of the ship hull.

[Vessel icing]

At low temperatures, spray dashed up from waves can result in ice formation on the ship body, if such water adheres and freezes on the deck structures. A large amount of vessel icing makes the ship top heavy, and there is a risk that it will undermine ship stability. Even in large vessels, this can lead to a worsening of bridge operations and reduced or suspended functionality of detection instrumentation, damage of such instrumentation, and so on.

[Brittleness failure]

At low temperatures, the toughness of some metallic materials can be compromised. This means that there is a chance that the steel etc., in the ship hull or deck instrumentation may lose elasticity, leading to brittleness failure.

[Deck freezing]

At low temperatures, puddles on deck or water which collects in the oil pan underneath the moorage and anchorage equipment can freeze. Deck freezing can reduce effectiveness in ship operations, invite the reduced functionality of deck equipment, etc. and also be the cause of falling and overboard accidents.

[Tank, pipe, and bulb damage]

At low temperatures, freezing of liquids such as freshwater or seawater, or increased viscosity and hardening of liquids such as oils can occur. There is a chance that the increase in volume caused by the freezing of these liquids will cause ballast water tanks, freshwater tanks or oil tanks, etc., or pipes and bulbs for freshwater, seawater, and oil to become clogged or to burst.

[Cooling seawater clogging]

In frozen waters, there is a risk that sherbet-like seawater and ice cakes can be taken in seawater reservoir inlet via the sea chest in the ship hull, used for secondary cooling of the main engine. When these reach the freshwater cooler, they induce clogging within the cooler, and efficient cooling is impeded, which can lead to overheating of the engine, etc.

3.1.2 Main ice classes

Ice class is awarded to a ship which has passed the inspections implemented by each classification society or other bodies under the uniform rules which are based on guidelines drawn up by the International Association of Classification Societies (IACS) or as stipulated by each classification society. Each classification society stipulates rules for inspection and authorization with regards to standards for ice class ship construction, engine, equipment, instrumentation, and so on. The content of these regulations comprises diverse rules to ensure the safety of ships and environmental protection of the polar seas with due consideration given to the specific dangers of vessel operation in icebound seas, as stipulated in most cases by the IMO or by respective national governments.

Table 1-7: Comparison of ice classes

極地氷海船階級（IMO）	アイスクラス（ロシア船級協会）	耐氷船階級（FSICR）
PC1		
PC2	Arc9	
PC3	Arc8	
PC4	Arc7	
PC5	Arc6	
PC6	Arc5	IA Super
PC7	Arc4	IA
	Ice3	IB
	Ice2	IC
	Ice1	ID

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Table 1-7 picks up on three of the foremost ice classes used throughout the world, and shows a broad comparison of how their levels correspond with one another

Polar Class refers to uniform rules with regards to ice class as stipulated by the IACS, to which the major classification societies in the world are affiliated, in accordance with the “Guideline for ships operating in Arctic ice-covered waters” as ratified by the IMO. Polar Class also targets vessels capable of independent navigation in the Arctic Ocean, and is divided into seven levels from PC1 to PC7. The lower the classification number, the higher the icebreaking or ice-strengthened capacity of the vessel.

Of the ice class stipulated by the Russian classification society, classes Arc9 to Arc4 are mainly for icebreakers capable of independent operation in the Arctic Ocean. Ice3 to Ice1 are mainly for ice-strengthened ships utilizing navigation support such as icebreaker guidance in the Arctic Ocean. The larger the number, the higher the vessel’s icebreaking or ice-strengthened capacity.

Ice-strengthened class is an ice class based on “FSICR (Finnish-Swedish Ice Class Rules)” stipulated by both Finland and Sweden. Originally, it was intended to certify the ice-strengthened capacity of vessels navigating in sea areas such as the North Baltic Sea which freeze only in winter and spring. However, it is now the most popular one applied throughout the world with regards to the ice class of ice-strengthened ships.

3.1.3 Target vessels by ice class ranking

Table 1-8 shows the reference values for ice conditions, seasons of navigation and ice thickness, to indicate what kind of ships are subject to the respective Polar Class. These can be used as a guide when building a vessel meeting a certain class, to decide the construction requirements, etc.

Table 1-9 shows the definition of vessels on the capacity, as required by each grade of ice-strengthened ship class.

It can be said that Polar Class as based on the uniform rules of IACS is an ice class for icebreakers operating in mainly multi-year ice conditions; ice-strengthened class as based on the FCISR rules is an ice class for ice-strengthened ships operating in mainly first-year ice; and the ice class as stipulated by the Russian classification society is for both vessel types.

However, there is no obligation to acquire ice-class and it is at the discretion of the ship owner. Indeed, possession of ice class is not a prerequisite to navigate in icebound seas. In fact, there are vessels which do not possess ice class even while their hulls and propulsion systems have been reinforced to withstand contact with ice, and which exceed a certain level for icebreaking and ice-strengthened capacity.

Table 1-8: Target vessels by class for ice conditions, seasons, etc. of navigation (Polar Class)

極地氷海船階級(IMO)	氷況及び季節	氷厚の参考値(cm)
PC1	すべての極地氷水域を通年航行する極地氷海船。	350以上
PC2	中程度の厳しさの多年氷が存在する氷水域を通年航行する極地氷海船。	300～350
PC3	多年氷が一部混在する二年氷の中を通年航行する極地氷海船。	200～300
PC4	多年氷が一部混在する厚い一年氷の中を通年航行する極地氷海船。	120～200
PC5	多年氷が一部混在する中程度の厚さの一年氷の中を通年航行する極地氷海船。	70～120
PC6	多年氷が一部混在する中程度の厚さの一年氷の中を夏季又は秋季に航行する極地氷海船。	50～90
PC7	多年氷が一部混在する薄い一年氷の中を夏季又は秋季に航行する極地氷海船。	30～60

Table 1-9: Definition of ship capacities required by each class (ice-strengthened ship class)

耐氷船階級(FSICR)	能力面での船舶の定義
I A Super	砕氷船の支援なしに厳しい氷水域を航行する能力を有する船舶
I A	砕氷船のもとに厳しい氷水域を航行する能力を有する船舶
I B	必要に応じて砕氷船の支援を受けることにより、穏やかな氷水域を航行する能力を有する船舶
I C	必要に応じて砕氷船の支援を受けることにより、航行が容易な氷水域を航行する能力を有する船舶
I D	一般海域を航行できる構造強度を有し、耐氷補強は行われていないものの、非常に航行が容易な氷水域を航行する能力を有する船舶

These are no obligatory requirements for possession of ice class for navigating vessels using the Northern Sea Route, even in Russian law. However, the standards for permission of navigation may be relaxed for ice-strengthened ships possessing ice class, such as permission for independent navigation without navigation support including guidance by icebreakers is given according to the grade of their class, season of passage, navigated sea area, and ice conditions during passage. At the same time under this system, vessels without ice class, or ice-strengthened ships with only a lower grade ice class, may be subject to strict navigation standards for permissions, and may not be granted permission for winter passages or be required to navigate using support such as icebreakers even in mild ice conditions of summer.

3.2 Role of ice class ships

Ice class ships include icebreakers, equipped to navigate alone while breaking through ice covering the sea surface. They have resilient ship hulls and propulsion systems to withstand collisions with ice in the Arctic or Antarctic Oceans, and bow specifications specially designed to facilitate the crushing or elimination of ice in their path. Many icebreakers are owned by governments, etc. or they may be naval or scientific survey vessels, however some are merchant ships or tourist vessels. Icebreakers normally have an ice class such as Polar Class, an official certification in recognition of their capacity to break ice as bestowed by each certification society.

The vessel “Shirase” is famous as a Japanese icebreaker used to dispatch personnel or to transport commodities to the Antarctic research bases. While Shirase is referred to as an Antarctic research vessel by the Ministry of Education, Culture, Sports, Science and Technology under the jurisdiction of the Antarctic research, it is referred to as an icebreaker by the Ministry of Defense which operates the vessel. The Japan Coast Guard vessels “Souya” and Teshio”, which are patrol boats in the sea around the coast of Hokkaido, and Garinko II, Aurora and Aurora 2, which are known as drift ice tourist ships in the winter Okhotsk Sea, are also icebreakers.

The first of the primary roles of an icebreaker is navigation support. Icebreakers provide navigation support such as guidance in icebound seas or crushing ice floes to open a lead through a given passage.

The second role of icebreakers is rescue operations. Icebreakers assist in rescue operations for ships whose passage has become impeded due to, for example, engine failure in icebound seas, or ships which have run into a beset after becoming enclosed by ice, by means of towing or by opening a lead.

The third role of icebreakers is to support resource development. Icebreakers provide assistance for resource development in coastal areas of the Arctic Ocean, etc. by removing ice surrounding icebound sea construction such as production and excavation platforms and protecting them from ice load, or supporting transport of personnel or commodities to such platforms, etc.

The fourth role of icebreakers is to support monitoring research. Icebreakers function as self-contained mobile marine observation platforms, in addition to supporting the transport of personnel and commodities to observational facilities and bases in the coastal areas of the Arctic Ocean or Antarctica.

The fifth role of icebreakers is freight transport. Icebreaking-capable merchant vessels which can navigate independently in icebound seas such as bulk carriers, tankers, LASH ships, or multifunctional cargo ships are constructed in countries such as Russia and Canada, and play a role in the transport of energy resources and cargo.

The sixth role of icebreakers is the environmental maintenance of, for example, harbors. In frozen harbors or rivers, opening of leads, buoy maintenance, inspections and safety patrols by icebreakers are implemented.

Table 1-10: Icebreaker roles and descriptions

砕氷船の役割	具体的内容
航行援助	氷盤を破壊して水路を開放する等の航行援助
救助活動	曳航又は水路開放等による救助活動
資源開発支援	氷海構造物の周囲の氷除去、人員・物資輸送
観測支援	観測施設・基地への人員・物資輸送、移動式洋上観測プラットフォーム
貨物輸送	エネルギー資源及び貨物等の輸送
環境整備	凍結港・河川における水路開放、ブイ等の保守・点検、安全パトロール等

Meanwhile, while ice-strengthened ships do not have the equivalent capacity of icebreakers to break ice, they are reinforced to be able to withstand a degree of ice load, and are capable of pushing through and removing ice on sea surfaces. However, in severe ice conditions, they can only navigate under navigation support such as guidance by icebreakers, etc.

Ice-strengthened ships are equipped with specialized designs such as sturdy hulls and propulsion systems capable of withstanding contact with ice. In normal circumstances, ice-strengthened ships have ice class, an official grade bestowed by respective ship certification societies to certify that they have ice-strengthened capacities. Ice-strengthened merchant vessels are often used in the transport of energy resources, cargo, and so on.

3.3 Features and construction of ice class ships

Ice class ship design is based on the concept of safe and efficient navigation in icebound seas, and has characteristic features and construction which differ from general ships.

3.3.1 Hull weight

Ice class ships must reinforce their hulls and propulsion systems so that these do not sustain damage when they come in contact with ice. For this reason, along with the increased volume of steel materials required for the reinforcements, the hull weight of ice class ships is greater than ships of comparable size that have been constructed for navigation in general seas. Accordingly, when navigating in sea areas other than icebound seas, ice class ships have the tendency to be less fuel efficient when compared to equivalent or comparable general ships.

3.3.2 Hull shape

Of the various types of ice class ships, icebreakers have a distinctive hull shape. To improve their handling and performance and icebreaking capacity in icebound seas, icebreakers are equipped with a distinctive stocky hull, which is also broader in relation to ship length when compared to ice-strengthened ships and general ships.

The vessels type is expressed to show the degree of stubbiness, with hull width increasing as L/B value decreases (comparative value of vessel waterline length and breadth). In normal circumstances, oceangoing pure car carriers constructed for use in general sea areas have an L/B within 5.5 to 6.2; oceangoing bulk carriers have an L/B within 5.8 to 6.2; VLCCs (very large crude carriers; giant ships with deadweight capacity of 20-30 tons) have an L/B within 5.3 to 5.9; and large ferries have an L/B within 7.3 to 8.0.

Meanwhile, the L/B of icebreakers is within 4.5 to 5.0 for large size icebreakers and 4.0 for medium size icebreakers. Small icebreakers, intended for use in the environmental maintenance of harbors, etc. need enhanced maneuvering capacity, meaning that their L/B is even lower.

3.3.3 Maximum cargo capacity

To increase the icebreaking capacity, ice class ships are equipped with a main engine with a more powerful propulsion system when compared with vessels of a similar type constructed for use in general waters. For this reason, the main engine is heavy and the engine room is more spacious. Accordingly, compared to similar size ships constructed for use in general waters, they have a 20% to 30% reduced cargo capacity.

The value of the deadweight (tons) divided by full load displacement (tons) is called the deadweight carrying capacity, and is an estimation of the vessel’s cargo carrying efficiency. In normal circumstances, the deadweight carrying capacity is around 0.86 to 0.88 for oceangoing bulk carriers or VLCC constructed for use in general waters, around 0.60 to 0.70 for oceangoing container ships, and around 0.35 to 0.38 for large ferries.

Meanwhile, the deadweight carrying capacity for ice-strengthened oceangoing bulk carriers and tanker ships is around 0.6, equivalent to the level of oceangoing container ships constructed for use in general waters. The deadweight carrying capacity of icebreakers is around 0.3, equivalent to the level of large ferries constructed for use in general waters.

Pic. 1-15: Russian nuclear-powered icebreaker “NS 50 Let Pobedy” (*50 years of Victory*)
(courtesy of Jin Saijou)

3.3.4 Engine power

Ice class ships are characterized by high engine powers relative to their ship type, to increase ice-breaking capacity. The value of the shaft horse power (SHP) divided by the full load displacement (tons) is used to estimate the relative dimensions of a ship propulsion system. In normal circumstances, this value is around 0.5 for oceangoing pure car carriers constructed for use in general waters; around 0.1 to 0.15 for oceangoing bulk carriers; around 0.1 for VLCCs; around 0.75 for overseas container ships; and around 1.5 to 2.0 for large car ferries.

With regards to ice class ships, the Russian nuclear-powered icebreaker “NS 50 Let Pobedy” (*50 years of Victory*), with an engine power of 49,000 kilowatts (66,620 horsepower), has full load displacement of 25,480 tons, meaning the value is 2.58. The Japanese Maritime Self-Defense Force icebreaking Antarctic research vessel “JMSDF AGB SHIRASE (Second) class” has a power of 22,070 kilowatts (30,010 horsepower) and a full load displacement of 12,500 tons, meaning the value is 2.40. Both have a powerful propulsion system on a par with a large car ferry.

Further, the JAMSTEC Japanese oceanographic research vessel “RV Mirai” has a power of 7,352 kilowatts (9,996 horsepower) and a full load displacement of 10,627 tons, meaning it has a value of 0.94 and thus a large propulsion system on a par with a oceangoing container ships.

3.3.5 Bow shape

Many ice class ships have a ship bow shape appropriate to breaking and pushing through ice. Icebreakers in particular usually have a modified sloping bow, which allows them to complete passage while crushing, bending and pushing through the broken ice. To reduce resistance, the pitch angle of the hull to the water surface (angle of the stem of the hull abaft and angle of the flair of the hull abeam) is smaller.

For icebreaker bow shapes, apart from what is referred to as the traditional shape used by the Antarctic research vessel “Shirase” and the icebreaker patrol boat “Teshio”, there are variations such as spoon bows, concave bows, waas bows, and conical bows.

The underside of icebreaker bows are usually equipped with a partition known as a fore foot or a bow stopper, to prevent impeded steering from excessive rollover of the hull on the ice sheet.

Meanwhile, many ice-strengthened ships do not assume independent navigation in icebound seas, but presuppose navigation support from icebreakers. Accordingly, most do not have modified sloping bows, and, in particular circumstances some have the same bulbous bow as vessels constructed for use in general waters. Also, bow shapes appropriate to remove brash ice following an icebreaker passage may be adopted, rather than those suitable for breaking and pushing through ice.

Pic. 1-16: Bow of icebreaker patrol boat “Teshio”
(Source: the Japan Association of Marine Safety)

3.3.6 Stern shape

Many ice class ships have a modified stern shape to improve icebreaking capacity in sea ice areas. Icebreakers in particular have a stern shape appropriate to quickest feasible elimination of ice on the underside of the icebreaker to mitigate hull resistance from ice loads, and to prevent damage to the propeller or rudder from contact with ice. Usually most icebreakers have slanted sterns like the bow, although this may also depend on the propeller or rudder configuration, as well as the position and number.

However, ice-strengthened ships assume navigation support by icebreakers, meaning that the stern shape is often the same as a ship constructed for use in general waters.

The propeller and rudder located at the stern are more easily susceptible to damage by collisions or contact with ice than the reinforced bow. For this reason, the upper part of the rudder of ice class ships are usually fitted with an ice knife or a triangular projection known as an ice horn, to prevent damage to the propeller or rudder from contact with ice particularly when going astern.

In ice class ships, in particular icebreakers, the propeller and rudder are located in a relatively deep position from the sea surface to minimize the risk of contact with ice to the extent possible.

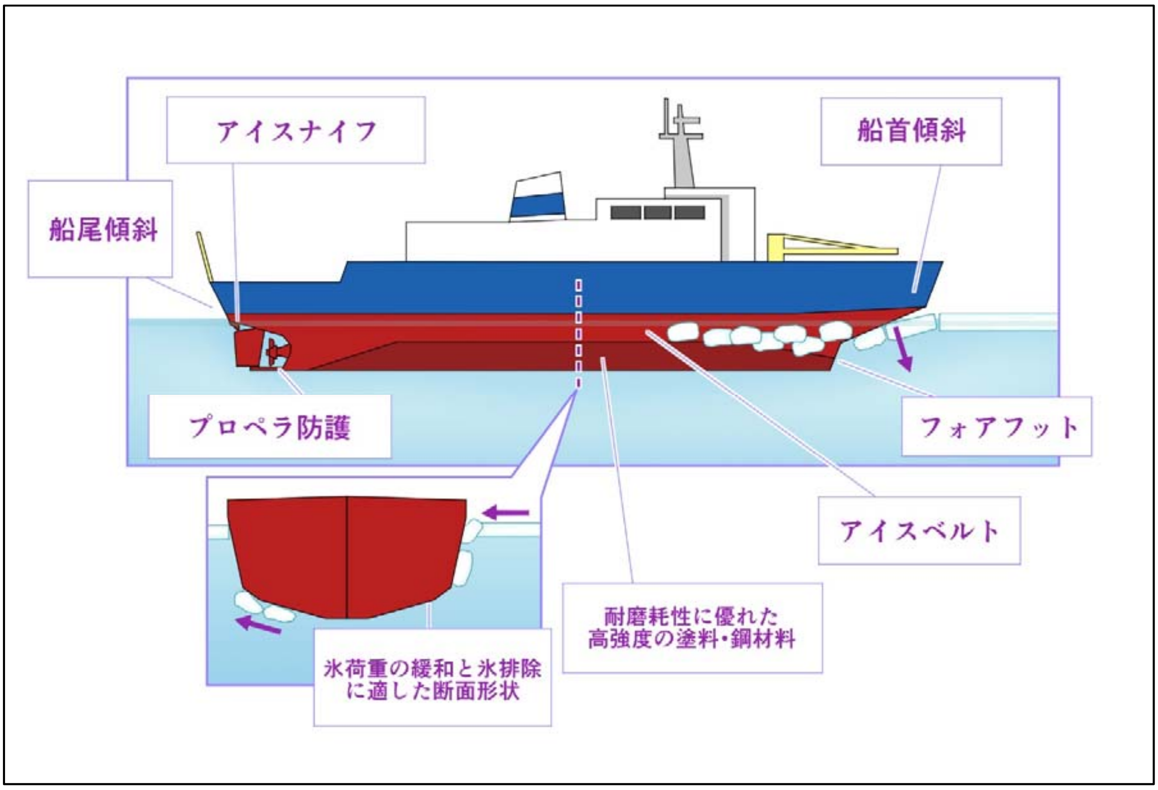


Fig. 1-26: Typical features of icebreakers

3.3.7 Ship bottom and transection

Many ice class ships, in particular icebreakers, are given sloped bottoms and sides in order to eliminate ice which gets under the bottom during ice-breaking as swiftly as possible.

While the transection of ships constructed for use in general waters is approximately rectangular in shape, that of icebreakers has slanted bottom and sides as described above, or is a somewhat rounded tea bowl-like shape, to mitigate hull resistance from ice load or to quickly eliminate ice over which the ship bottom passes. As they can also not be fitted with a bilge keel, they sway easily in waves and surges.

3.3.8 Ice belt

A large ice load acts on the ice belt around the water line of ice class ships. For this reason, their ice belts, in particular those of icebreakers, are often stronger than other parts and are specially reinforced with steel to withstand low temperatures.

Also, there is a risk that abrasion and flaking will easily occur around the ice belt and the fore of ice class ships due to contact with ice, if the same coating agent as that for ships in general waters is used. For this reason, in order to reduce friction between the ice and the hull and prevent abrasion, a special low-temperature-resistant coating agent for icebound seas is very often used.

Some icebreakers do not coat the metal surfaces but rather use a stainless clad metal (steel covered with stainless clad surface) on the ice belt to increase resistance to abrasion and corrosion, and mitigate hull resistance from ice load. In such cases, corrosion-proofing measures are implemented as electrolytic corrosion may occur due to a difference of potential between the normal steel used around the ice belt and the stainless clad metal.

3.3.9 Propulsion systems

Many ice class ships, in particular icebreakers, normally have 2 or 3 propellers, as they must be prepared for situations where navigation cannot proceed due to damage from contact with ice.

Many also use a means to run the propellers without directly connecting to the diesel engine, by temporarily running the motor using diesel power - namely an electric propulsion system, in order to enable quick and reliable switching between forward and reverse movements during torque fluctuation caused by contact with ice as well as ramming (maneuvering method to break ice floes by repeated forward and reverse movements). However, a comparatively large number of ice-strengthened ships, in particular ice-strengthened merchant vessels, like ships constructed for use in general waters, have only one propeller which is directly connected with the diesel of the main engine.

Meanwhile, certain ice class ships use propulsion devices such as an azimuth thruster, with a horizontal direction range of 360 degrees, to improve steering performance in sea ice areas. An advanced propulsion device is a POD propeller, whereby a cocoon-shaped apparatus called a POD containing an electric motor is directly connected to the propeller.

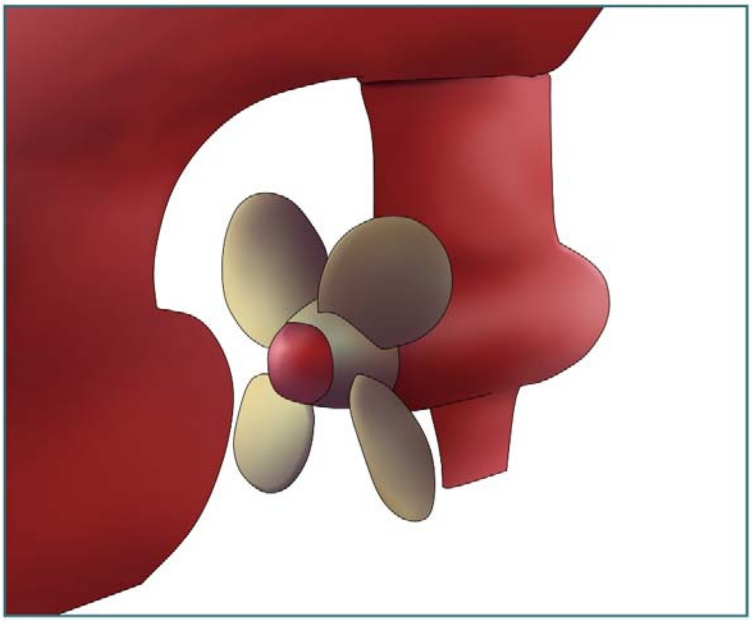


Fig. 1-27: POD propeller

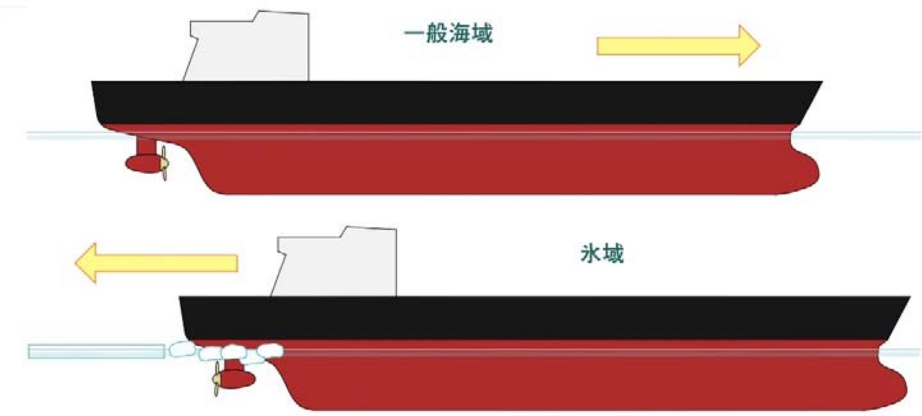


Fig. 1-28: Double acting ship (DAS)

Furthermore, a double acting ship (DAS) is an ice class ship which can freely navigate in forwards or backwards directions, to facilitate effective navigation whether the vessel is in icebound seas or general seas. When navigating in general seas, they run ahead using the POD propeller installed in the conventional stern towards the conventional bulbous bow. Meanwhile, when in reverse during navigation of ice areas, it turns around and proceeds towards the traditional astern. On such occasions, it is configured so the orientation of the wheelhouse is reversed or the POD propeller is run in the opposite horizontal direction. The stern is solidly made and is shaped to allow navigation while pushing down through and bending and crushing the ice.

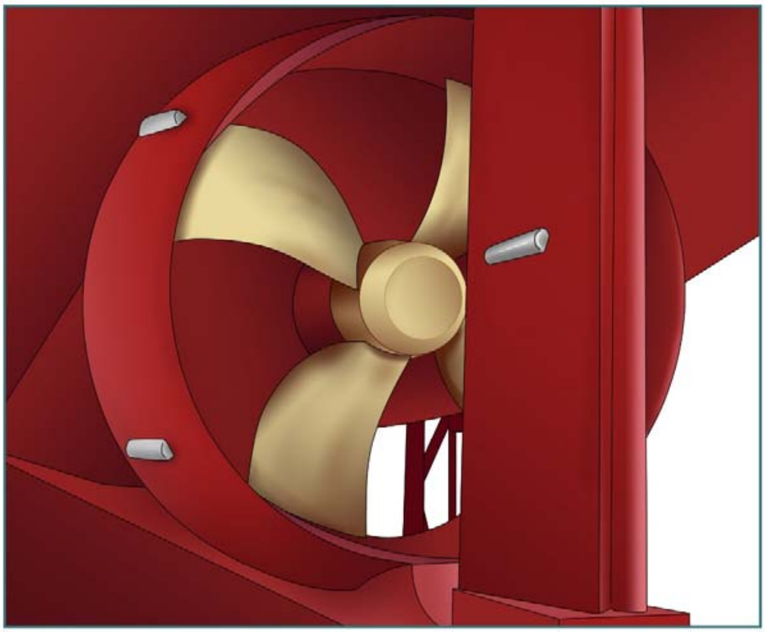


Fig. 1-29: Ducted propeller

The thickness and diameter of ice class ship propellers are designed with consideration to torque from contact with ice and ice load, etc. In addition, a comparatively large gap is reserved between the propeller wingtip and hull so that ice cakes are not chewed up. Moreover, to protect the propeller from contact with ice, a ducted propeller with the entire propeller covered by a cylindrical guard is sometimes employed.

The tourist ship Garinko II of Monbetsu City, Hokkaido, is an ice class ship which has a special propulsion device called an Archimedes' screw motor, in addition to a normal propeller. When the Garinko II navigates in general waters, it mainly uses the stern propeller like a general ship. Meanwhile, in ice areas, it runs ahead while running two rotors of 6 meters length and 1.5 meters thickness equipped on the bow. It mounts and crushes the ice with the weight of the hull by using the rotational power of the rotors against the thick ice. This applies the screw principle of the ancient Greek inventor, Archimedes, that turning a screw produces forward movement. While this is an uncommon propeller, even on a world scale, it is never used by ice class ships navigating on the Northern Sea Route.

3.4 Facilities and equipment of ice class ships

Ice class ships have a number of facilities and equipment which differ from general ships, to facilitate safe and efficient navigation on icebound seas and protect the hull and instruments, etc. from cold temperatures or ice encroachment.

3.4.1 Sea bay

When ice class ships navigate in ice areas, there is a risk that ice cakes or sherbet seawater will be taken in from the sea chest for secondary cooling of the main engine. Should these reach the freshwater cooler, the internal part of the cooler becomes blocked and cannot effectively refrigerate, causing the main engine, etc. to overheat, which could result in emergency shutdowns. For this reason, countermeasures such as installation of tanks and sea bays are taken to store chilled seawater in ice class ships temporarily and thaw the ice cakes, etc. which have been taken in together.

3.4.2 Heating devices

In addition to using materials intended to prevent freezing, and withstand low temperatures and ice encroachment, various heating devices such as a trace heater, heating cable and space heater are installed in the ballast tanks, freshwater tanks, pipes and deck equipment of ice class ships. Certain ice class ships are also equipped with de-icing system to mechanically remove ice when ice encroaches on the hull, etc.

3.4.3 Towing equipment

In sea areas where ice conditions are extremely poor, icebreakers may tow assisted ships. This includes circumstances where the continued passage of ships under assistance becomes repeatedly unfeasible, due to the blocking of channels, and continued icebreaker guidance is endangered.

Many icebreakers have towing devices such as a towing winch, towing wire or towing chain. Some icebreakers are also equipped with a special device called a stern notch to tow a ship with both ships in contact without using a towline.

Pic. 1-17: Preparation of towing equipment (courtesy of The Nippon Salvage Co. Ltd.)

3.4.4 Air bubbling

Some ice class ships are equipped with an air bubbling system which forcibly generates air bubbles within tanks, as a freezing prevention measure for ballast tanks or freshwater tanks, to prevent freezing of liquid.

There are also icebreakers which have an air bubbling system to release air bubbles from the bows and cover the ship bottom and sides. In this case, broken ice cakes quickly float to the surface with air bubbles, resulting in the prevention of broken ice cakes adhering to the ship bottom while navigating in seasons of severe cold, and the reduced resistance during icebreaking. In addition, this system may be used when navigating ahead of another vessel, as there are less ice cakes floating to the surface in the wake.

3.4.5 Water jet

Frictional resistance between the ice and the hull reduces the icebreaking capacity of ice class ships. In particular, the frictional resistance is considerably increased and impedes icebreaking if there is snow accumulated on the ice sheet, and in worst cases can lead to stalled or crippled vessels. For this reason, there are icebreakers which are equipped with a water jet on their bow. The water jet blows away or thaws accumulated snow by spraying seawater, etc. using a water sprinkling device installed on the bow of ice class ships. It thus reduces frictional resistance between the ice and the hull to prevent impediments to effective icebreaking.

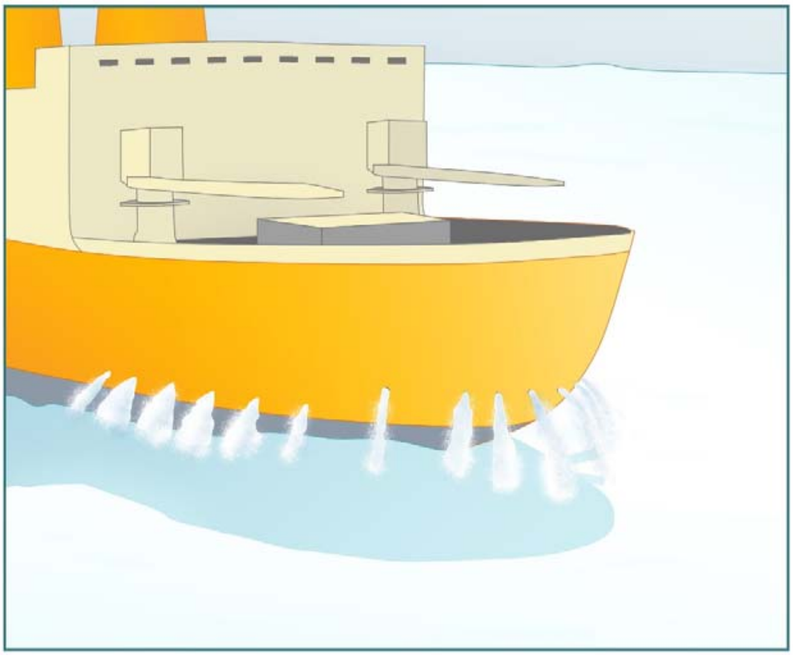


Fig. 1-30: Water jet

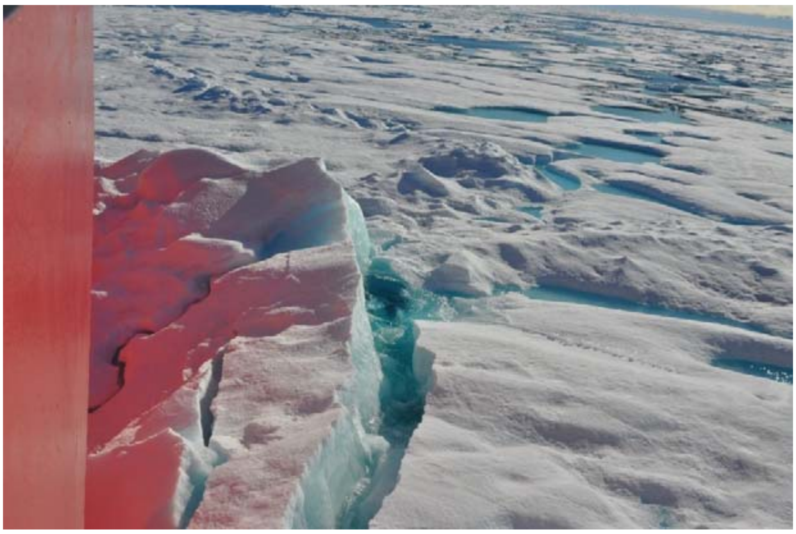
3.5 Icebreaking methods of ice class ships and ice load

There are several types of icebreaking methods used by ice class ships. The main ice load at work on the hull also differs according to icebreaking method.

3.5.1 Continuous-mode icebreaking and flexure fracture

The ship handling method by ice class ships in icebound seas whereby the vessel navigates at a constant low speed without stopping, while continually break apart or pushing through ice, is called continuous-mode icebreaking. Among ice class ships, it is mainly icebreakers which carry out continuous-mode icebreaking. Ice-strengthened ships do not implement continuous-mode icebreaking, excepting circumstances with relatively low ice concentration and thin first-year ice, or when they have entered sea areas without the guidance of icebreakers.

During continuous-mode icebreaking, icebreakers navigate while using the specially slanted bow, to push down through, bend and fracture the ice. As shown in Fig. 1-31, fractures occur where the ice and the hull meet, and the ice is crushed, and bend-breaks. This kind of smashing of ice is called flexure fracture. For continuous-mode icebreaking, icebreakers mainly use flexure fracture to break the ice. Flexure fracture causes radial or elliptical fractures in the ice, normally resulting in broken ice in a crescent or semi-elliptical shape.



Pic. 1-18: Ice cakes broken into crescent shape by a ship bow (courtesy of Hiroki Shibata)

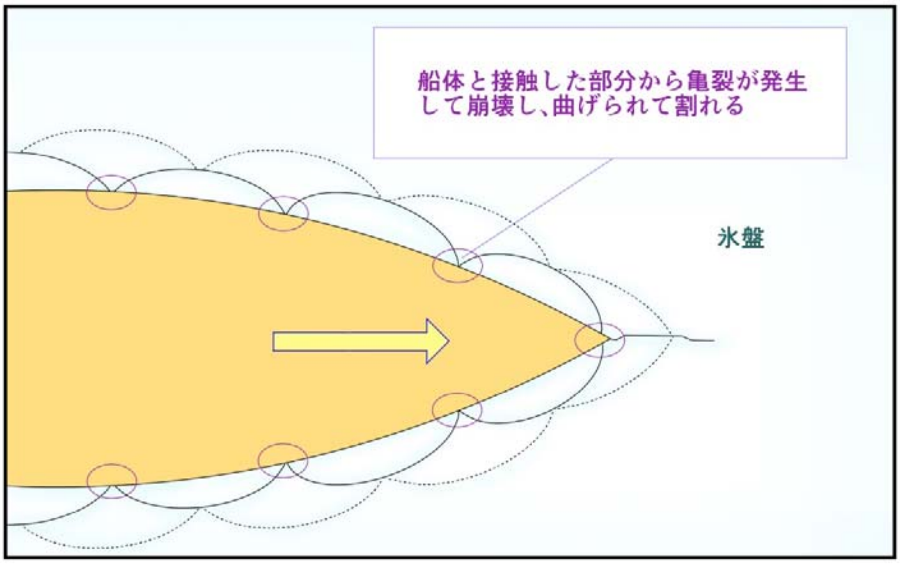


Fig. 1-31: Flexure fracture during continuous-mode icebreaking

Pic. 1-19: Pulverized ice after crushing by ramming (courtesy of Seiji Shigehara)

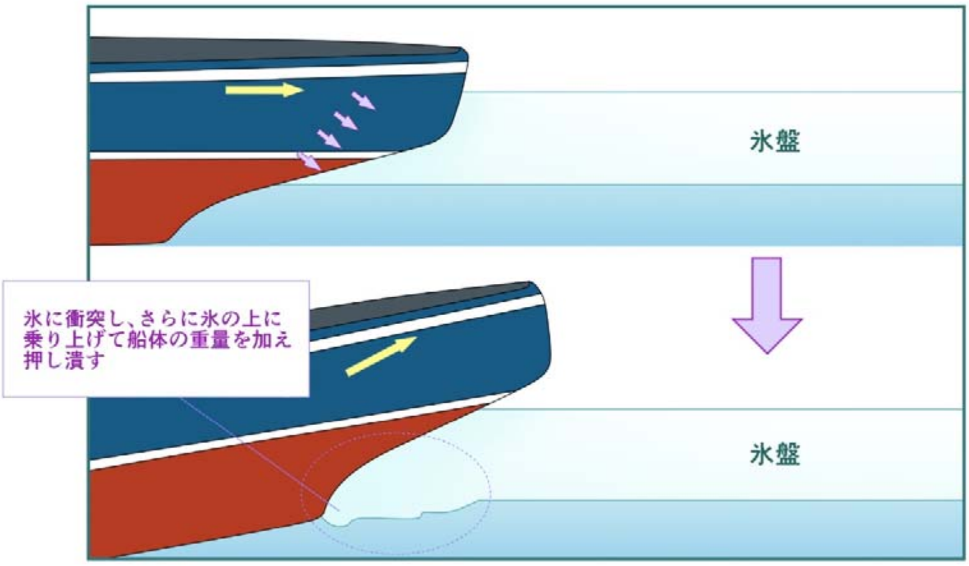


Fig. 1-32: Crushing during ramming

3.5.2 Ramming and crushing

Ramming refers to the icebreaking method whereby the hull temporarily reverses from the ice in front, and then runs ahead at speed to collide with and break apart the ice. It is used when thick ice impervious to continuous-mode icebreaking is encountered. Icebreakers are the mainly ice class ships which implement ramming, as ramming by ice-strengthened vessels, or general ships would result in damage to the hull, in particular in vessels with bulbous bows.

As shown in Fig. 1-32, during ramming the icebreaker collides with ice, and initially breaks apart the ice by means of compression. This is called crushing. Further, by the addition of the weight of the hull mounting the ice it is forcibly weighed down so it bends and breaks. Also, after mounting the ice, some icebreakers enhance this effect by flooding the bow trim tank with seawater, etc., to increase the weight of the bow.

3.5.3 Ice load action on ice class ships

The ice class ships which carry out continuous-mode icebreaking or ramming are commonly icebreakers. Ice-strengthened ships do not carry out continuous ice-breaking, excepting unusual circumstances, such as when ice concentration is relatively low and they have inadvertently entered ice areas of thin first-year ice, or when they must urgently evacuate.

Instead, ice-strengthened ships in normal circumstances are guided by icebreakers, and navigate by the lead opened by the continuous-mode icebreaking or ramming carried out by those icebreakers. In this case, ice-strengthened ships navigate while pushing through or sinking any brash ice which has accumulated in their path. These are usually small ice cakes of under 2 meters diameter, but at times ice cakes, etc. which the icebreaker has not sufficiently broken will also be encountered, resulting in impacts. Also, in unavoidable circumstances in which ice-strengthened ships are obliged to carry out continuous-mode icebreaking, there is a chance of collisions with ice cakes, etc.

Accordingly, the design of ice-strengthened ships normally requires consideration of ice load which accompanies pushing through or sinking of small ice cakes, collisions with such ice cakes, and so on. Meanwhile, the design of icebreakers requires consideration of ice load which accompanies breaking of ice floes such as flexure fracture during the continuous-mode icebreaking or crushing during ramming, in addition to the same ice load experienced by ice-strengthened ships. There is huge variation between the kind of scenarios to be envisaged in relation to ice load when designing icebreakers or ice-strengthened ships.

Chapter II: Navigation Practices on the Northern Sea Route

1. Basic principles of navigation

When navigators unaccustomed to navigation in sea ice areas navigate the Northern Sea Route, the existence or the potential existence of ice may be one of the greatest threats to them. In fact, if a vessel failed to recognize drifting multi-year ice due to inadequate lookout or any other reasons and collided with it at its normal service speed, the vessel would suffer serious damage, which could lead to a severe marine accident, such as a wreck in the worst-case scenario. However, when you acquire correct knowledge necessary for navigation in sea ice areas and put it into practice with certainty, it is possible to ensure safe navigation just like in other sea areas. This chapter describes the basic principles of navigation on the Northern Sea Route mainly from the perspective of ice-strengthened ships.

1.1 Principle of ice avoidance

For an ice-strengthened ship navigating on the Northern Sea Route, it is essential to navigate in open water, in principle, following the directions given by the NSRA and a service control station commissioned by the NSRA, and avoiding encounters with ice as much as possible. When a vessel is at risk of getting close to a sea ice area, it must bypass the area as soon as possible, based on information about weather and ice conditions, seeking direction from a service control station or an icebreaker, or advice from an ice pilot, except in cases where it receives navigation aid from an icebreaker, including guiding.

If ice concentrations in a sea ice area are relatively low and ice is not thick, many merchant vessels using the Northern Sea Route are ice-strengthened ships whose bodies have been reinforced sufficiently to navigate pushing ice out of the way. However, if the vessel operator overestimates the performance of the vessel's body or his ship handling ability and allows the vessel to enter the sea ice area blindly without navigation aid from an icebreaker, the operator may put the vessel at risk for an accident, including damage to the vessel body. Even though its body has no damage, there is a risk that the vessel cannot continue to navigate due to damage to the propeller or rudder. A merchant vessel whose mission is to transport cargo safely should not take such a risk. It is one of the principles of navigation on the Northern Sea Route to avoid any avoidable risks to the extent possible.

Advice: Avoid encounters with ice as much as possible!

1.2 Principle of maintaining a safe speed

In the case where a vessel fails to find an appropriate bypass route and gets close to or enters a sea ice area while navigating the Northern Sea Route, it is one of the principles of navigation on the Northern Sea Route to immediately reduce speed to a safe speed. If the vessel collides with ice without reducing speed, it may suffer damage to its propeller, rudder, or body.

In particular, in the case where an ice-strengthened ship enters a sea ice area alone without navigation aid from an icebreaker for any compelling reason, it should seek directions from the relevant service control station or icebreaker, or advice from an ice pilot, etc., in order to immediately evacuate to a safe zone such as open water. In the course of evacuation, the vessel needs to assess the ice conditions (e.g., concentrations, thickness and hardness), the vessel body's capacity and operational performance, and the operator's ship handling ability, and to navigate as carefully as possible at a safe speed following a path with low ice concentrations or thin ice.

Advice: Maintain a safe speed in sea ice areas at all times!

Pic. 2-1: Survey icebreaker navigating a sea ice area (courtesy of Kazutaka Tateyama)

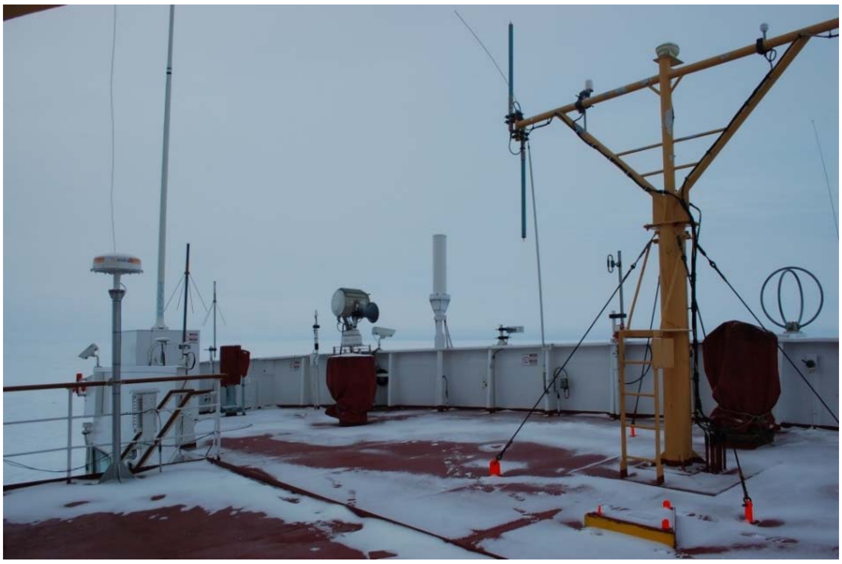
1.3 Principle of high-place lookout

In such sea areas as the Northern Sea Route where ice exists or is likely to exist, it is important for an ice-strengthened ship to place a lookout in as high a place as possible to find ice quickly. There is an actual case of a ship surrounded by ice where its lookout raised his eye level slightly without panic and then found a space with low ice concentration, and as a result, the ship was able to get off the spot. In other words, if a lookout's eye level remained low, the lookout might not only take a long time to find ice but also mistake a black space in the shadow of ice for an open water surface, resulting in wrong ship handling.

In order to raise eye height, it is effective for a lookout to be stationed at a flying bridge deck above the wheelhouse or to go up a mast on which a special shielded crow's nest is installed. However, lookout for a long time at an extremely low temperature or in a strong wind may pose a risk. In that case, it is necessary to engage a lookout in keeping watch from a high place from time to time, not all the time.

It is also important for lookouts engaged in keeping watch in sea ice areas to use sunglasses effectively. It is because a sea ice surface reflects sunlight in fine weather, which can be an obstacle to them. Also, it is necessary to protect their eyes from strong ultraviolet rays specific to polar zones. In the case of night navigation, search lights should be used effectively.

A lookout who gets accustomed to keeping watch for ice comes to be able to determine to some extent how thick or hard ice is at the mere sight of its color tone, shape, etc. On the other hand, an inexperienced lookout may mistake seabirds, etc., floating on the sea surface for ice. It is essential that lookouts gain experience in keeping watch for ice and quickly get used to their duties.



Pic. 2-2: Flying bridge deck of a survey icebreaker (courtesy of Kazutaka Tateyama)

Advice: Place a lookout in a high position!

Pic. 2-3: A lookout from the bridge of a survey icebreaker—sternward (courtesy of Hajime Yamaguchi)

Pic. 2-4: A lookout from the bridge of a survey icebreaker—to the stem (courtesy of Hajime Yamaguchi)

Advice: Effectively use sunglasses in fine weather!

2. Lookout procedures

In general, the purpose of lookouts is to confirm navigational safety by paying attention to surrounding circumstances such as the passage of other vessels, the potential to suffer a collision, deadlock or any other incident, and the existence of an obstacle that may pose a danger to their own vessels. When navigating in waters like the Northern Sea Route where ice exists or is likely to exist, unlike in other waters, ice-related matters are an additional purpose, including reading signs of the presence of ice, discovering open water, and grasping ice conditions. This section describes the lookout procedures on the Northern Sea Route mainly from the perspective of icebreakers.

2.1 Reading a sign of ice from ice blink

A phenomenon called ice blink is sometimes seen in the sky over waters where ice exists. Ice blink is one fairly-reliable sign to detect the presence of ice. If ice blink is visually recognized, it can be evidence to assert with probability that your vessel is passing near sea ice waters.

Pic. 2-5: Ice blink seen above the Arctic Ocean (courtesy of Kazutaka Tateyama)

Ice blink is a phenomenon caused by sunlight reflected from the ice surface and reflecting off clouds in the sky, and generally refers to a white or yellowish white luminous reflection on the underside of the clouds near the horizon. When the ice surface is covered with snow, the clouds look bright white, and when it is covered with fresh snow, the brightness of white increases. When ice is not covered with snow, the clouds look pale yellowish white. Ice blink seen on a sunny day does not look so bright, but may look like yellowish haze.

Even when there are few clouds in the sky above the ice, the bluish tone of the sky becomes slightly more vivid by sunlight reflected from the ice surface. Therefore, it is possible to detect the presence of ice if you observe the sky carefully. Ice blink can be seen even at night in clear weather from the reflection of moonlight or starlight.

Advice: Find ice blink to detect ice!

2.2 Detection of other signs of ice

In addition to finding ice blink, the presence of ice can be detected by the following methods.

2.2.1 Encounter with fog

Ice is likely to exist near a foggy area, while fog is likely to occur near ice. As your vessel gets closer to sea ice areas, it will encounter dense fog with high probability. In order to detect a sign that ice is present early, it is important to place a lookout to detect the presence of fog in the distance.

Pic. 2-6: An encounter with fog means that your vessel is close to ice!

(taken by the Japan Association of Marine Safety)

Advice: An encounter with fog is a sign of ice!

2.2.2 Drastic fall in temperature

As your vessel gets closer to sea ice areas, the ambient and water temperatures will fall drastically. When the ambient temperature falls by 2-4 degrees Celsius or more, or when the water temperature falls by 2 degrees Celsius or more, within a short time, sea ice areas are likely to exist close to your vessel. In the neighborhood of an iceberg in the Atlantic Ocean, there is a case where the water temperature suddenly fell by 15 degrees. In order to detect signs of ice, it is also important to focus the lookout's attention to changes in the ambient and water temperatures.

2.2.3 Calmer sea surface

Because ice has windproof and wave-attenuation effects, the surface in a sea ice area is often calmer than in open water even during stormy weather.

Therefore, as your vessel gets closer to sea ice areas, the wind blowing around the vessel will suddenly get weaker or the sea surface will suddenly get calm.

Particularly, when your vessel comes closer to sea ice areas from the leeward side, the sea surface tends to get calm suddenly. To detect a sign of ice, lookouts must not miss such changes in the sea surface.

2.2.4 Disturbed sea surface

As your vessel gets closer to sea ice areas, it will suddenly become difficult to determine the direction that waves or swells are coming from, due to diffused reflection from the sea surface caused by collision with ice. To detect the presence of ice, lookouts must not miss such changes in the sea surface.

2.2.5 Encounter with ice cakes

As your vessel gets closer to sea ice areas, small pieces of ice called ice cakes are often found. When drifting ice cakes are detected, sea ice areas are likely to exist not far from the present location. To detect the presence of ice, lookouts must not miss such drifting ice cakes.

2.2.6 Encounter with animals

As your vessel gets closer to sea ice areas, some pinnipeds living on the ice or its surrounding areas, such as ringed seal and walrus, can be seen. An encounter with kinds of seabirds that cannot be seen normally or a rapid increase in number of seabirds can also be a sign of getting closer to sea ice areas. To detect the presence of ice early, it is important to focus the lookout's attention on finding any animal in the distance.

Pic. 2-7: Walruses on the ice (courtesy of Koji Shimada)

Pic. 2-8: Seabirds on the ice (courtesy of Hiroki Shibata)

2.2.7 Change in sound

As your vessel gets closer to ice, the sounds of groaning ice or breaking waves may be heard. The whistle or engine noise of your vessel may echo off the ice. To detect the presence of ice, lookouts must not miss such changes in sounds.

Advice: Do not miss any type of sign of ice!

2.3 Detection of open water

In contrast to ice blink, a phenomenon called water sky can sometimes be seen in the sky above open water where no ice exists. Water sky is a very reliable sign of open water.

Water sky is dark patches of the cloud bottom in the sky because there is no reflection of sunlight on the open water surface where no ice exists. Specifically, black or dark gray spots, stripes, or other patterns can be seen at the cloud bottom above open water. Dark spots tend to appear when clouds are low in the sky, while stripes or a black block tend to appear when clouds are high in the sky.

In the fog, black spots can also be seen directly above open water. In this case, however, it is very difficult to detect them from a distance unlike water sky which appears at the bottom of clouds in cloudy weather.

In the Arctic Ocean, a distant terrestrial object can often look distorted, uplifted or enlarged by forming a virtual image mostly in fine weather due to extraordinary refraction of sunlight in the air that has different densities. This is a kind of mirage called mirage ice. When mirage ice occurs, the virtual image of sea ice areas appears to overlap the real image of open water and looks as if giant ice is near at hand, even though sea ice areas are located far away from your vessel.

Advice: Find water sky to detect open water!

Pic. 2-9: Ice edge in immediate vicinity of open water

(courtesy of Kazutaka Tateyama)

Pic. 2-10: Mirage ice photographed from fast ice in Antarctica

Advice: Don’t be fooled by mirage ice!

2.4 Principle of watching ice conditions, etc.

To accurately grasp the ice conditions surrounding your vessel, it is important to enable a lookout to watch with the naked eye in as high a place as possible.

For example, if a lookout watches from a bridge with an eye level of 22 meters, the distance within which the lookout can see ice conditions is no more than 1 mile because the real ice image is distorted beyond that distance. However, if a lookout watches from a flying bridge deck or a special shielded crow's nest on a mast to raise the eye level to 30 meters or more, the range of sight in a horizontal direction increases and the distortions of the real ice image are reduced, which may lead to significant accuracy improvement in grasp of ice conditions.

2.5 Determination of color tone, etc.

Ice thickness or hardness can be roughly determined by its color tone, shape, etc. In general, thin ice floes like one-year ice look white or gray/lead-white, while thick ice floes like two-year ice look blue or blue-green. Hummocked ice or pressure ridge created by overlapped and upheaved ice in a hummock shape is hard. Sea ice areas with high ice concentrations look almost pure white and provide a uniform color tone as a whole, while those with small ice concentrations look gray.

However, contrary to theory, ice is sometimes too hard even for an icebreaker to break, though it was determined to be thin. It is important to enable icebreaker crews to gain experience.

Pic. 2-11: White one-year ice and blue two-year ice (courtesy of Koji Shimada)

A mass of small broken ice cakes in various shapes with a diameter of less than 2 meters is called brash ice. Brash ice is also formed by an icebreaker passing through sea ice areas. After an icebreaker repeatedly passes through the same route in sea ice areas, a channel will be formed. When the channel is filled with ice cakes with a diameter of about 30 centimeters, it is called a brash ice channel.

Brash ice looks brown or gray-black. Generally, even if a channel is entirely covered with brash ice, an icebreaker can easily push the ice out and pass through the channel. Softened ice floes also look brown or gray-black.

Pic. 2-12: Pressure ridge formed by overlapped ice (courtesy of Koji Shimada)

Advice: Hummocked ice or pressure ridge upheaved in a hummock shape is hard!

2.6 Determination of concentration

Ice on the Arctic Ocean is not monolithic. A group of various-sized ice floes forms into sea ice areas. Typically, the amount of ice on the surface of sea ice areas is expressed by concentration. An ice concentration is the coverage of ice on the surface in a certain area of water which is expressed in deciles, percentiles, etc. For example, when half of the sea surface is covered by ice, the ice concentration is indicated as 5/10 (0.5), fifth decile, or 50%. The concentration of all ice on the sea surface is called the total concentration, while that of a certain part of the ice is called the partial concentration.

To ensure that a lookout correctly grasps ice concentrations in the surrounding waters is one of the basic points for not only icebreakers but also ice-strengthened ships to achieve safe navigation in sea ice areas. The term “ice concentration” is often used in communications with an icebreaker or service control station, so it is necessary to keep it in mind.

Advice: The term “ice concentration” is often used in communications!

Lookouts require a lot of skill to determine the ice concentration in sea ice areas ahead of their vessels at a horizontal level like on the bridge, not looking down from an airplane. For example, when you want to know the ice concentration in sea ice areas 1 mile ahead of your vessel, you need to take the trouble of checking the radar image to compare with the actual image of sea ice areas on a concentric circle 2 or 3 miles ahead, rather than determining it just by seeing the actual image.

According to ice concentration levels, sea surface conditions are classified as shown below.

- <Ice-free>: Waters with no ice whose ice concentration is 0/10 (0.0)
- <Open water>: Waters whose ice concentration is 1/10 (0.1) or less, which have open space where ice-strengthened ships can navigate freely
- <Very open ice>: Waters whose ice concentration is 1/10 (0.1) - 3/10 (0.3), which have a much larger area of sea surface than ice, where passage of ice-strengthened ships may be partially restricted
- <Open ice>: Waters whose ice concentration is 4/10 (0.4) - 6/10 (0.6), which are occupied almost evenly by ice and sea surface, where there are many leads, and where each ice floe is usually isolated but passage of ice-strengthened ships may be greatly restricted
- <Close ice>: Frozen sea whose ice concentration is 7/10 (0.7) - 8/10 (0.8), where most ice floes are stuck together and it is difficult for a vessel to navigate independently without the assistance of an icebreaker
- <Very close ice>: Frozen sea whose ice concentration is 9/10 (0.9) -

10/10 (1.0), where it is quite difficult for a vessel to navigate independently without the assistance of an icebreaker

- <Compact ice>: Frozen sea whose ice concentration is 10/10 (1.0), which is fully covered with ice, where the sea surface cannot be seen at all and it is almost impossible for a vessel to navigate independently without the assistance of an icebreaker
- <Consolidated ice>: Frozen sea whose ice concentration is 10/10 (1.0), where all ice floes are frozen together and it is extremely difficult for a vessel to navigate independently without the assistance of an icebreaker

When the ice concentration is 7/10 (0.7) or more, it is risky for a vessel to navigate independently without the assistance of an icebreaker even if it is an ice-strengthened ship whose body has been reinforced sufficiently to navigate pushing ice out of the way. However, under favorable conditions where each ice floe is relatively small and space between ice floes is filled with brash ice, it may be exceptionally possible to navigate independently without the assistance of an icebreaker even if the ice concentration is 7/10 (0.7) or more.

When the ice concentration is between 6/10 (0.6) and 7/10 (0.7), it may be possible for an ice-strengthened ship to navigate independently without the assistance of an icebreaker depending on conditions, for example in the case where ice floes are made up of relatively thin one-year ice, as long as its main engine and devices such as steering gear work properly, and it is operated appropriately while keeping a safe speed.

When the ice concentration is 6/10 (0.6) or less, it is possible for most ice-strengthened ships to navigate independently without the assistance of an icebreaker, as long as they weave their way with caution at a low speed to look for a lead or open pack which they can pass with the aim of minimizing damage due to collision with ice.

On the other hand, a non-ice-strengthened ship that does not belong to any ice class and whose body has not been reinforced to protect against ice loads is likely to become hopelessly beset when it is surrounded by ice whose concentration is relatively high even though it may be thin.

Advice: Determine whether or not to navigate by assessing ice concentrations precisely!

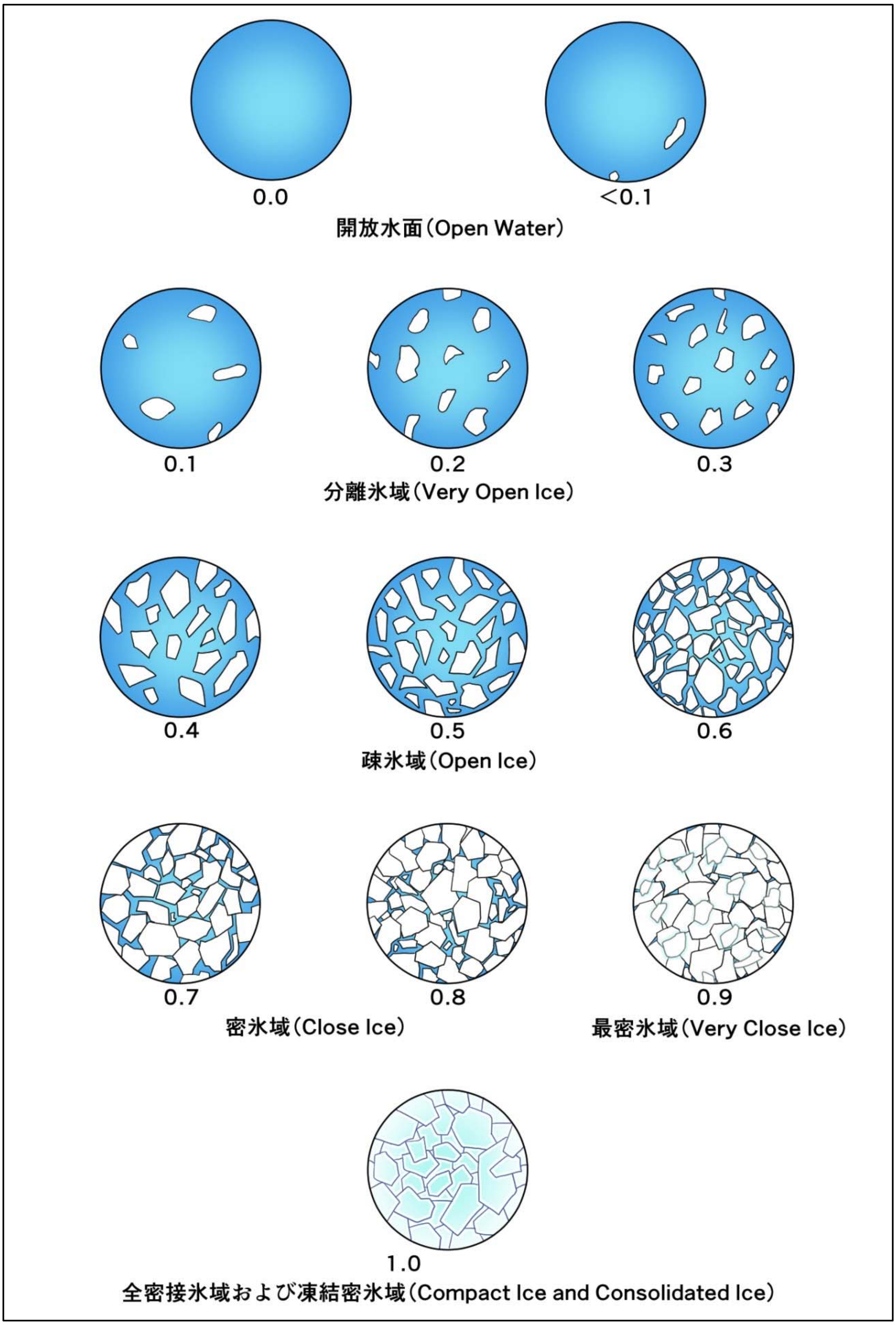


Fig. 2-1: Ice concentrations

Pic. 2-13: Very open ice (courtesy of Kazutaka Tateyama)

Pic. 2-14: Open ice (courtesy of Hiroki Shibata)

Pic. 2-15: Compact ice (courtesy of Kazutaka Tateyama)

3. How to use radar

On the Northern Sea Route, fog often occurs mainly in summer and hinders a lookout from detecting ice with the naked eye. Since ice tends to exist near fog, and fog tends to occur near ice, it is important to effectively use radar as a means of assisting a lookout in watching with the naked eye in waters where ice exists or is likely to exist. This section describes how to use radar on the Northern Sea Route mainly from the perspective of ice-strengthened ships.

3.1 Basic principles

Ice is almost invisible to radar unless it is properly adjusted and its performance is fully utilized. When using radar in sea ice areas, it is essential to conduct a performance inspection in advance after properly adjusting all switching devices for tuning, gain, sensitivity time control (STC), fast time constant (FTC), brightness, etc.

It is also important to choose the appropriate distance range (e.g. 6, 3, 1.5 miles) according to visibility or other conditions, and to grasp ice conditions with a good understanding of the features of radar that vary according to wavelength, transmission power, etc.

Pic. 2-16: Ice image captured by radar (courtesy of Jin Saijo)

3.2 Use of different wavelength radar by frequency

Marine radar systems use very short wavelength radio waves called microwaves. Those installed mainly in merchant vessels are classified into two types: S-band radars which use the 10cm wavelength and 3 GHz frequency bands; and X-band radars which use the 3 cm wavelength and 9 GHz frequency bands.

As S-band radar uses longer wavelengths than X-band radar and its radio waves are less likely to be weakened in the air, S-band radar has such features as being extremely capable of detecting a distant object and less affected by sea clutter.

On the other hand, X-band radar which uses shorter wavelengths than S-band radar has such features as emitting radio waves with high straight advancing property and directionality, and being capable of capturing the echo from an object.

Table 2-1: Classification of radio waves used by marine radars

レーダーの名称	周波数帯	波長帯
Sバンドレーダー	3GHz帯	10cm帯
（Cバンドレーダー）	（5GHz帯）	（5cm帯）
Xバンドレーダー	9GHz帯	3cm帯

Compared to X-band radar, S-band radar is more suitable for detecting ice at long range. By contrast, X-band radar which provides clearer ice images than S-band radar is more suitable for observing the ice conditions in detail.

Therefore, in waters where ice exists or is likely to exist, it is necessary to fully understand the respective features of radio wavelengths used for S-band and X-band radars, and to choose them properly according to the purpose, such as early detection of ice and grasp of ice conditions.

In addition to the purpose of grasping ice conditions, these radars must be used for detecting land or grasping the movement of passing vessels. It is also necessary to change the distance range (e.g. 6, 3, or 1.5 miles) or adjust the switching devices for gain, etc., in response to changes in visual conditions due to fog, etc. Even on the same Northern Sea Route, there is a difference in use of radar between open water where ice obviously does not exist, and sea ice areas, in how to change the distance range or adjust switching devices for gain, etc.

In other words, in order to ensure proper use of marine radar on the Northern Sea Route, it is necessary to use different radars in a more complicated manner than in general sea areas. In water where ice exists or is likely to exist as in the Northern Sea Route, it is advisable to always activate both S-band and X-band radars simultaneously, and to engage in both early detection of ice at long range, and observation of ice conditions around the ship.

Advice: Effectively use radar by fully understanding the features of each wavelength!

3.3 How to detect ice early

Generally, radar with larger transmission power, wider antenna opening area, higher receiver sensitivity, lower wave intensity reduction in the air, larger effective reflective area of objects, and higher antenna height, which is less affected by rain, snow or sea clutter, tends to have higher maximum detectable range.

With regard to early detection of ice, the same conditions as above apply in principle, though it is greatly affected by other conditions including rain, snow or sea clutter, size or shape of ice, and height of ice above sea level. It is a shortcut in detecting ice earlier to use two types of radar according to the climate or hydrographic conditions. For early detection of ice, radar with larger transmission power and higher antenna height is of advantage.

Advice: Radar with lower wave intensity reduction is advantageous for early detection of ice!

When radio waves emitted from radar hit an object and are reflected back to an antenna, the received power S (w) can be calculated using the following formula:

$$S = \left(\frac{PG}{4\pi R^2}\right) \times \left(\frac{\sigma}{4\pi R^2}\right) \times A = \frac{PG\sigma A}{\left(4\pi R^2\right)^2}$$

P: transmitted power(w), G: antenna gain, R: distance to an object (m), σ: effective reflective area of an object (m^2), A: effective opening area of antenna(m^2)

If the minimum received signal power which can be displayed on the radar screen is $Smin(w)$, the maximum detectable range $Rmax(m)$ can be calculated using the following formula. That is, it shows that the maximum detectable range is determined by the transmission power of the radar, the effective reflective distance of an object, and effective opening area of the antenna.

$$Rmax = \sqrt[4]{\frac{PG\sigma A}{(4\pi)^2 Smin}}$$

Moreover, if the antenna height of the radar is $h(m)$ and the height of an object is $H(m)$, the maximum detectable range $Rmax(m)$ can be calculated using the following formula. That is, it shows that the maximum detectable range is determined by the heights of the radar antenna and the object.

$$Rmax = 2.23\left(\sqrt{h}+\sqrt{H}\right)\times 1,852$$

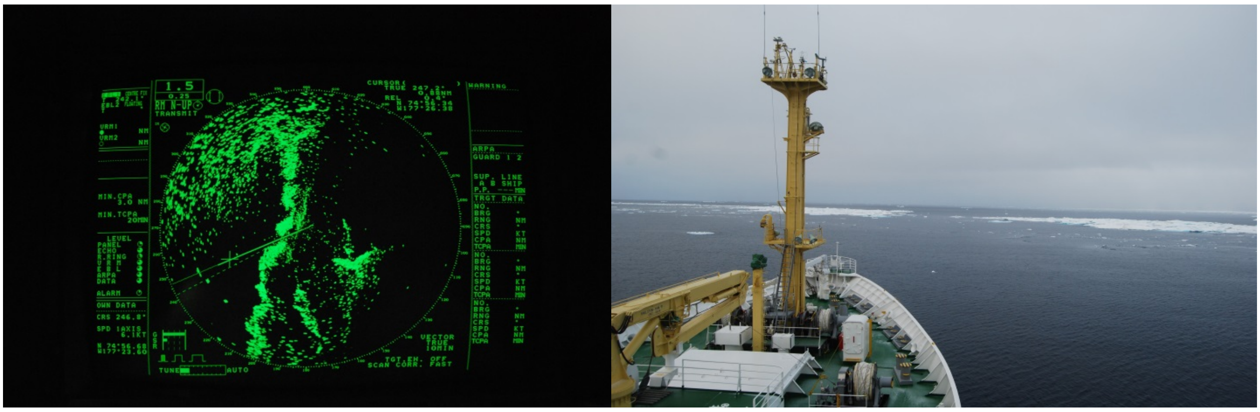
According to the first formula shown above, the maximum detectable range is proportional to the fourth root of the transmission power of the radar. Thus, in comparison to radar with 10-kilowatt transmission power, radar with 30-kilowatt transmission power is more capable of detecting ice early. According to the second formula shown above, the maximum detectable range is proportional to the square root of the antenna height. Thus, in comparison to radar with a 22-meter high antenna, radar with a 33-meter high antenna is more capable of detecting ice early.

However, the actual ice detection distance by marine radar is up to about 2-3 miles, and ice may not be detected 3-4 miles away or farther. Especially in the case of smooth-surface, plate-like ice or ice with insufficient height above sea level, early detection by radar is often difficult.

This is partly because ice floats with 90% of its volume under the surface and does not have sufficient height above sea level. It is also because smooth-surface, plate-like ice which has sufficient effective reflective area of radio waves has less reflection intensity than objects like iron ships. Particularly, snow piling up on the ice surface lowers the reflection intensity significantly.

In order to detect ice early by radar under such circumstances, it is necessary to contrive ways to operate radar equipment, such as change of distance range or adjustment of switching devices for gain, etc. It is also necessary to consider drastic measures, including installation of radar with high transmission power on a vessel navigating the Northern Sea Route.

Advice: Pay attention to ice with insufficient height above sea level!



Pic. 2-17: Radar image of ice and actual ice conditions (courtesy of Koji Shimada)

Attention should be paid to the fact that climatic impacts, such as rainfall, snowfall, fog and raging waves, sometimes make it difficult to detect ice, or that radar cannot always detect small ice cakes.

When navigating the Northern Sea Route, priority should be placed on lookouts with the naked eye without putting too much trust in radar just as with navigation in general sea areas. However, sometimes you have to depend on radar due to dense fog, storms, etc. It is important to increase experience in handling radar specific to sea ice areas, and to get accustomed to it as soon as possible.

3.4 How to grasp ice conditions

In order to precisely grasp the surrounding ice conditions, it is important to put a lookout in as high a place as possible. On the other hand, it is possible, to some extent, to grasp the ice conditions at long range using radar.

3.4.1 Grasp of ice concentration

Generally, radar tends to detect ice easily in waters with higher ice concentrations. When a sea ice area unanticipatedly far from your vessel is detected by radar, it is necessary to consider the possibility that ice concentration is high in the relevant sea area.

Even with high ice concentrations, when the height of ice above sea level is not sufficient or when ice is plate-shaped with a smooth surface, radio waves emitted from radar may rarely bounce back to your vessel. As a result, even in the case where a sea ice area with high ice concentrations is near at hand, you do not recognize it because it is invisible to radar, and you may confuse it with open water.

In calm waters, radar receives echoes from seabirds on the sea surface or a school of small fish, and you may mistakenly assume that an ice floe exists there. You must pay attention to that at any rate.

3.4.2 Impact of sea clutter, etc.

When navigating in sea ice areas, your vessel becomes insusceptible to the impact of sea clutter, etc., because the sea surface surrounded by ice is calm. Therefore, even though ice is plate-shaped with smooth surface, it is relatively easy to detect ice using radar if switching devices for gain, etc., are properly adjusted.

When your vessel is navigating open water areas, caution should be exercised because in some weather conditions ice edges in surrounding sea ice areas become obscure due to the impact of sea clutter, and it may be difficult to detect them by radar.

Sea ice areas with a certain degree of height and extent, where the reflection intensity of radio waves is strong, may appear like land on the radar screen more clearly than sea clutter in some weather conditions. Moving ice floes appearing on the radar screen may often be confused with sea clutter, so care must be taken.

When no sea clutter appears on the radar screen, you should understand that the surrounding sea surface is calm, and at the same time strongly suspect the existence of ice.

Advice: Suspect the existence of ice in calm sea where sea clutter is not reflected!

3.4.3 Grasp the existence of pressure ridges, etc.

As hummocks formed by the accumulation of ice blocks jostling with one another, or pressure ridges formed by a band of hummocks, are hard in most cases, you should always avoid them even when you have no choice but to navigate sea ice areas. Pressure ridges, etc., often reach a certain height above sea level and easily reflect radio waves emitted from radar, so it is relatively easy to detect them.

However, the radar images of pressure ridges, etc., closely resemble those of a kind of deformed ice formed by ice blocks overlapping with each other such as rafted ice. It is difficult to clearly identify them only by radar.

Advice: It is difficult to identify pressure ridges by radar!

Advice: Try to detect ice early using radar properly!

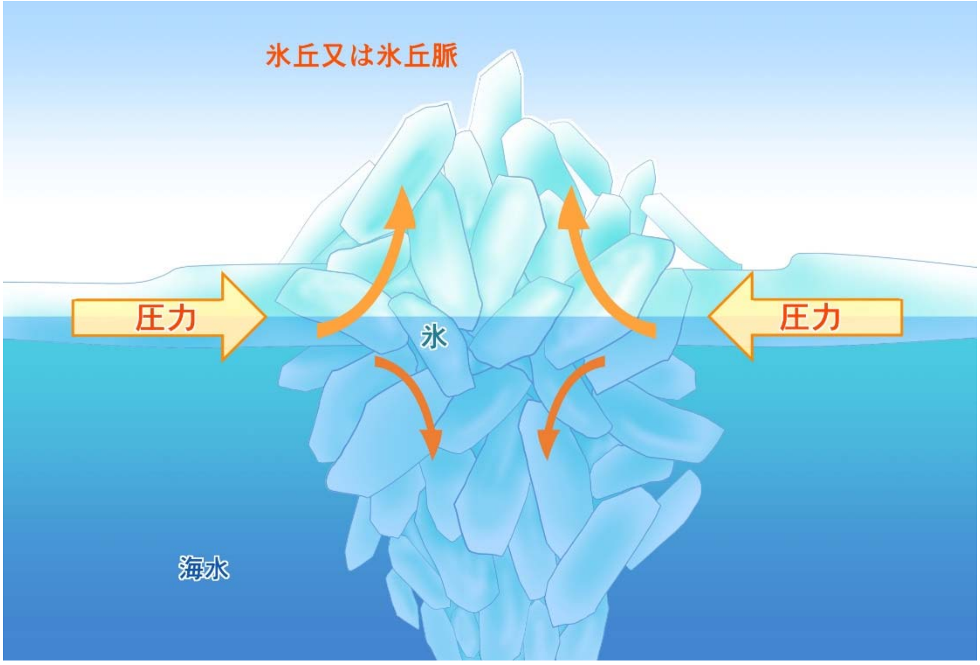


Fig. 2-2: Conceptual image of formation of a hummock or pressure ridge

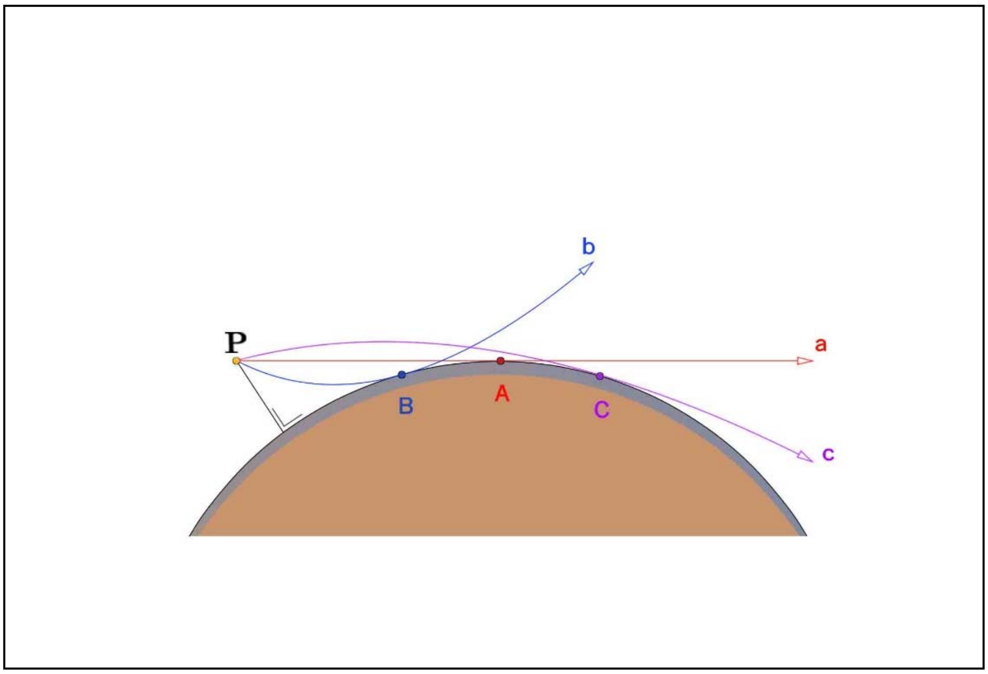


Fig. 2-3: Principle of sub-refraction

P: radar antenna of a vessel; a: abnormal propagation of radio waves going straight; b: abnormal propagation of radio waves bent upward into the sky; c: normal propagation of radio waves

3.4.4 Impact of sub-refraction

In polar regions like the Arctic Ocean, air conditions may sometimes differ from non-polar regions significantly. For example, the temperature fall rate increases drastically up in the air, or the relative humidity goes up as altitude increases. Under such circumstances, an abnormal radio wave propagation phenomenon called sub-refraction occurs as shown in Fig. 2-3, and radio waves emitted from radar go straight or are bent upward into the sky, resulting in a possible reduction in the maximum detectable range in the horizontal direction.

When sub-refraction occurs, detection of an iceberg, etc., by radar may be more difficult than detection of other objects. So, care must be taken.

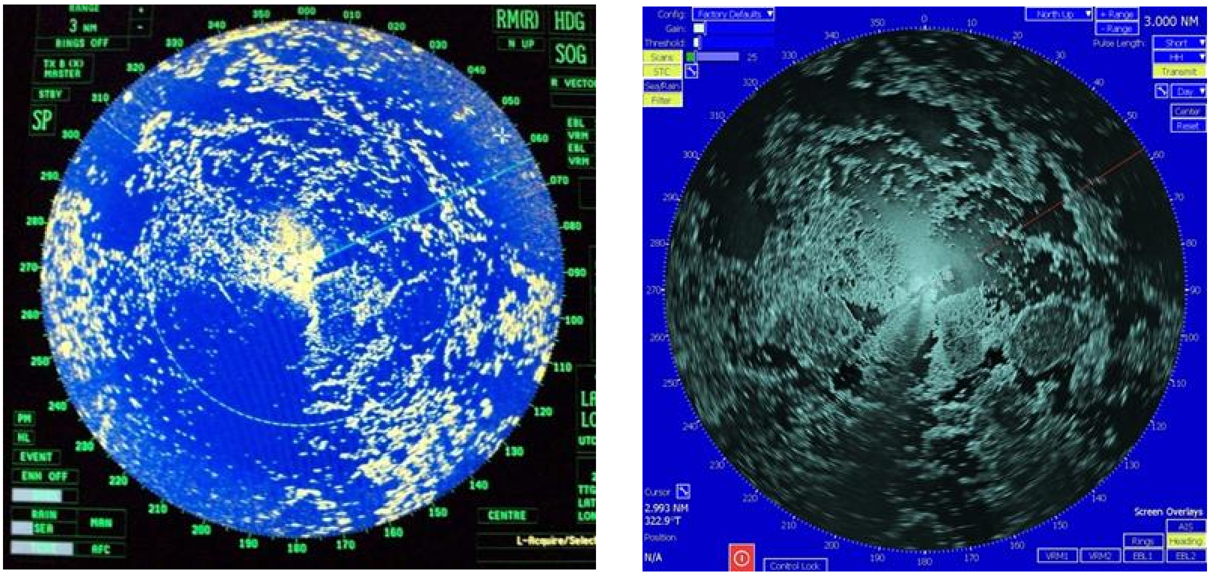
3.5 Sea-ice radar

In accordance with the Polar Code (international standards established by the IMO for the purpose of ensuring the safety of vessels navigating the Arctic and Antarctic Oceans, and environmental preservation of polar waters), vessels navigating polar waters, including the Northern Sea Route, are required to install devices that display ice location information. Sea-ice radar is an example of those devices.

Conventional type marine radar used in general sea areas is designed to identify land and grasp the movement of passing vessels. On the other hand, sea-ice radar is specially designed to produce more than a certain level of effects for early detection of ice and grasp of ice conditions.

Pic. 2-18: Example of processing equipment installation for sea ice (courtesy of Furuno Electric Co., Ltd.)

Generally, sea-ice radar takes out various signals, including a video signal, trigger signal and antenna rotation signal, from conventional X-band radar, converts those signals into a form that makes it easier to identify ice using special processing equipment, and displays its image on a dedicated screen. A new type of X-band radar, which is mounted with the above processing equipment, has also been developed.



Pic. 2-19: Images of conventional X-band radar (left) and enhanced X-band radar (right)

(Source: Canadian Coast Guard Website)

Sea-ice radar can provide a clear and real image of ice and can improve accuracy in grasping ice conditions, including making a distinction between open water and sea ice areas. According to the size or shape of ice, sea-ice radar can detect it at longer ranges compared to conventional-type radar. Sometimes, it is also possible for sea-ice radar to make a distinction between pressure ridges, leads, rafted ice, etc., though it is difficult for conventional type radar to do so.

Advice: Improve accuracy for grasping ice conditions by using sea-ice radar!

4. How to grasp ice conditions by type

Different types of ice have different characteristics according to visibility to the naked eye or radar image. Lookouts engaged in keeping watch in waters like the Northern Sea Route where ice exists or is likely to exist need to fully understand such characteristics. This section describes how to grasp ice conditions by type mainly from the perspective of ice-strengthened ships.

4.1 Icebergs

An iceberg is an ice gorge with a height of 5 meters or more above sea level, derived from glaciers resting on land or ice sheets called ice shelves anchoring to coastal areas or floating, which split off and flowed out on the sea. Icebergs are classified into several types, such as table-shaped, dome-shaped, wedge-shaped, pinnacle-shaped, and weathered. In addition, there are other types of icebergs, such as those drifting on the sea and those settled on the ocean floor.

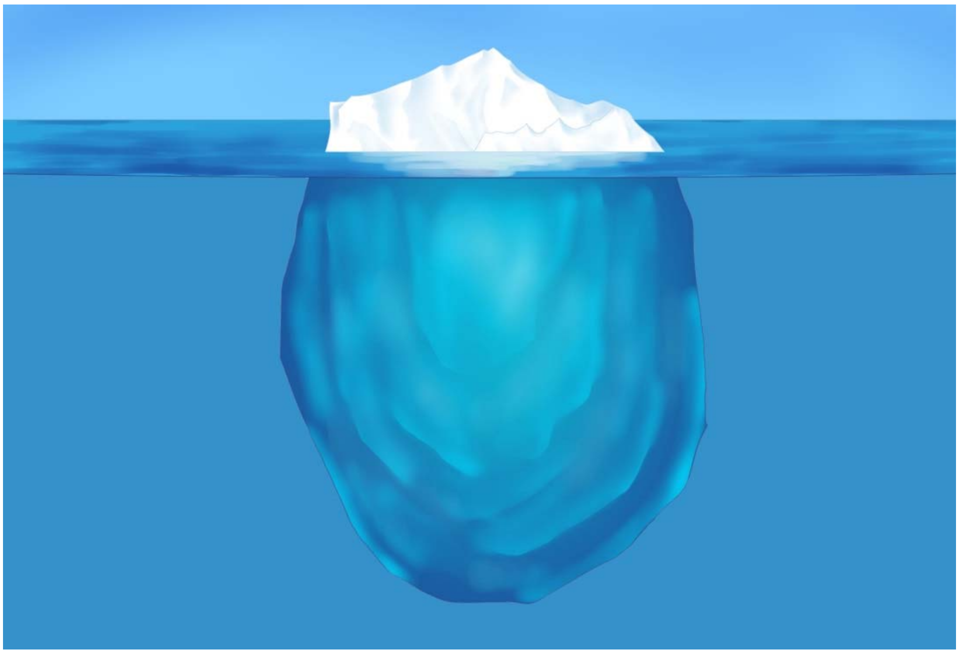


Fig. 2-4: Lateral transmissive image of an iceberg

Most icebergs seen in the northern hemisphere are ice gorges which split off from glaciers resting on land in Greenland and flowed out to the Atlantic Ocean. Therefore, ships rarely encounter icebergs near the Northern Sea Route along Russian coastal areas. However, in the case of navigation along Canadian coastal areas in North America, there is a potential for encountering icebergs in the Arctic Ocean off Greenland. For that reason, you should know how to detect them.

In the daytime with fine weather, icebergs, etc., protruding largely from the sea surface can be detected relatively easily by a lookout with the naked eye. Depending on their size or shape, icebergs strongly reflect radio waves emitted from radar, and appear on the radar screen as clearly as vessels, etc.

In contrast, in the case of icebergs protruding from the sea surface only slightly or having a smooth plate-like or snow-covered surface, it is sometimes difficult for a lookout to detect them early with the naked eye. In some cases, the radio wave reflection from icebergs is reduced and they may not appear clearly on the radar screen. When intense sea clutter occurs due to stormy weather or other causes, icebergs may not visibly appear on the radar screen.

In general, the detection range of ice by radar is 2-3 miles at maximum, and it often fails to detect ice from a distance of 3-4 miles or more. On the other hand, large icebergs can sometimes be detected easily depending on their size or shape, even when they are 4 miles or more away, or in some conditions more than a dozen miles away. However, because of the influence of rainfall, snowfall, fog, etc., it may become difficult to detect icebergs, so you should not rely on radar too much. In the case of a huge iceberg very close to a ship, even when it strongly reflects radio waves emitted from radar, it may appear smaller on the radar screen or may not be visible in some circumstances.

In waters where ice exists or is likely to exist, the existence of icebergs cannot be completely denied even when they are not detected by radar. Keep in mind that it is most important to rely on a lookout with the naked eye using binoculars and searchlights effectively for the detection of icebergs.

On the other hand, even when an iceberg is not detected directly by radar, its shadow may appear on the radar screen, because it blocks radio waves emitted from radar and sea clutter behind it disappears. Such a shadow gets bigger as your ship get closer to the iceberg. However, the location where it is visible or its shape may differ according to the relative position of your vessel and the iceberg, and may change as time proceeds. Early detection of such a shadow sometimes leads to early detection of an iceberg.

Pic. 2-20: Iceberg sedately drifting in open water (courtesy of Hiroki Shibata)

Advice: Do not miss the shadow of an iceberg not detected by radar!

4.2 Multi-year ice, etc.

Ice which has survived at least a single summer is called old ice, whose thickness sometimes reaches 2.5 to 3 meters. Old ice with a thickness of around 2.5 meters which has survived a single summer is called second-year ice, while old ice with a thickness of 3 meters or more which remains without melting for at least two summers is called multi-year ice.

Vessels rarely encounter icebergs on the Northern Sea Route along Russian coastal areas, but sometimes encounter multi-year ice that has grown to a small iceberg size. Generally, most ice that vessels encounter on the Northern Sea Route and the surrounding waters is one-year ice, whose thickness is usually about 2 meters in winter and 0.5 meters in summer. On the other hand, multi-year ice sometimes grows to 5 meters or more in thickness. Inadvertent collision with multi-year ice might cause severe damage to the body of your vessel. Even when no iceberg exists, you have to be careful when navigating waters where multi-year ice, etc., is likely to exist.

Multi-year ice, etc., protruding largely from the sea surface can be detected by a lookout with the naked eye in the daytime with fine weather. Depending on its size or shape, it strongly reflects radio waves emitted from radar, and may appear on the radar screen as objects which look very much like sea clutter, vessels or protruding rocks.

In contrast, in the case of multi-year ice, etc., protruding from the sea surface only slightly or having a smooth plate-like or snow-covered surface, it is sometimes difficult for a lookout to detect it early with the naked eye. In some cases, the radio wave reflection from multi-year ice, etc., is reduced, and it may not appear on the radar screen. When intense sea clutter occurs due to stormy weather or other causes or when radar is affected by rainfall, snowfall, fog, etc., multi-year ice, etc. may not visibly appear on the radar screen.

It is difficult to clearly distinguish between multi-year ice, etc., and one-year ice by using radar only. Regardless of whether detection by radar is possible or not, there is no choice but to make a final decision based on naked-eye detection by lookouts.

On the surface of multi-year ice, etc., there are many regularly-arrayed pools of water called puddles formed by melted ice due to a temperature rise in summer. The color tone of two-year ice is white on a snow-covered surface, and blue-green on a bare surface and puddles. On the surface of multi-year ice there are big and randomly-shaped puddles, and its color tone is white on a snow-covered surface, and blue on a bare surface and puddles. For thin ice like one-year ice, the color tone is white or gray/lead-white.

In sea ice areas, a lookout must keep watch with the naked eye from as high a place as possible to distinguish between multi-year ice, etc., and one-year ice by determining the difference in color tone and whether puddles exist. If a lookout watches from a bridge with an eye level of 22 meters, the distance within which the lookout can distinguish between multi-year ice, etc., and one-year ice is no more than 1 mile. However, if a lookout raises the eye level higher, the range of sight is expected to increase.

Advice: Radar cannot distinguish between one-year ice and multi-year ice!

Pic. 2-21: Puddles on the ice surface (courtesy of Koji Shimada)

Pic. 2-22: Two-year ice mixed in one-year ice (courtesy of Kazutaka Tateyama)

4.3 Fast ice

Ice anchoring to the coast, etc., is called fast ice. Fast ice is formed by freezing of seawater on the spot, or consolidation of ice floes drifting down to the seashore.

When fast ice is connected to land, it is difficult for a lookout to distinguish it by watching with the naked eye. Rather, it may be possible to clearly distinguish it on the radar screen by properly adjusting switching devices for gain, etc. It is important for crews to gain experience.

Pic. 2-23: Fast ice (courtesy of Seiji Shigehara)

Advice: Detect fast ice by adjusting radar switching devices!

4.4 Ice cakes

When getting close to sea ice areas, your ship may encounter ice cakes before reaching that area. When drifting ice cakes are found, sea ice areas are likely to exist not far from your vessel. As it is very difficult for radar to detect ice cakes, you have to depend mainly on a lookout who keeps watch with the naked eye. A large ice cake or a group of ice cakes can be potentially detected by radar.

Ice cakes drift mainly due to the influence of wind, so sea ice areas are likely to exist on their windward side. As shown in Fig. 2-5, when a group of ice cakes are detected by radar or a lookout with the naked eye, sea ice areas existing on the windward side can possibly be avoided by making a long detour toward the leeward side.

Advice: Sense sea ice areas by detecting ice cakes!

Pic. 2-24: A group of ice cakes appearing ahead on the open water surface

(courtesy of Hajime Yamaguchi)

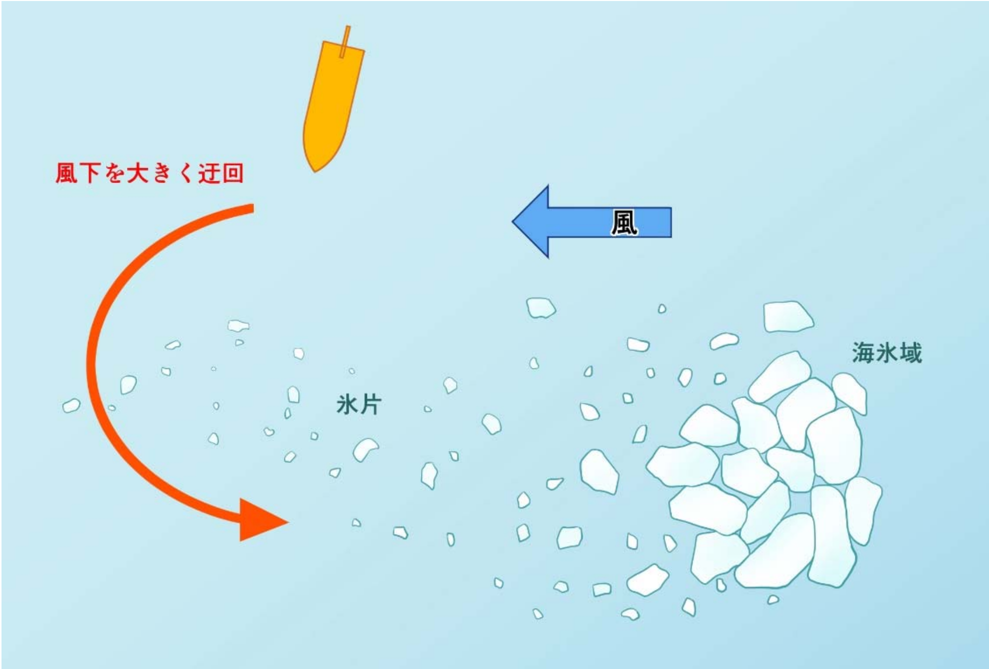


Fig. 2-5: Avoidance of sea ice areas by veering away to the leeward side of ice cakes

Pic. 2-25: Glacier pouring into ocean (courtesy of Hajime Yamaguchi)

Pic. 2-26: Icing on the bow (courtesy of Kazutaka Tateyama)

5. Points to remember under narrow visual field or other conditions

On the Northern Sea Route, fog occurs mainly in summer and often prevents a lookout from watching with the naked eye. In such waters as the Northern Sea Route where ice exists or is likely to exist, close attention needs to be paid with a narrow visual field to prevent collision with a vessel or running aground on a shoal, etc., just like in general sea areas, as well as to prevent collision with ice. When navigating during the night or in the darkness in such sea areas, it is necessary to take stricter measures against collision with ice than under bright light. This section describes the points to remember under narrow visual field or other conditions on the Northern Sea Route mainly from the perspective of ice-strengthened ships.

5.1 General points to remember

In general, with a narrow visual field, it is necessary to prevent collision with a vessel or running aground on a shoal, etc., while paying attention to maintaining a proper lookout at all times and proceeding at a safe speed in compliance with statutory navigation rules. In addition, attention must be paid to the following, which apply to the Northern Sea Route and are listed for confirmation.

5.1.1 Safe speed

In order to take appropriate and effective action to avoid collision with other vessels or to stop the vessel at a distance appropriate for the situation at the time, you must keep navigating your vessel at a safe speed at all times according to visual conditions.

5.1.2 Proper lookout

In order to properly determine the surrounding situation and the possibility of collision with other vessels, you must allow lookouts to keep watch properly at all times visually, auditorily, or by any other means appropriate for the situation at the time. You must also increase the number of lookouts as needed and put them in the right place.

You must ensure effective and proper use of nautical instruments and radio communication devices, including radar, automatic radar plotting aids (ARPA), automatic identification system (AIS), and international VHF.

To improve the accuracy of auditory detection by lookouts, you must minimize noise inside the vessel as much as possible.

5.1.3 Compliance with statutory navigation rules

With a narrow visual field, you must comply with the navigation rules stipulated in the "Convention on International Regulations for Preventing Collisions at Sea (COLREGS)" in 1972, and the "Act for Preventing Collisions at Sea" as follows.

- Always be ready to promptly handle the main engine.
- Give due consideration to the situation at the time and the visibility limit when changing course to avoid collision with vessels, etc.
- In the case of detecting the presence of any other vessel only by radar, determine whether your vessel will get very close to the detected vessel, or whether there is a possibility that your vessel collides with it.
- In the case of detecting the presence of any other vessel only by radar, as long as you think that your vessel will get very close to the detected vessel or there is a possibility that your vessel will collide with it, take

necessary action to avoid such a situation while there’s still enough time to do so.

- When changing course to avoid collision with a vessel detected only by radar, which is located anterior to your vessel, do not veer off to the left unless it is absolutely necessary (e.g., when trying to overtake the detected vessel).
- When changing course to avoid collision with a ship detected only by radar, which is located just beside of or posterior to your vessel, do not veer off in the direction of the detected vessel.
- In the case of hearing a fog signal of another vessel in an anterior direction, or in the case where it is impossible to avoid getting close to another vessel located anterior to your vessel, reduce speed to the minimum that allows you to hold your vessel on course, or stop it as needed, except when you have determined that there is no possibility that your vessel will collide with the other vessel.
- In the above case, keep navigating with great caution until there is no longer a risk of colliding with the other ship.
- Display lights and day shapes as regulated, or send out fog signals.

5.1.4 Voyage planning

Obtain and analyze the latest climate information to prepare a voyage plan with plenty of time to spare.

5.1.5 Navigational watch

When assuming the duties of navigational watch with a narrow visual field, keep the following in mind.

- While changing course to avoid collision with a vessel, etc., continuously monitor the movement of such a vessel, etc., until your vessel gets away from it, and confirm the effectiveness of that action.
- Never fail to check the ship position or to make soundings as appropriate.
- When feeling anxiety about the ship position, etc., make a detour to a safe sea area.
- Oblige bridge watch officers to inform the captain that the visual field has narrowed.

5.2 Additional points to remember in sea ice areas

On the Northern Sea Route, vessels may be forced to navigate with a narrow visual field due to fog occurring mainly in summer, as well as snow, sleet, freezing rain, Arctic haze (smog), etc. In winter (between the autumnal and vernal equinoxes) on the Northern Sea Route, days in which the sun never rises (polar nights) or days in which nighttime is much longer than daytime continue, so vessels may also be forced to navigate in the darkness for a long time.

When ice-strengthened ships navigate the Northern Sea Route with a narrow visual field, at night or in darkness (hereinafter referred to as “under narrow visual field or other conditions”), it is necessary to take account not only of the general points to remember mentioned above, but also the following additional points to remember in consideration of the environmental circumstances specific to the Arctic Ocean, including the need for prevention of collision with ice.

5.2.1 Principle of detour from sea ice areas

In principle, ice-strengthened ships must avoid entering sea ice areas without navigation aid from an icebreaker under narrow visual field or other conditions.

When deciding that the ice-strengthened ship is at risk of getting close to sea ice areas due to unavoidable reasons under narrow visual field or other conditions, try to make a detour from such sea ice areas and escape to a safe area as soon as possible, except in the case of receiving navigational aid such as navigation support from an icebreaker.

5.2.2 Slowdown/stop, etc., in sea ice areas

When getting close to sea ice areas due to unavoidable reasons under narrow visual field or other conditions, an ice-strengthened ship must slow down to the minimum speed at which it can continue on the course or stop, regardless of predicted ice conditions, including ice thickness and concentrations.

After slowing down or stopping the ice-strengthened ship because it gets close to sea ice areas due to unavoidable reasons under narrow visual field or other conditions, the type and scale of potential risks in the relevant sea ice areas must be promptly determined. Such risks must be properly determined using all information and means, and never increase speed or start until you feel certain that the decision is correct.

In sea ice areas where ice cakes are scattered under narrow visual field or other conditions, even when an ice-strengthened ship is navigating smoothly at a safe speed, the ship must be slowed down immediately whenever there is a possibility of worse ice conditions. Especially when there may be a possibility of multi-year ice, etc., do not think twice about stopping the vessel.

After the ice-strengthened ship reduces speed due to the possibility of worse ice conditions under narrow visual field or other conditions, the details and extent of these ice conditions must be carefully checked, and speed must never be increased until safety is ensured.

Pic. 2-27: Ice floes suddenly appearing in a narrow visual field due to fog (courtesy of Jin Saijo)

Advice: Immediately slow down when detecting worse ice conditions!

5.2.3 Effective use of searchlights

In accordance with the Polar Code, vessels navigating in polar waters including the Northern Sea Route are required to install remote-operated searchlights (horizontal full-rotation type) which can illuminate throughout a range of 360 degrees from the bridge. When an ice-strengthened ship navigates under narrow visual field or other conditions, lookouts must try to keep watch properly by using such searchlights effectively to detect obstacles such as ice, early. Points to remember for the use of searchlights are shown below.

- Keep in mind that the illumination range of a searchlight is limited.
- Note that searchlights are highly capable of detecting sparsely-scattered ice cakes or floes floating on a dark sea surface, but may have difficulty in detecting a change in ice conditions when the surrounding sea surface is covered with ice floes and looks stark white.
- Searchlights are essential to navigation in sea ice areas. Never fail to perform maintenance on them under normal circumstances in order to prevent occurrence of defects such as light reduction and remote control disabled state during use.
- When your vessel receives any navigation aid such as navigation support from an icebreaker, use searchlights illuminated from the back of the icebreaker as a guide to stay on its tail under narrow visual field or other conditions or in dim light.
- Even under narrow visual field or other conditions, the use of searchlights in the fog or during rainfall may often induce glare and actually impede detection of obstructions such as ice. Glare is a phenomenon in which you feel uncomfortable with any highly bright object within the visual field, or it becomes difficult to see or blinded by such objects.

5.2.4 Voyage planning reflecting ice conditions

In order to keep your ice-strengthened ship away from sea areas or sea ice areas where there is a risk of being placed in a narrow visual field, the latest climate information as well as ice condition information should be obtained and analyzed to prepare a voyage plan with plenty of time to spare.

In recent years, Arctic cyclones with intense rain and snow storms have often hit the Arctic Ocean in summer. You must bear in mind that accurate prediction of the occurrence of such cyclones is sometimes difficult.

5.2.5 Navigational watch considering the peculiarities of sea ice areas

When assuming the duties of navigational watch on board an ice-strengthened ship with a narrow visual field on the Northern Sea Route, lookouts must keep the following in mind.

- When detecting an image of what looks like ice only on the radar screen under narrow visual field or other conditions, prevent such an image from being lost by adjusting various switching devices for tuning, gain, STC, FTC, brightness, etc., as appropriate, so as not to lose sight of ice due to the influence of sea clutter, etc., and continue to catch radio waves by properly performing continuous radar plotting.
- When detecting an image of what looks like ice only on the radar screen under narrow visual field or other conditions, perform automatic tracking using automatic radar plotting aids (ARPA).
- Under narrow visual field or other conditions, always activate more than one radar unit concurrently. Use them differently according to the situation based on a full understanding of their respective characteristics due to differences in wavelength, etc., and properly switch the distance range. The aim is to detect ice early as far away as possible from it, and to observe ice conditions of the surrounding areas.
- Clear distinction between multi-year ice, etc., and one-year ice only by radar is difficult. When detecting an image of what looks like ice only on the radar screen under narrow visual field or other conditions, take action in view of the possibility that it may be multi-year ice, etc., unless a lookout confirms safety with the naked eye.
- Under narrow visual field or other conditions, when receiving any navigation aid such as navigation support from an icebreaker or being

part of a convoy (a group of vessels guided by an icebreaker, which navigate in a column), do your best to prevent collision accidents between those vessels from happening by properly ensuring close information exchange, steady communications, and continuous monitoring of the distance between vessels using nautical instruments such as radar.

6. Voyage planning and route selection, etc.

Navigation on the Northern Sea Route requires voyage planning and route selection considering the danger peculiar to the polar regions, including the existence of sea ice, low temperature and icing. On the Northern Sea Route, a special lookout to watch ice needs to be posted, and joint operations by several vessels, such as a convoy, are conducted when they are guided by an icebreaker. Therefore, it is necessary to form a bridge team differently from navigation in other sea areas, and to ensure complex communications among other vessels. This section describes the points to remember about voyage planning, route selection, navigational watch, etc., on the Northern Sea Route mainly from the perspective of ice-strengthened ships.

6.1 Voyage planning

With the aim of ensuring the optimal passage route for safe and economic ship operations, a voyage plan is prepared based on an overall assessment of all potential dangers posed during navigation, in view of climate and hydrographic conditions, impact of external forces, performance of your vessel, traffic environment, compliance with rules, existence of obstructions in fairways, etc. Normally, it should be prepared by the responsible navigation officer under the direction of the captain of a passing vessel, and should be submitted to the personnel in charge of the operating company after gaining final approval from the captain.

Aside from this, in the case of navigation on the Northern Sea Route along the Eurasian coastal region in Russia, it is necessary to apply to the NSRA for permission in accordance with Russian domestic laws. In view of the ice class of the applicant passing vessel and ice conditions, the NSRA may impose certain conditions for navigation permission, including navigational aid by an icebreaker. According to the navigation experience of the Northern Sea Route that the captain of the applicant passing vessel has, the NSRA may also impose the obligation to take an ice pilot on board. Applicant passing vessels cannot navigate on the Northern Sea Route unless they observe those conditions and obligations. As the NSRA or a service control station commissioned by the NSRA normally gives detailed directions, including the passage route, passing vessels must follow those directions.

In the case of the Northern Sea Route, unlike general sea areas, a voyage plan must be prepared based on the directions from the NSRA, etc., such as passage route. As a matter of course, with regard to the passage route, etc., directed by the NSRA, etc., the captain of the applicant passing vessel must precisely understand the purpose of the directions by voluntarily analyzing the ice and climate conditions.

Even when the passage route, etc., are decided under the direction of the NSRA, etc., the applicant passing vessel should assume final responsibility for preparing a voyage plan. The captain of the applicant passing vessel must prepare a voyage plan in line with the environmental conditions specific to the Northern Sea Route in accordance with the Polar Code established by the International Maritime Organization (IMO). In doing so, the captain must refer to the “IMO Guidelines for Voyage Planning”, and obtain information necessary for safe and economic ship operations from the information sources listed below to reflect such information in the voyage plan.

- Catalogue of Charts and Publications (Russian, British, Canadian and other versions)
- Charts (Russian, British, Canadian and other versions)
- Notices to Mariners (Russian, British, Canadian and other versions)
- Sailing Directions (“Admiralty Sailing Directions” in British version, etc.)

- List of Aids to Navigation (“Admiralty List of Lights and Fog Signals” in British version, etc.)
- List of Radio Signals (“Admiralty List of Radio Signals” in British version, etc.)
- Distance Tables (“Admiralty Distance Tables” in British version, etc.)
- Tide Tables (“Admiralty Tidal Publications” in British version, etc.)
- Navigational Warnings (Russian and other versions)
- Meteorological data (text data, current weather map, weather forecast map, numerical weather prediction map, satellite images, etc.)
- Hydrographic data (text data, wave chart, sea surface temperature map, tidal current map, current chart, satellite images, etc.)
- Sea-ice data (text data, ice chart, short- and mid-term prediction, satellite image, etc.)
- Other

6.2 Ice charts and Egg Codes

In the preparation of a voyage plan in sea ice areas, ice charts are one of the most important information sources. Generally, ice charts use egg-shaped symbols called Egg Codes developed by the World Meteorological Organization (WMO) as international standards. Egg codes consisting of numbers and symbols represent ice condition information, such as ice concentrations, developmental stages by ice thickness, and ice floe sizes by ice thickness in relevant sea areas. When preparing a voyage plan, it is necessary to understand how to read these Egg Codes and ice charts. Note that ice charts are expressed in an original manner without using Egg Codes in some countries.

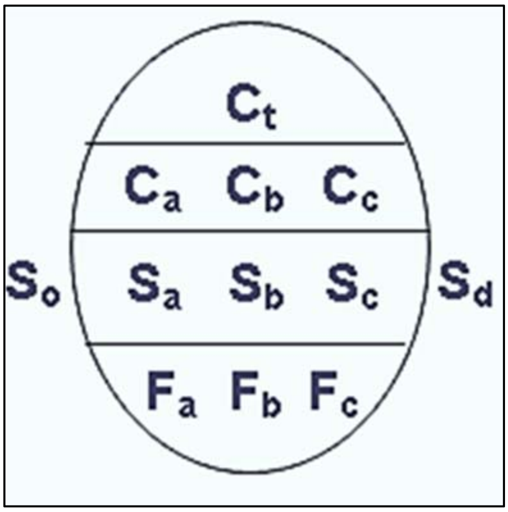


Fig. 2-6: Egg Codes

The symbol C_t in the first layer indicates the ice concentration in the relevant sea area as a whole.

The symbols in the second layer indicate the ice concentrations by thickness. Namely, C_a indicates the concentration of the thickest ice in the relevant sea area; C_b indicates that of the second thickest ice; and C_c indicates that of the third thickest ice. The numbers used in Egg Codes indicate ice concentration levels as shown in Table 2-2.

Table 2-2: Numbers used in Egg Codes (concentrations)

数字	0	1	2	3	4	5	6	7	8	9	9+	10
密接度	1/10未満	1/10	2/10	3/10	4/10	5/10	6/10	7/10	8/10	9/10	9/10~10/10	10/10

The symbols in the third layer indicate the developmental stages by ice thickness and the thickness itself. Namely, S_a indicates the developmental stage and thickness of the thickest ice in the relevant sea area; S_b indicates those of the second thickest ice; and S_c indicates those of the third thickest ice.

S_o indicates the developmental stage and thickness of thicker ice than S_a with a concentration of less than 1/10, while S_d indicates those of ice other than the above. The numbers used in Egg Codes indicate the developmental stages and thickness of ice as shown in Table 2-3.

Table 2-3: Numbers used in Egg Codes (developmental stages and thickness)

数字等	0	1	2	3	4	5	6	7	8	9	1.	4.	7.	8.	9.	▲.	X
発達段階及び厚さ	無氷海面	ニューアイス・新成氷	ニラス／10㎝未満	ヤングアイス／10～30㎝	グレーアイス／10～15㎝	グレーホワイトアイス／15～30㎝	一年氷／30㎝～200㎝	薄い一年氷／30～70㎝	薄い一年氷／30～50㎝	薄い一年氷／50～70㎝	並みの一年氷／70～120㎝	厚い一年氷／120㎝以上	古い氷	二年氷	多年氷	陸氷	不明

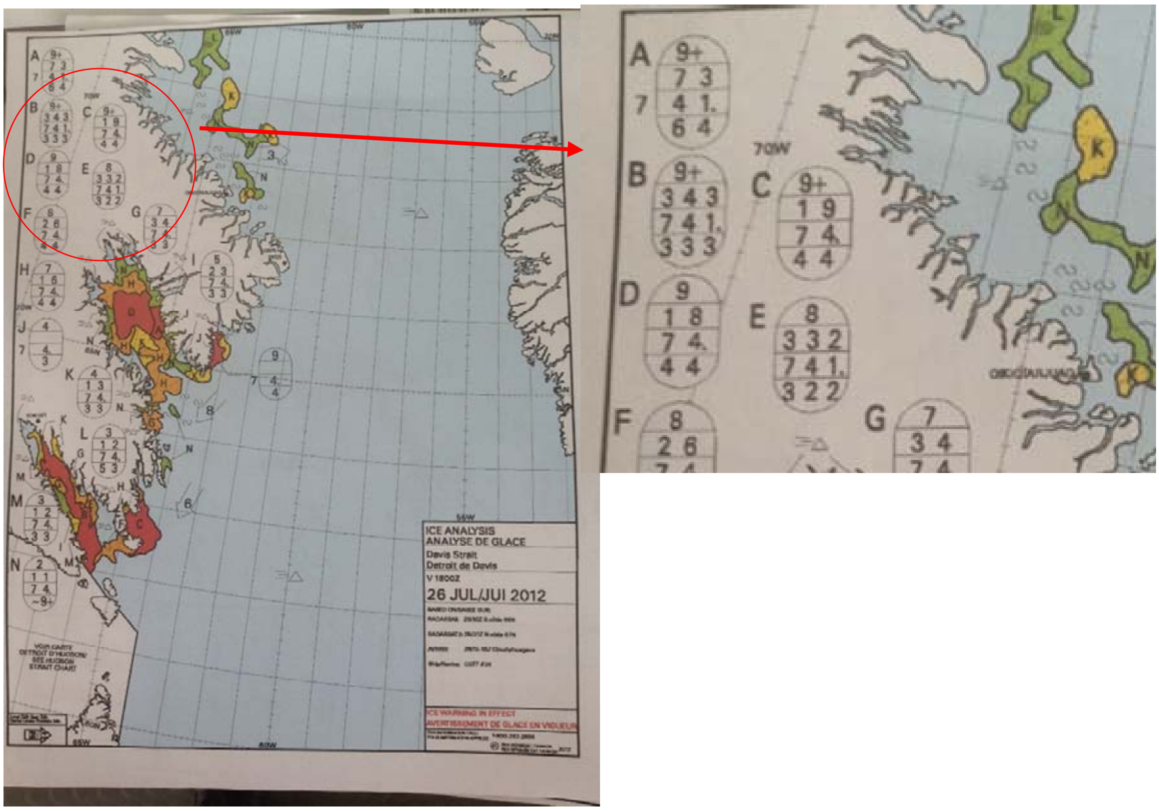
The symbols in the fourth layer indicate the size by ice thickness. Namely, F_a indicates the size of the thickest ice in the relevant sea area; F_b indicates that of the second thickest one; and F_c indicates that of the third thickest one. The numbers used in Egg Codes indicate the ice floe size as shown in Table 2-4.

Advice: Understand Egg Codes to make full use of ice charts!

Table2-4: Numbers used in Egg Codes (ice floe sizes)

数字等	0	1	2	3	4	5	6	7	8	9	X
氷盤の大きさ	パンケーキアイス／30～300cm	ブラッシュアイス・小板氷／200cm未満	板氷／2～20m	小氷盤／20～100m	中氷盤／100～500m	大氷盤／500m～2km	巨氷盤／2～10km	巨大氷盤／10km以上	定着氷	氷山	不明

Note that some countries may independently add information represented by Egg Codes.



Pic. 2-28: Canadian ice chart (courtesy of Hajime Yamaguchi)

6.3 Route selection, etc.

With regard to navigation on the Northern Sea Route, the NSRA designates two standard routes (northern and southern passages) based on empirical rules, but may instruct to take a mixed route combining these two passages according to ice conditions when passing in those areas (see page 17).

- Northern passage: A route from the Barents Sea, through waters on the north side of Severnaya Zemlya off the northeastern end of Novaya Zemlya, waters on the northern end of the Novosibirsk Islands (Tikhonov Route) and the De Long Strait, to the Bering Strait
- Southern passage: A route from the Barents Sea, through the Kara Gate Strait, the Vilkitskiy Strait, Sannikov Strait and the De Long Strait, to the Bering Strait
- Mixed route: A route combining the northern passage and the southern passage as appropriate

In general, a passing vessel navigating the Northern Sea Route along the Eurasian coastal region in Russia may receive instructions on the route, course, speed, etc., from the NSRA, a service control station commissioned by the NSRA, or an icebreaker which provides navigational aid such as guiding on the spot, in view of the surrounding circumstances. The passing vessel is required to fully understand the purpose of such instructions and to follow them. Vessels navigating along the Northern Sea Route should, regardless of whether they receive any instructions, observe the following rules for safe navigation.

- Select a course to avoid sea ice areas as much as possible in order to eliminate the risks of damage to the vessel body due to contact or collision with ice, or low visibility due to encounter with fog. Especially in view of frequent occurrence of fog near ice edges, or movement of ice caused by external forces, keep a sufficient distance from sea ice areas when detouring around them.

- Keep a safe offshore distance in view of draft, ship type, speed, whether it is day or night, visibility conditions, ice conditions, climate and hydrographic conditions, navigation experience on the Northern Sea Route, existence of shallows and sunken rocks, etc.
- When passing a strait, etc., set a clearance line after checking the depth of the course and surrounding areas, locations of shallows and sunken rocks, etc., on the navigational chart, and focus on ship handling that allows to stay away from those areas. As the navigational chart has a margin of error in distance, area or angle in high-latitude regions, it is recommended to set a clearance line based on the orientation of a stern mark or object.
- Confirm the points to remember about how to get close to a strait, etc., how to select a course, and how to pass through it by checking the sailing directions and other materials in advance.
- Maintain a safe and sufficient depth in consideration of draft, ship type, speed, tides, climate and hydrographic conditions, and reliability of water depth data.
- Avoid a course change at a large angle around a cape, etc., or shortcut as much as possible when navigating especially in sea areas where ice is likely to be present, sea areas whose water depth data are unreliable, or sea areas where unpredictable tides are likely to occur. When it is unavoidable, change course at a small angle several times.

- Keep a longer distance from shallows, sunken rocks, etc., when navigating especially in sea areas where ice is likely to be present, sea areas whose water depth data are unreliable, or sea areas where unpredictable tides are likely to occur.
- In sea areas whose water depth data are unreliable, be sure to activate an echo sounder to measure and check the water depth during navigation without placing too much trust in the navigational chart.
- To ensure safe and economic ship operations, you can use weather routing services (fare-paying services of a weather information company, which give passing vessels information on climate, hydrographic phenomenon and sea-ice, as well as advice about routes on which fuel consumption can be reduced or on which speed can be increased based on weather forecasts).
- With regard to instructions on route selection given by the NSRA etc., when an ice pilot is aboard, seek advice from the ice pilot.
- Keep in mind that navigation on the Northern Sea Route is a joint operation by a passing vessel, the NSRA, a service control station, an icebreaker, etc.

Advice: Keep sufficient distance from sea ice areas when detouring around them!

6.4 Navigational charts, sailing directions, etc.

The points to remember about navigational charts, sailing directions, etc., on the Northern Sea Route are described below.

6.4.1 Projection methods for navigational charts

Normally, the majority of navigational charts use the Mercator projection. It is also known as the cylindrical orthomorphic projection, and is designed to represent the spherical surface of the earth in a plan view. In other words, a plan view is created using a technique to put the globe into a cylinder and project the globe surface on the inside surface of the cylinder. In this process, only the equatorial area of the globe has contact with the cylinder, and the distance between the surfaces of the globe and the cylinder is longer as it gets closer to the polar regions. In a plan view, longitude lines are all parallel to each other at equal spaces, while spaces between latitude lines vertical to longitude lines get bigger and reach a maximum in the polar regions.

One of the big features of the Mercator projection is that you can draw a rhumb line, or a course to the destination, which connects the starting point and the arrival point by a straight line on the map, though it is not the shortest distance between the two points. For that reason, because of its high convenience in navigation, it was highly valued along with the popularization of the compass in Europe, and has been used broadly throughout the world as a standard projection method for navigational charts.

On the other hand, the Mercator projection in which the surface of a sphere is projected on a plane is characterized by the difference in length and area between the map and actual size, which is greater at higher latitudes and the greatest at the poles. As a result, the Mercator projection causes significant distortions and errors in distance, area or angle in high-latitude regions including the Northern Sea Route. Especially in the case of small-scale navigational charts that extensively cover sea areas surrounding the Northern Sea Route, it cannot be expected to obtain an accurate rhumb line.

In order to correct the distortions caused by the Mercator projection and reduce errors in distance, etc., if only by a little, the universal polar stereographic projection (UPS), which is a special projection method for the North and South Poles based on the plane orthogonal coordinate system, is commonly used for small-scale navigational charts of the areas surrounding the Northern Sea Route. In some cases, some other projection methods, including the polyconic projection in which several circular cones split along two longitude lines on the globe contact each other, and the Lambert conformal conic projection in which the axis of each cone overlaps at the North pole of the globe, may be used.

When using a navigational chart on the Northern Sea Route, you must confirm which projection method is used in that chart and choose the one whose scale size is as large as possible. Also, you must always keep in mind that any chart can always have more or less errors in distance, area or angle, and must give your full attention to them. Particularly with regard to preparation of a voyage plan, you must take safety measures, including keeping a longer distance from shallows, etc., than in general sea areas. Moreover, it is necessary to actually measure, at every opportunity, the direction or distance by cross bearing or radar, and to check it against the chart.

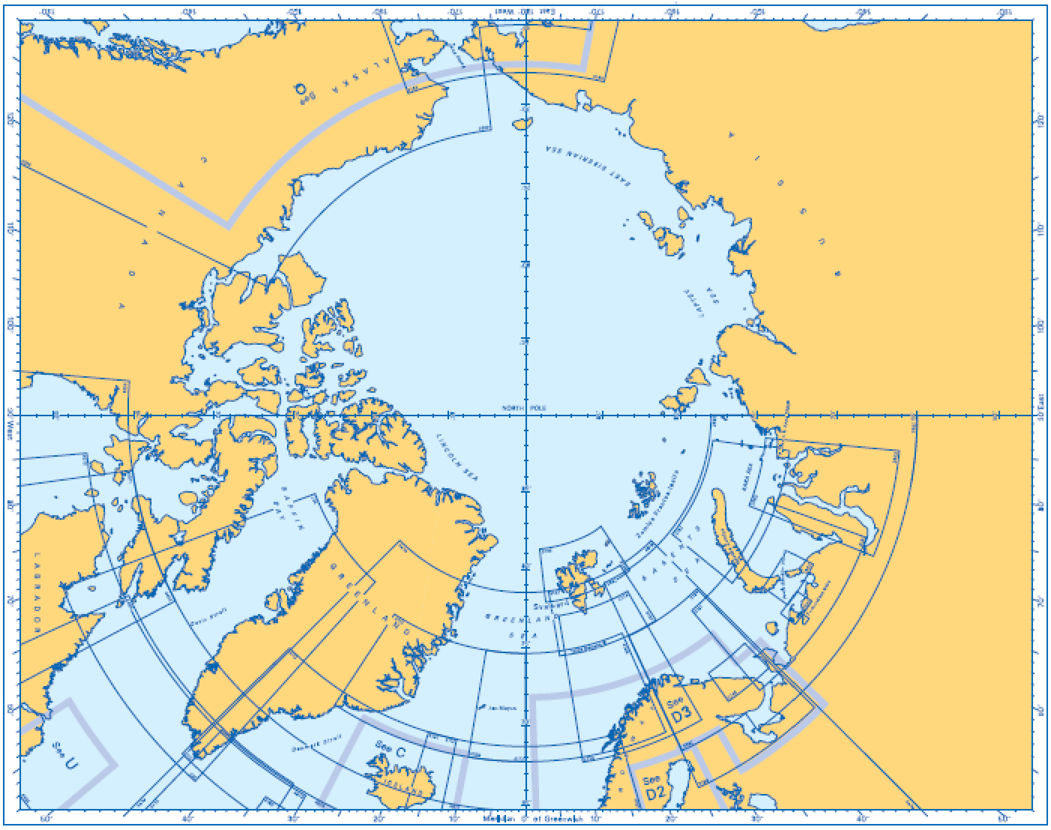


Fig. 2-7: Areas in the Arctic Ocean covered by the BA Chart (Source: Catalogue issued by the UK Hydrographic Office)

6.4.2 British Admiralty Chart

Navigational charts issued by the United Kingdom Hydrographic Office (UKHO) are commonly called BA Charts (British Admiralty Charts), with 3,000 or more editions distributed in print or electronic formats, and cover almost the whole world. BA Charts, which are trusted with a history of over 200 years and written in English, are used by many merchant vessels engaged in international navigation.

However, when it comes to the Northern Sea Route along Eurasian coastal regions in Russia, BA Charts cover only the areas around the Barents Sea and the central regions of the Kara Sea on the European side, and those around the Bering Strait on the Asian side.

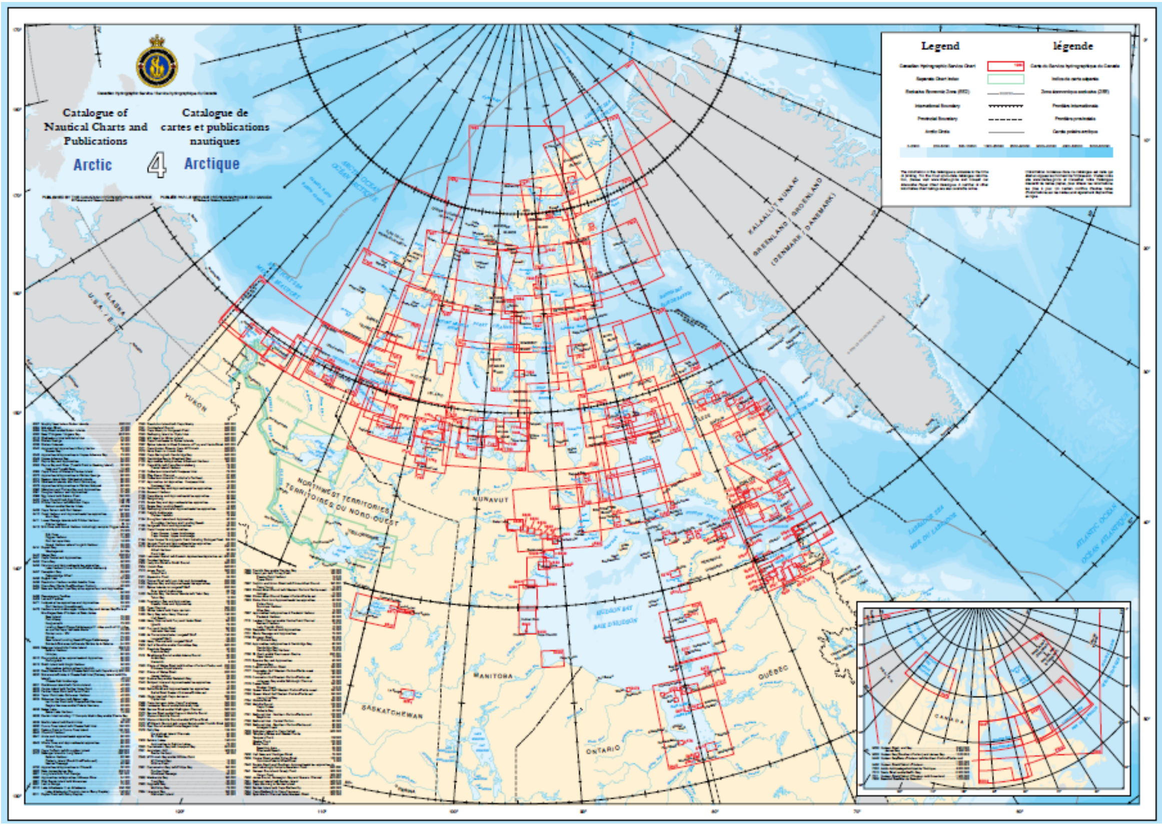


Fig. 2-8: Areas in the Arctic Ocean covered by a Canadian navigational chart (Source: Catalogue issued by the Canadian Hydrographic Service)

6.4.3 Canadian navigational charts

The Canadian Hydrographic Service (CHS) has a history of a hundred years or more, and has issued 900 or more editions of navigational charts in print or electronic formats. However, as for the Arctic Ocean, the charts cover only the areas along Canadian coastal areas, and do not cover the Northern Sea Route along the Eurasian coastal regions in Russia.

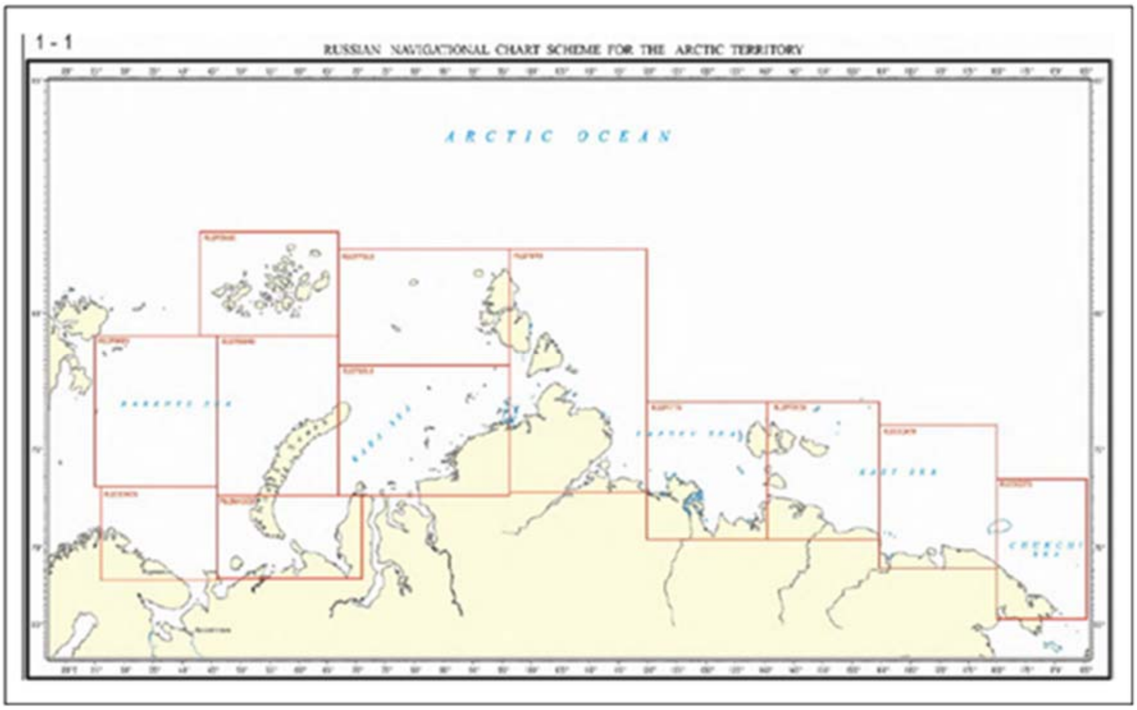
6.4.4 Russian navigational charts

The Hydrographic Service of the Russian Federation Navy is one of the agencies under the Department of Navigation and Oceanography of the Russian Federation of Ministry of Defense (DNO of the RF MD). Russian navigational charts issued by the Hydrographic Service have a history of about

130 years. More than 10,000 editions have been distributed in print or electronic formats, and they cover almost the whole world.

The Northern Sea Route along the Eurasian coastal regions in Russia and the surrounding areas are covered by about 980 editions in paper format and about 250 editions in electronic format as of 2011. For navigation on the Northern Sea Route, you need to obtain Russian navigational charts. However, many of them are basically written in Russian, and only a few of them are written in both Russian and English. Therefore, if those who are not good at Russian use them, it is necessary to take measures such as preparation of a translation glossary of Russian navigational chart terms.

Unlike BA Charts, there are only a few ways to obtain Russian navigational charts in Japan. If you need to obtain Russian navigational charts for the purpose of preparing a voyage plan, be sure to arrange to obtain them as early as possible.



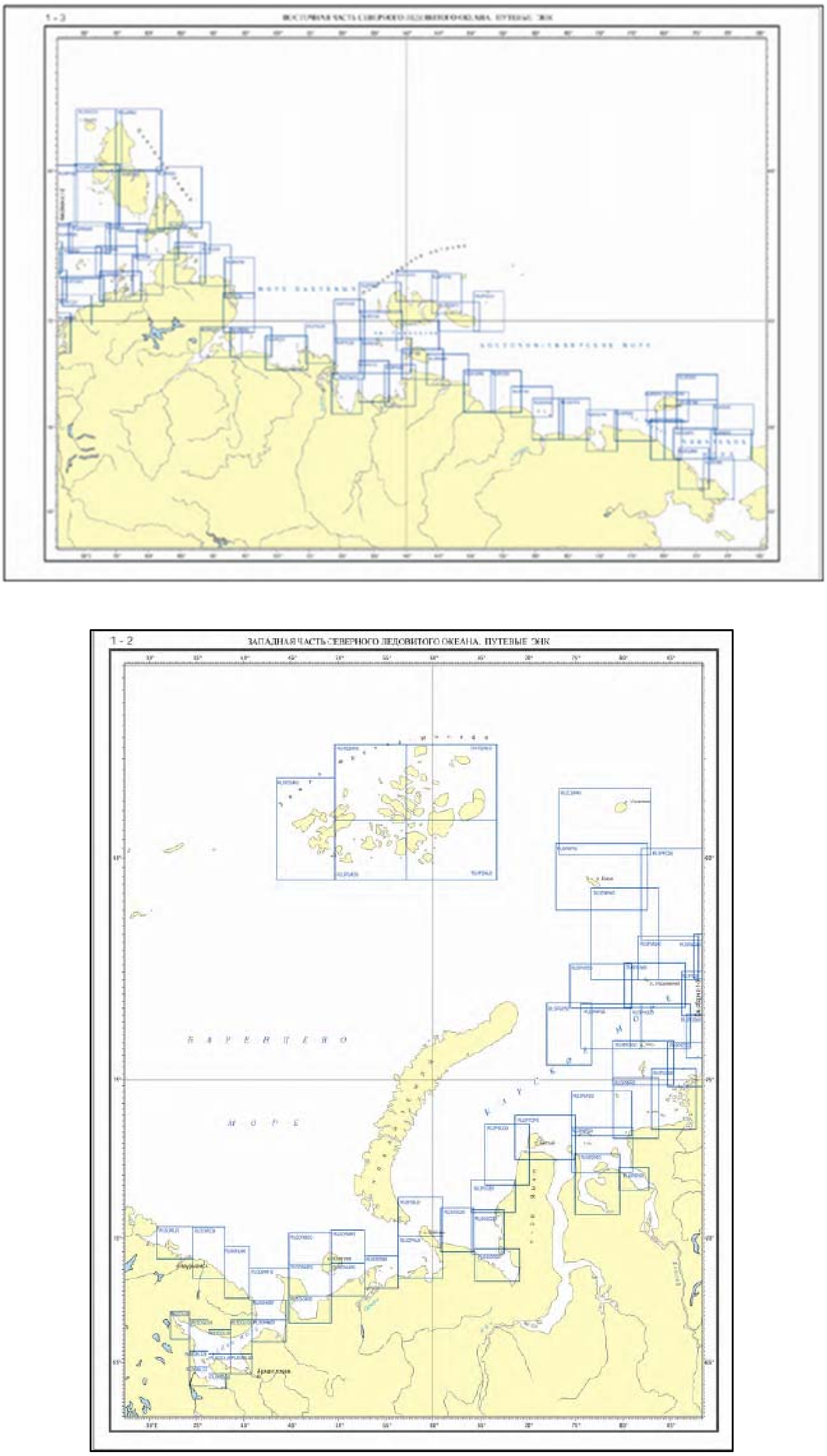


Fig. 2-9: Areas on the Northern Sea Route covered by Russian navigational charts

(Source: National Report of Hydrographic Service of the Russian Federation Navy 2011)

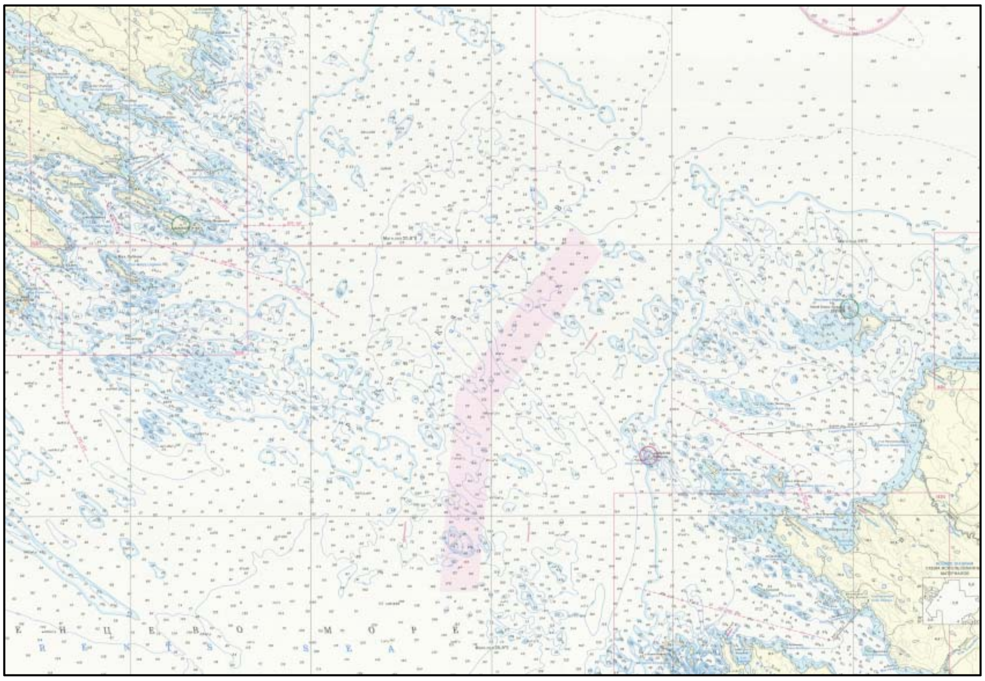


Fig. 2-10: Russian navigational chart image of the Kara Gate Strait

(Source: Proliv Karskiye Vorota: Kara Sea DNO of the RF MD)

Many Russian navigational charts of the Northern Sea Route and surrounding areas were created based on surveys conducted in the 1990s. In order to correct deficiencies in data on water depth, etc., re-surveys have been conducted at present. In sea areas whose water depth data are unreliable, be sure to activate an echo sounder to measure and check the water depth during navigation without placing too much trust in the navigational chart.

6.4.5 Sailing directions, etc.

When using navigational charts, check sailing directions to obtain more detailed information on the route. The sailing directions include various information such as climate and hydrographic conditions of each sea area, route conditions, course determining methods, geography, and facilities in coastal areas and ports.

The Admiralty Sailing Directions issued by the UK Hydrographic Office consisting of a total of 74 volumes cover the whole world, and are used by many merchant vessels engaged in international navigation. When navigating the Northern Sea Route along the Eurasian coastal region in Russia, it is advisable to prepare the following materials and use them in combination with navigational charts. These sailing directions include a Russian-English translation glossary of navigational chart terms.

- “NP10 Arctic Pilot”
- “NP23 Bering Sea and Strait Pilot”
- “NP72 Southern Barents Sea and Beloye More Pilot”

In addition, it may be useful to prepare the List of Aids to Navigation issued by the UK Hydrographic Office.

- “NP84 List of Lights and Fog Signals Volume L Northern Seas, Coast of Norway north of latitude 60deg. 55`N, Svalbard, the Faeroes, Iceland, Greenland and coast of Russia to Bering Strait”

6.5 Bridge team

On the Northern Sea Route, just as in other sea areas, it is necessary to form a bridge team suitable for the conditions of the moment and to engage them in keeping watch on the bridge to ensure safe navigation, in consideration of visibility conditions, traffic environment, impact of external forces, performance of your vessel, vessel type, ship handling ability, and health conditions of vessel operators, etc.

Meanwhile, when navigating the Northern Sea Route, there is a possibility of implementing the following special navigation practices that are not assumed in other sea areas.

- Detection and avoidance of ice

- Independent navigation in sea ice areas (such as weaving your way through a navigational channel at low speed)
- Staying on the tail of an icebreaker guiding in sea ice areas
- Staying on the tail of a convoy in sea ice areas (navigation in a column guided by an icebreaker)
- Navigation in sea ice areas guided by an icebreaker using a tow rope
- Other

Therefore, there may be a need to form a different bridge team from the one for other sea areas. In some cases, additional members should be assigned to the bridge team according to the difficulty level of navigation practices in order to avoid placing too much burden on some of the crew. Thus, it is necessary to form an appropriate bridge team to ensure safe operations by responding to changes in surrounding circumstances. Examples of members of a bridge team according to the difficulty level of navigation practices are shown below. Ice pilots are not included in team members.

[Level 1]

- Independent navigation in ice-free waters (with no possibility of ice): 1 navigation officer and 1 steersman
- Navigation guided by an icebreaker in ice-free waters (with no possibility of ice): 1 navigation officer and 1 steersman
- Independent navigation in ice-free waters (with a possibility of ice): 1 navigation officer, 1 steersman, and 1 deckhand (bridge lookout)
- Navigation guided by an icebreaker in ice-free waters (with a possibility of ice): 1 navigation officer, 1 steersman, and 1 deckhand (bridge lookout)

[Level 2]

- Independent navigation in ice-free waters (e.g., narrow channels with shallows, etc.): Captain, 1 navigation officer, 1 steersman, and 1 deckhand (bridge lookout)
- Navigation guided by an icebreaker in ice-free waters (e.g., narrow channels with shallows, etc.): Captain, 1 navigation officer, 1 steersman, and 1 deckhand (bridge lookout)
- Independent navigation in sea ice areas with low concentrations (the passing vessel weaves its way at low speed while looking for a navigable channel, etc.): Captain, 1 navigation officer, 1 steersman, and 1 deckhand (bridge lookout)
- Navigation guided by an icebreaker in sea ice areas with low concentrations (the icebreaker weaves its way at low speed while carrying out continuous-mode icebreaking or looking for a navigable channel, etc.): Captain, 1 navigation officer, 1 steersman, and 1 deckhand (bridge lookout)

[Level 3]

- Navigation guided by an icebreaker in sea ice areas with high concentrations (the icebreaker carries out continuous-mode icebreaking): Captain, 2 navigation officers, 1 steersman, 1 deckhand (bridge lookout), and 1 deckhand (stern lookout)
- Navigation guided by an icebreaker in sea ice areas with high concentrations (e.g., narrow channels with shallows, etc.): Captain, 2 navigation officers, 1 steersman, 1 deckhand (bridge lookout), and 1 deckhand (stern lookout)

[Level 4]

- Navigation guided by an icebreaker in sea ice areas with high concentrations (the icebreaker implements ramming): Captain, 2 navigation officers, 2 steersmen, 1 deckhand (bridge lookout), and 1 deckhand (stern lookout)

[Level 5]

- Navigation towed and guided by an icebreaker in sea ice areas with high concentrations (the icebreaker carries out continuous-mode icebreaking or ramming.): Captain, 2 navigation officers, 2 steersmen, 1 deckhand (bridge lookout), 1 deckhand (stem lookout), and 1 deckhand (bow lookout)

To ensure safe operations, it is necessary to enhance the qualification of bridge watch by raising the skill levels of not only individual members of a bridge team, but also the team as a whole in cooperation with each other. For that purpose, it is effective to hold a briefing for all members plus an ice pilot before starting bridge watch, to share information on various matters, including the voyage plan, lookout operating procedures, seamarks, and predictable climate and hydrographic conditions, and to clarify the division of roles with each other.

Navigation via the Northern Sea Route is a joint operation not only by the bridge team members of a passing vessel but also by many other people from the NSRA, service control stations, an icebreaker (and its operating company), etc. In the case of navigation in convoys, etc., it is necessary to ensure complex communication with other vessels. Communication means can be more complex because other languages such as Russian are used in addition to English. In order to prevent accidents caused by human error, always try to exchange accurate information and establish steady communication.

Chapter III: Practical Ship Handling on the Northern Sea Route

1. Basic principles

When navigating in a sea area, it is important to have knowledge of the kinds and extents of effects of external forces including the wind, waves and tides, and geographical features of the environment including shallows and narrow channels on the steering functions of ships. Having attained a grasp of these effects, appropriate adjustments to the course and speed and assured control of the hull are the basic principles of steering methods referred to as ship handling. One of the most important considerations to be aware of when ship handling on the Northern Sea Route, and one of these external forces, is the presence of ice, which can prove to be an obstacle to navigation equivalent to that posed by geographical features of the environment such as shallows or narrow channels. This chapter describes the basic principles as they apply to ship handling on the Northern Sea Route mainly from the perspective of ice-strengthened ships.

1.1 Principle of ice avoidance

Ice load from collisions or contact with ice has the following possible risks for ship handling of ice-strengthened ships.

- Contact with the hull increases hull resistance during navigation or changes of course.
- Collision with hull causes damage to the outer body, propeller, rudder, etc.
- Contact with propeller causes sudden torque increase (ice torque).
- Blocking of hull surroundings thwarts any ability to maneuver (beset). In worst cases ice compression crushes the hull.

The presence of ice is a significant danger for inexperienced vessel operators handling ice-strengthened ships on the Northern Sea Route. However, if a ship hull with capabilities above a certain level is assuredly handled while availing of navigation support such as guidance by icebreaker when necessary, a safe passage can be achieved, even with ice presence. Many successful passages of the Northern Sea Route by ice-strengthened ships are testament to this fact.

In general, the most important factor influencing a safe and successful voyage by an ice class ship in sea ice areas is the maintenance of optimum, unimpeded ship handling while avoiding, to the extent feasible, encounters with ice. For example, even icebreakers which have entered sea areas with severe ice conditions can have their free operation impeded after their hulls are overpowered by ice, and may be forced to proceed in the same direction in which the ice is moving. The handling of ice-strengthened ships in these kinds of conditions, with or without navigation support such as guidance by icebreaker, will require great labors and perseverance perhaps to an extent never before experienced. This should be avoided at all costs.

The fundamental principle in the ship handling of ice-strengthened ships on the Northern Sea Route is avoidance, to the greatest extent possible, the dangers of encounters, contact or collisions with ice. If a suitable route of circumvention is not found, and an ice-strengthened ship has entered a sea area with severe ice conditions, independently, it will be necessary to implement ship handling to allow a retreat to a safe area such as open water as soon as possible. However, in cases where you are directly confronted with dangerous circumstances such as compression accompanying becoming beset, a priority must be made of ship handling to retrace the navigated route and you should not hesitate to make a 180 degree turnaround. On the Northern Sea

Route, the important thing for ship handling is not “Make haste, and go round!” but “Make haste, and go back (turn around)”.

Pic. 3-1: Icebreaker research vessel navigating the Northern Sea Route

(courtesy of Koji Shimada)

Advice: Always ship-handle under the principle of “Make haste, and go back (turn around)!”

1.2 Principle of ship handling

Ship handling should always adhere to the following principles in cases where, for unavoidable reasons, an ice-strengthened ship is approaching, or has entered, sea ice areas on the Northern Sea Route.

1.2.1 Principle of guidance by icebreaker

When there is a risk that ice-strengthened ships are approaching or have entered sea ice areas, they should contact the NSRA or a service control station commissioned by the NSRA, and request and receive navigation support such as guidance by icebreaker as soon as possible.

Advice: If there is a chance you are entering a sea ice area, promptly request guidance by icebreaker!

1.2.2 Principle of complying with instructions and advice

When ice-strengthened ships are approaching or have entered sea ice areas, they should contact the NSRA or a service control station commissioned by the NSRA, or icebreakers, etc. to request navigation support in advance, and comply with any and all commands or instructions. Icebreaker or ice pilot advice should also sought and complied with.

1.2.3 Principle of engine preparation

When ice-strengthened ships are approaching or have entered sea ice areas, they should implement a test run in forward or reverse and confirm that they are ready to stop at any time, while initiating main engine standby.

Ice-strengthened ships having the diesel engine as the main engine for navigating in sea ice areas should reserve sufficient compressed air for activation in the air tank in advance.

Advice: Initiate main engine standby!

1.2.4 Principle of maintaining a safe speed

A safe speed should always be maintained when ship handling in sea ice areas.

Vessel collisions with thick or hard ice when navigating at an excessive speed invite the risk of severe hull damage. Always remember to adjust speeds with the safety awareness in accordance with ice conditions.

When the ice concentration in a sea ice area is low, or there are only thin or soft ice floes, there is a tendency to hurry ahead, and to heedlessly increase speed. Ice-strengthened ships must always remain vigilant even if the lead or channel, etc. is covered with brash ice.

1.2.5 Principle of vigilant lookout

When approaching or entering sea ice areas, you should ensure a lookout in a high position, and implement ship handling which reflects a thorough and accurate ongoing understanding of the surrounding ice conditions.

To prevent propeller or rudder damage from contact with ice floes, ship handling should be conducted with an astern lookout posted as necessary.

Advice: Ensure a lookout in a high position, and post an astern lookout!

1.2.6 Principle of avoiding ship handling at night

Ice-strengthened ships should avoid approaching or entering sea ice areas at night as much as possible.

If an ice-strengthened ship has unavoidably approached or entered a sea ice area at night, it should make effective use of searchlights or radar, etc. However ensure not to over-rely on these means.

1.2.7 Principle of responding to weather and related information

When approaching or entering sea ice areas, implement ship handling which reflects a grasp and analysis of the latest weather information and information on ice conditions.

With regards to information on ice conditions, you should at the very least ensure to have an understanding of the general features of ice conditions in the sea area on your course, as well as the position and conditions of the ice edge, and predicted ice condition changes for the forthcoming few days.

1.2.8 Principle of mastery of functions and ship handling capacities

Ice-strengthened ships approaching or entering sea ice areas should have a mastery of the functions and handling capacities of their own vessel.

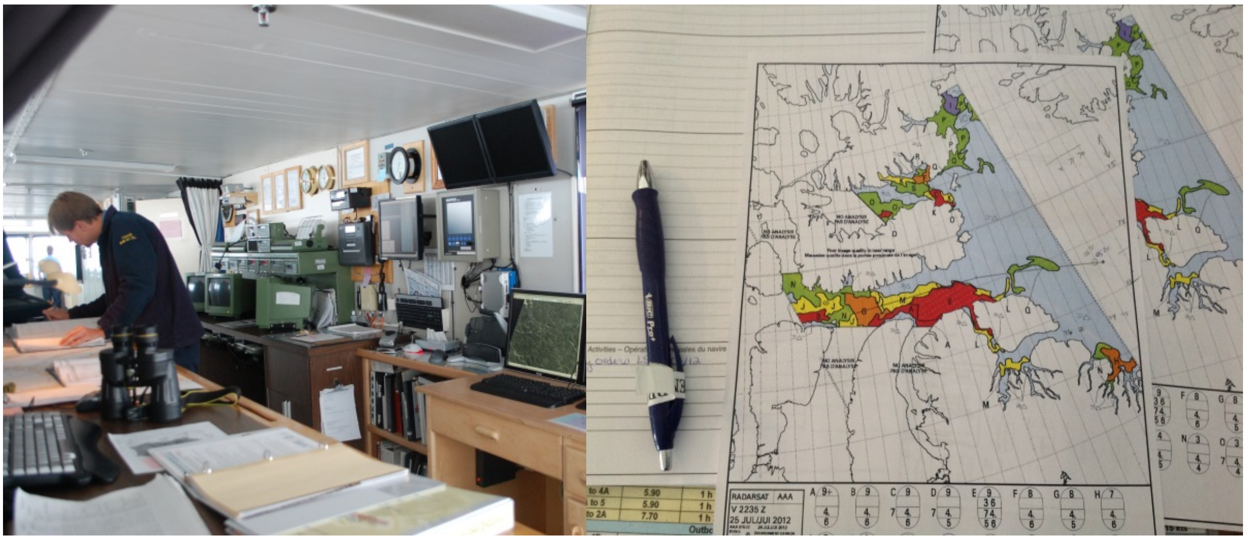
When there is a risk that a ship is approaching a sea ice area whose characteristics would exceed the functions and handling capacities of that vessel, support from an icebreaker should be requested as soon as possible.

When you are approaching or entering sea ice areas, be wary not only of the ice thickness but also the concentration and hardness. If ice floes are sufficiently thin for ice-strengthened capacity of a vessel, attention should be given to the possibility that the vessel will still be unable to deal with them depending on their thickness or hardness.

1.2.9 Principle of adjusting draft and trim

When approaching or entering sea ice areas, the draft should be made as deep as possible, and the trim of the stern should be adjusted to protect the propeller or rudder from damage due to contact with ice floes. However, an incline to the extent that the bow rises to break the surface will reduce maneuverability or render the underside of the bows vulnerable to ice floes, so this must be avoided.

Advice: Adjust the draft and trim to prevent damage from ice!



Pic. 3-2: Acquiring and analyzing information on ice conditions are basic ship handling means (courtesy of Kazutaka Tateyama and Hajime Yamaguchi)

1.2.10 Principle of avoiding ship handling against ice direction

An ice-strengthened ship in a sea ice area should not conduct ship handling which goes against the main movement of the ice as a whole. It is better to skillfully use that movement to enhance ship handling.

Advice: Never go against the ice!

1.2.11 Principle of maintaining appropriate bridge shift system

When ice-strengthened ships approach or enter sea ice areas, a bridge team (bridge shift system) appropriate to the ice conditions should be formed.

Additional members should be assigned to the bridge team according to the difficulty level of navigation practices in order to avoid placing too much burden on some of the crew. Thus, it is necessary to form an appropriate bridge shift system to ensure safe operations by responding to changes in surrounding circumstances.

Advice: Organize a bridge team appropriate to the conditions in the sea ice area!

1.2.12 Principle of countermeasures for chilled seawater

When navigating in sea ice areas, there is a risk that sherbet-like seawater or ice cakes will be taken in from the ship intake reservoir (sea chest) for secondary cooling of the main engine etc., located on the hull. Vigilance should be maintained that when these reach the freshwater cooler, they can clog the internal mechanisms and impede refrigeration, causing the main engine, etc. to overheat and necessitating emergency stops.

Advice: Countermeasures for chilled seawater in icebound seas are essential!

1.3 Principle of hull, equipment, and related systems, etc.

In sea ice areas, ship handling requires a variety of speedy and fine techniques, including maneuvering to skillfully use the movement of the ice as a whole; maneuvering to safely evacuate from sea ice areas by finding the weak point in ice and using that as a breakthrough; and ship handling to urgently avoid collision with ice floes. It is also necessary to minimize and prevent impacts on ship handling from contact with ice, low temperatures, and low seawater temperatures.

When ice-strengthened ships have unavoidably approached or entered sea ice areas, it is important to at least ensure that the following principles are sufficiently observed, with relation to the hull, equipment, and related systems, etc.

- Have special measures in accordance with vessel ice class, such as hull reinforcement to withstand ice load or a hull shape to lessen ice load
- Have the main engine and steering apparatus for swift and fine response to all instructions on ship handling.

- Have the main engine for which routine maintenance, inspections, cleaning are carried out to avoid combustion failures even at low load operation over long periods, and high quality fuels.
- Ensure that a foolproof communications system is in place for reliable communication with icebreakers or service control stations at all times.
- Ensure that preparations such as radar with correctly and accurately calibrated functions; fully-functional searchlight with no issues such as being dim or inoperable; hydraulic machinery which has been warmed up and operates smoothly; nautical instruments in prime condition, etc. are in place.
- Ensure that the draft and trim are appropriately adjusted by filling or positional adjustment of ballast water to protect the outer body, propeller, rudder etc., from damage due to contact with ice, and to ensure swift and sensitive ship handling.
- Have enough fuel, freshwater, boiler water, compressed air, food, and so on in place for long periods of ship handling and repeated stoppages of the main engine.
- Have the ship intake reservoir (sea chest) for cooling of the main engine switched from a high to a low position to prevent intake of sherbet-like seawater or ice cakes. Ensure a sea bay (a tank where chilled seawater is temporarily stored to thaw the ice cakes) and so on, with cleaned air vents is prepared.
- Have the sensor for the electromagnetic log, etc., mounted on the ship bottom stowed to prevent damage from contact with ice.
- Ensure that heating devices, heating cables, space heaters, etc. to prevent freezing and as low temperature countermeasures for tanks,

pipes, motors, windlass and crane, are checked for operation and prepared.

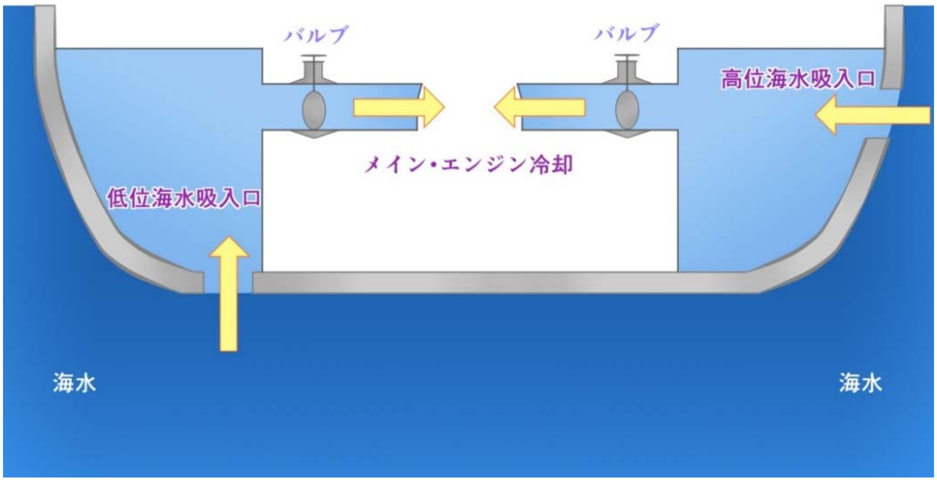


Fig. 3-1: Switching of seawater reservoir inlet

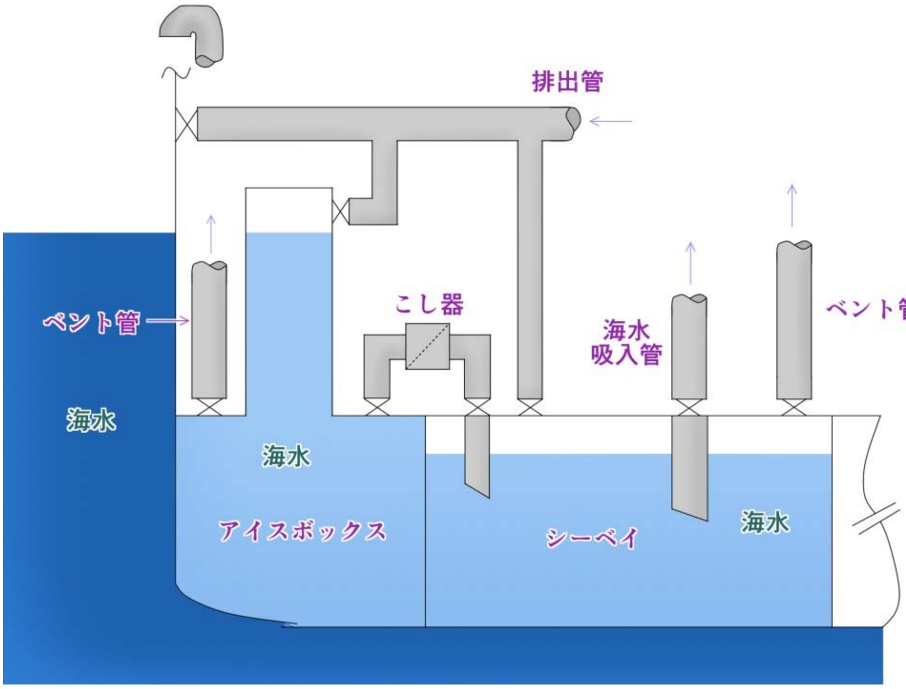


Fig. 3-2: Example of sea bay system

1.4 Natural phenomena to be considered

It is necessary to be vigilant not only to ice, but to the potential of being subject to the following natural phenomena when ship handling on the Northern

Sea Route. If for unavoidable reasons an ice-strengthened ship is approaching or entering a sea ice area, it should acquire and analyze the latest ice condition and weather information to understanding the impacts of natural phenomena on ship handling.

- Various effects of low temperatures and low sea ice temperatures or low humidity, etc. on the main engine and related instrumentation, steering apparatus, and so on.
- Visibility impacts, such as those caused by fog, snow, sleet, freezing rain, arctic haze (smog), and so on.
- Hull impacts such as those from strong winds, high waves, and so on.
- Effects of icing on hull or deck equipment, etc.
- Geomagnetic effects on nautical instruments, etc.
- Effects of magnetic field variations due to auroral storms on communication systems or nautical instruments.

Pic. 3-3: The aurora appears in the Arctic Ocean (courtesy of Koji Shimada)

Advice: Beware of auroral storm effects on nautical instruments!

Pic. 3-4: Ice condition survey by helicopter (courtesy of Hajime Yamaguchi)

Pic. 3-5: Giant tabular berg offshore of Canada (courtesy of Hajime Yamaguchi)

2. Countermeasures for vessel icing

When navigating in sea areas where there is the possibility of low temperatures, such as on the Northern Sea Route, when stormy weather is encountered and vessels are lashed by sea spray, this can sometimes adhere to the deck structures and be frozen in place. This phenomenon is called vessel icing. When large volumes of vessel icing occur, a vessel can become top-heavy and lose stability, with possible impacts on safe ship handling. For small fishing boats, the weight of the ice can cause vessels to lose stability in a short time, with the potential to cause a serious maritime accident such as an insurmountable list or vessel capsize.

To avoid vessel icing, adjust course and speed, and be vigilant in ship handling which mitigates the soaking of the ship by sea spray, the main cause of vessel icing, to the extent possible. Also, in unavoidable cases where vessel icing has occurred, it is necessary to implement de-icing operations before this becomes dangerous.

There is tendency to assume that vessel icing will not occur during the peak season for passages of the Northern Sea Route in summer, as temperatures around the route are around +5 °C to +10 °C. However, you cannot discount the possibility of vessel icing even in summer on the Northern Sea Route, as cold conditions with temperatures dropping below freezing are encountered, depending on the wind or wave conditions. Accordingly, countermeasures for vessel icing should be in place throughout the year on the Northern Sea Route. This section describes the countermeasures for vessel icing mainly from the perspective of ice-strengthened ships.

2.1 Occurrence mechanism

In normal circumstances, vessel icing occurs when a stormy weather is encountered and the ship is lashed by water droplets from sea wave spray, which adheres to the desk structures and freezes at low temperatures. The process which concludes in freezing is highly complicated, and will vary depending on factors such as the vessel cargo situation, the hull movement and the position and shape of the deck structure, in addition to the prevailing weather and hydrographic conditions in a given sea area.

Besides sea spray, vessel icing may also be caused by moisture adherence from fog, snow, sleet and rain. It may moreover be caused by freezing of dew condensation on the surface of the deck structures; or the freezing of puddles on the deck, or water which has accumulated in the oil pan installed under the moorage and anchorage equipment. If puddles, etc., on the deck freeze, there is a risk that these will merge with icing from sea spray and other water sources and be mutually accentuated.

It is said that vessel icing can be expected in low temperature sea areas, when prevailing temperatures drop below -2 °C and wind reaches Beaufort Scale 5 (equivalent to wind speeds of 17 to 21 knots: 8.0 to 10.7 m/s). In particular if both of these criteria occur simultaneously, the chance of vessel icing is extremely high. In brackish waters around the mouths of rivers or in rivers, vessel icing may arise even at higher temperatures and at times above zero.

As shown in Table 3-1, generally there is a possibility of light vessel icing around Beaufort Scale 5, medium vessel icing around Beaufort Scale 7 (equivalent to wind speeds of 28 to 33 knots: 13.9 to 17.1 m/s), and severe vessel icing in excess of Beaufort Scale 8 (equivalent to wind speeds of 34 to 40 knots: 17.2 to 20.7 m/s).

Table 3-1: Relationship between Beaufort Wind Scale levels and icing

風力階級	名称		相当風速		着氷状況
	和名	英名	ノット	m/s	
0	平穏	calm	0～1	0.0～0.2	
1	至軽風	light air	1～3	0.3～1.5	
2	軽風	light breeze	4～6	1.6～3.3	
3	軟風	gentle breeze	7～10	3.4～5.4	
4	和風	moderate breeze	11～16	5.5～7.9	
5	疾風	fresh breeze	17～21	8.0～10.7	軽度
6	雄風	strong breeze	22～27	10.8～13.8	〃
7	強風	near gale	28～33	13.9～17.1	中度
8	疾強風	gale	34～40	17.2～20.7	重度
9	大強風	strong gale	41～47	20.8～24.4	〃
10	全強風	storm	48～55	24.5～28.4	〃
11	暴風	violent storm	56～63	28.5～32.7	〃
12	颱風	hurricane	63以上	32.8以上	〃

In addition, as shown in Table 3-2, it is general said that vessel icing can easily progress within temperature ranges of -5 °C to -15 °C , and progress is most pronounced around -10 °C. Meanwhile, at temperatures below -16 °C, as sea spray can instantly freeze and fall on the vessel in the form of ice crystals, the progress of vessel icing is impeded.

This means that temperature conditions of around -10 °C, and wind conditions in excess of Beaufort Scale 6 (equivalent to wind speeds of 22 to 27 knots: 10.8 to 13.8 m/s), are most conducive to severe vessel icing. However, accurate prediction of the progress of vessel icing is extremely difficult.

Advice: Countermeasures for vessel icing must be taken throughout the year on the Northern Sea Route!

Table 3-2: Relationship between temperature and icing conditions

気温（℃）	着氷状況
-2未満	汽水域又は河川等では着氷の可能性あり
-2～-4	着氷の可能性あり
-5～-10	着氷が進行しやすい
-10前後	着氷がもっとも進行
-10～-15	着氷が進行しやすい
-16以下	着氷が進行しにくい

2.2 Sites of vessel icing

The sites of vessel icing from sea spray following encounters with stormy weather, etc. vary according to the prevailing relative relationships between the wind and waves or directions of swells and the ships course.

Generally, vessel icing becomes severe at the bows or sites located on the windward side. Also, vessel icing becomes most acute when the buffeting of wind and spray is received from the direction of the bow. Lateral wind and sea spray can subject the deck structures, etc. located on the windward to accelerated icing, potentially unbalancing both starboard and portside, with the risk of a lateral list. Generally, deck structures such as the following are most often subject to vessel icing.

- Deck superstructures (forecastle, bridge, crane house, winch table, winch platform, bulwark, hand rail, etc.)
- Decking/passageways (upper deck, flying passage, etc.)
- Mast (fore mast, radar mast, etc.)
- Anchorage and moorage equipment and installations (windlass, anchor, hawser, hawsepipe, winch, capstan, fairleader, chock, bitt, bollard, etc.)
- Loading equipment and installations (deck crane, derrick post, derrick boom, hatch cover, hatch board, hatch side coaming, hatch, side stanchion, tank dome, manifold, etc.)
- Loading and unloading rigging (cargo fall, topping lift, guy, block, tackle, etc.)

- Ventilation equipment (ventilator, etc.)
- Piping (cargo oil piping, seawater piping, freshwater piping, hydraulic piping, miscellaneous air vents, etc.)
- Deck cargo (containers, lumber, etc.)
- Other (ship light fittings, antenna, etc.)

2.3 Consideration for anchorage equipment

You should be aware that vessel icing has the potential to cause not only loss of stability and impediments to safe ship handling, but also malfunctions and impediments to the proper working order of instruments, devices and facilities which have undergone icing. Icing of anchorage equipment in particular, such as the windlass, can impede the normal completion of anchorage due to malfunction and cause maritime accidents.

Accordingly, it is necessary to carry out advance de-icing on the anchorage equipment such as the windlass particularly when ice-strengthened ships are navigating narrow channels, in preparation for the potential of emergency anchorage to avoid stranding accidents accompanying sudden blackouts.

The causes of malfunction of the anchorage equipment include, in addition to icing of the windlass, the hawsepipe or hawse locker penetrated by spray which then freezes, causing the hawser or locker to become blocked. Accordingly, in addition to de-icing operations on the body of the windlass itself, it is also necessary to periodically warm up the windlass and finely adjust the hawser to prevent clogging of the pipes and locker.

Advice: Vessel icing impedes safe ship handling!

2.4 General precautionary measures

In general, it is necessary to be vigilant in ship handling which will limit spraying to the ship to the extent possible, which is the main cause of vessel icing. As such you must appropriately adjust the course and speed of the ice-strengthened ship to limit exposure to sea spray. Specifically, reductions of speed and course changes to avoid spray from waves, reductions of speed and changes of course to limit the bow movement, and course change in the direction of calmer or warmer areas of the sea are required.

Sea ice areas are often milder than areas of open water even in times of stormy or unsettled conditions, due to the ice's sheltering effect from wind and calming effect on waves. Accordingly, it should be noted that when confronted with an emergency situation, it may be necessary to deliberately enter a sea ice area in order to avoid severe vessel icing.

Some countries on the coastline of the Arctic Ocean do however forecast and issue advisory weather alerts including the likelihood of sea spray which could lead to vessel icing. However, the presence and severity of vessel icing greatly vary according to the size, type, and so on, of a vessel, and vessel icing of a particular ship will not necessarily occur in line with weather forecasts. Meticulous care should be paid to relevant weather information, and awareness maintained that vessel icing may occur even if there are no advisory alerts if strong winds are predicted and the temperature may drop below -2 °C.

One potential idea is to use water repellent and heat-blocking fluoroplastics and silicone coatings, which have been developed to have both anti-icing and removal effects, in advance of passages in sea areas with low temperatures. Other than the above, it is necessary to take appropriate measures such as those below when vessel icing is expected.

- Place the movable equipment or other fixtures on the deck as well as fishing tools, etc. in storage below deck to the extent possible; or move and secure them in as low a position as possible on deck.
- Move the deck crane, derrick boom, etc. to the lowest part of the deck and secure them. Cover the equipment, fixtures, facilities, lifeboats, etc., on the deck, with sturdy water-resistant covers and secure them with rope.
- Ensure the scupper has been cleaned in advance to rapidly eliminate seawater which has splashed on deck.
- Remove the grating from the scupper in advance to facilitate elimination of any seawater which has fallen on deck.
- Move and secure any items which may cover the scupper and obstruct the draining of seawater from the deck.
- Ensure that the necessary locking devices for water-tight doors, portholes, etc. are secured.
- Fill empty ballast tank with water to the extent feasible in advance if there is room on the topside.
- Secure emergency wireless communication means for navigation support from icebreakers or search and rescue organizations in preparation for emergency situations.

When vessel icing is particularly severe, with de-icing operations compromised and further icing predicted to the extent that the worst-case scenario such as stability loss can happen, ice-strengthened ships must not hesitate to change course to evacuate to the nearest port, or chart a passage close to the coast.

2.5 Precautionary measures for ship lights, etc.

Ship lights such as navigation lights function as a heating element when lit, meaning that there is a relatively low chance of icing. However, lights such as the bow mast light can easily be exposed to sea spray, leading to icing and unusable if care is not taken to prevent this. It is preferable that the navigation lights, etc. are kept constantly lit when navigating in low temperature sea areas.

When ice-strengthened ships are navigating in low temperature sea areas, the wire antenna and the whip antenna, etc. should ideally be fitted with a protective sheet to prevent icing of the antennas.

For the radar, radiative effectiveness may be reduced by the blocking which accompanies icing of the antenna aperture, which could lead to impediments such as reduction in the maximum detection range. Icing of the antenna pedestal could lead to malfunctions such as an increase of the motor load. It is preferable that the antenna aperture and the antenna pedestal be fitted with appropriately deployed heaters in advance to ensure their continued functionality, as freezing prevention or low temperature measures. However, remember that failure in turning off the heater switch when temperatures are higher can result in outages from overheating.

2.6 De-icing operations

When icing of ice-strengthened ships has unavoidably occurred even when measures have been taken, it will be necessary to carry out de-icing operations as needed. Speedy de-icing is particularly necessary for smaller vessels, as the loss of stability from the weight of ice can in a short time lead to serious maritime accidents such as an insurmountable list or capsize. The shipmaster should issue orders to begin preparatory de-icing operations, based on the consideration to the size and type of the vessel, the weather and hydrographic conditions in the present location and the ship movements, as well as prediction to the greatest accuracy possible of the duration of stormy weather with potential icing and the speed of progression of icing.

The usual method of de-icing is to beat ice with a wooden, rubber or plastic mallet to knock the ice off, while using a hose to spray seawater. Although some ships have mechanical de-icing systems, their numbers are limited.

Outdoor work in low temperatures is extremely demanding, and during vessel icing the deck often freezes to resemble an ice-rink, meaning it carries the dangers of falls, falling into water, and so on. Foolproof preparations must be put in place, such as hanging a lifeline on the deck and wearing protective wear including hard hats, protective footwear and lifejackets as needed.

Pic. 3-6: De-icing operations (courtesy of 1st Regional Coast Guard Headquarters)

3. Ship handling during independent passages

Basic principles for ice-strengthened ships on the Northern Sea Route are to navigate mainly in open waters and avoid encounters with ice to the extent possible. When approaching or entering sea ice areas, it is preferable to avail of navigation support such as guidance by icebreaker even if the vessel is reinforced and has ice class. This is because, once they have inadvertently entered sea areas with severe ice independently, in worst cases the vessels may be ruled by ice, without further control over the situation.

However, the chance remains that ice-strengthened ships navigating on the Northern Sea Route will inadvertently find themselves having entered areas of sea ice, when they are unable to find a suitable route of circumnavigation, or are not in time to avail of navigation support such as guidance by icebreaker. In these circumstances, ice-strengthened ships will be obliged to navigate independently in areas of sea ice while they are waiting for the arrival of the icebreaker or retreating to safe sea areas such as open water. In such cases, ice-strengthened ships will need to carry out ship handling with heed to the following points.

3.1 Basic principles

It is said that most ice-strengthened ships at ice concentration of 6/10 (0.6) or less can complete independent passages without availing of navigation support through guidance by icebreakers, etc. by carefully beating through a navigable lead at a low speed while receiving instructions from the NSRA or a service control station commissioned by the NSRA or ice pilots.

In addition, even if the ice concentration is from 6/10 (0.6) to 7/10 (0.7), independent navigation without navigation support such as guidance by icebreakers may be possible. However, particular minimum criteria should be in place, such as being under instruction from service control stations or ice pilots; carefully beating a navigable lead at a low speed; and that ice is comparatively thin and soft first-year ice, etc.

There is a high chance that ships which are not ice-strengthened and do not have ice class, will lose freedom of maneuver with comparative ease and find themselves completely unable to move if they are surrounded by high ice concentration, regardless of the thickness or hardness of the ice. The basic principles of ship handling for independent passages by ice-strengthened ships are described below.

Pic. 3-7: Fisheries research vessel immobile, with forward direction impassable from high ice concentration (courtesy of Hiroki Shibata)

Advice: Beware that non-ice-strengthened ships can easily fall into a beset!

3.1.1 Entering sea ice areas

Ice-strengthened ships should pay heed to the following points when entering sea ice areas.

- When entering sea ice areas, you may be able to discover a navigable lead if you navigate along the ice edge (the boundary of sea ice territory with open waters). However, pay due heed that fog can easily occur in these vicinities, in addition to the risk of collisions with ice floes around the ice edge.
- When entering sea ice areas, use areas with the lowest ice concentration you can find as a breach (suitable entrance point).
- Find a breach by approaching the ice edge from the windward side of the ice when entering sea ice areas as illustrated in Fig. 3-3. This is because when the ice edge is approached from the windward side, both the shape of the ice edge boundary and the boundary with open water are clear. Meanwhile, the ice edge is indistinct and the boundary with open water is also unclear, rendering it difficult to enter sea ice areas if the ice edge is approached from the leeward side, as illustrated in Fig. 3-4. Pay due heed that while indications of ice such as ice cakes are often evident when the ice edge is approached from the leeward side, there are no such indications and ice often unexpectedly appears when the ice edge is approached from the windward side.

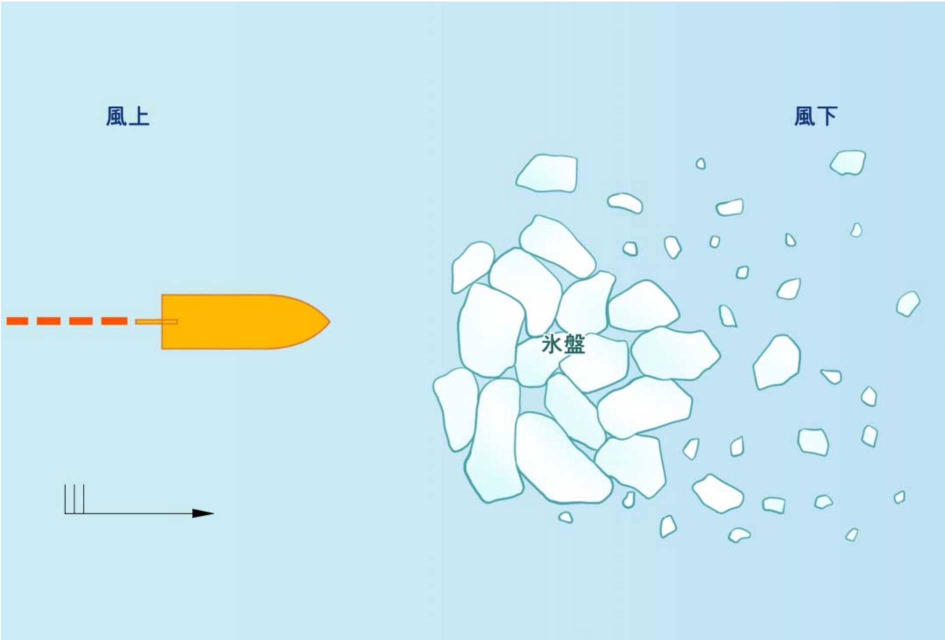


Fig. 3-3: Windward side approach of the ice edge

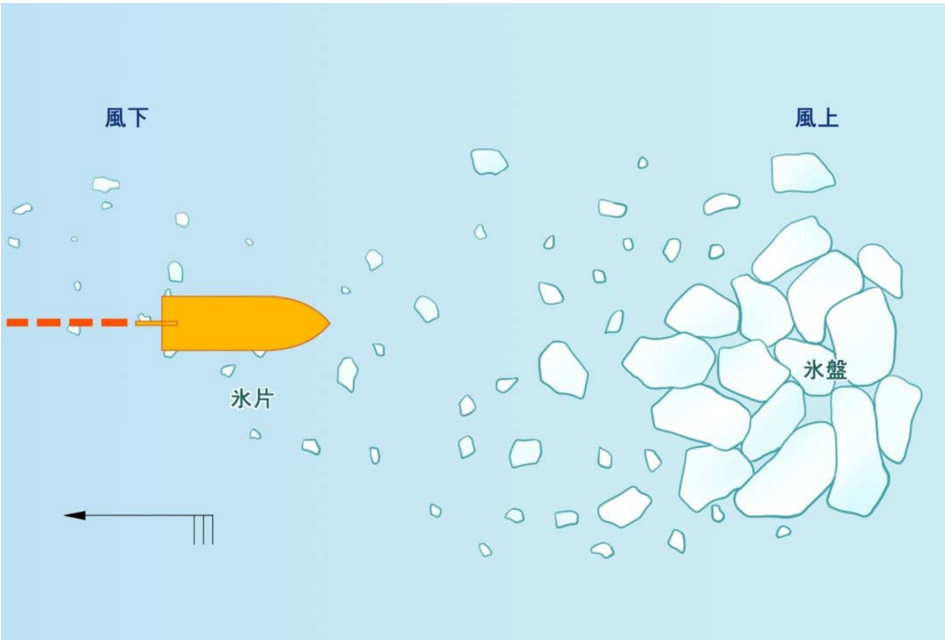


Fig. 3-4: Leeward side approach of the ice edge

- Fractures, etc. which can serve as potential entrances to leads in sea ice areas are often multiple rather than singular. Select the most suitable fracture as a passageway from the several candidates available when entering sea ice areas.

- You should remain aware that even if you have discovered fractures, etc. as potential entrances to leads in sea ice areas, temporal changes in the positional relationships of the various ice formations mean that such leads may imperceptibly disappear.

Pic. 3-8: Lead opened by an icebreaker (courtesy of Koji Shimada)

3.1.2 Safe speed

Ice-strengthened ships should always ensure to maintain a safe speed in accordance with ice conditions, ship capacities and steering performance when they have entered sea ice areas.

3.1.3 Selection of a passageway

Awareness should be maintained by ice-strengthened ships which have entered sea ice areas that instructions and recommended passageways issued by the NSRA or a service control station commissioned by the NSRA are the most suitable based on the latest weather information and ice conditions. In principle, vessels should navigate in accordance with the indicated route when approaching or entering sea ice areas.

Ice-strengthened ships entering sea ice areas should also post a lookout at a high vantage point, find a lead through sea ice areas with low ice concentration or relatively thin and soft ice, and beat a route in a zig-zag pattern aiming for safe sea areas such as open waters.

3.1.4 Decisions on hardness or thickness of ice

Ice-strengthened ships should pay heed to the following points when making decisions on the hardness or thickness of ice.

- When approaching or entering sea ice areas, monitor the color, shape, etc. of the ice to appropriately judge the ice thickness or hardness, and reflect this in ship handling.
- As shown in Fig. 3-3, thin ice floes such as first-year ice are generally white, grey or off-white in color, while multi-year ice such as second-year ice generally appears blue or aquamarine. Brash ice made up of small ice cakes of less than 2 meters in diameter and dirty ice which has drifted ashore to the coast are brown or grayish black. There may in addition be icebergs or bergy bits which appear a transparent blue.
- Vessel operators must avoid over-reliance on their own experience when making decisions on the thickness or hardness of ice. If there is the slightest doubt, err on the side of caution and presume that ice is harder or thicker than it appears.
- Try to avoid approaching sea ice areas which have washed down to the leeward side as much as possible, as these are often made up of ice formations which have overlapped and hardened.

Table 3-3: Approximation of ice types and their colors

氷の種類	色調
氷山、氷山片等	明瞭な空色等
二年氷、多年氷等	青色もしくは緑青色
一年氷	白色又は灰色・鉛白色
ブラッシュアイス、海岸に漂着した汚れた氷等	褐色又は黒灰色

- Try to avoid approaching hummocks caused by separate bodies of ice pushed against and overlapping with each other, or ridges along the swells of hummocks, as these are often hard.

3.1.5 Ice movement

Ice-strengthened ships should take note of the following points with regards to ice movement.

- All floes in sea ice areas are in a constant state of movement under the influence of external forces (currents and wind). Carefully decide on whether a given sea ice area will tend towards opening up or closing based on precise and continuous plotting and a solid understanding of the direction and speed of ice movement.
- As shown in Fig. 3-5, the movement of large bodies of ice such as icebergs is generally easily influenced by sea currents. Maintain awareness of the direction and speed of sea currents when maneuvering in their vicinity.
- As shown in Fig. 3-5, the movement of small bodies of ice is generally easily influenced by the wind. Maintain awareness of the direction and speed of wind when maneuvering in their vicinity. However, caution should be maintained that multi-year ice, etc. which has grown to the

level of an iceberg, may move like iceberg, such as moving upwind or cutting across prevailing wind directions and moving in the same direction as currents.

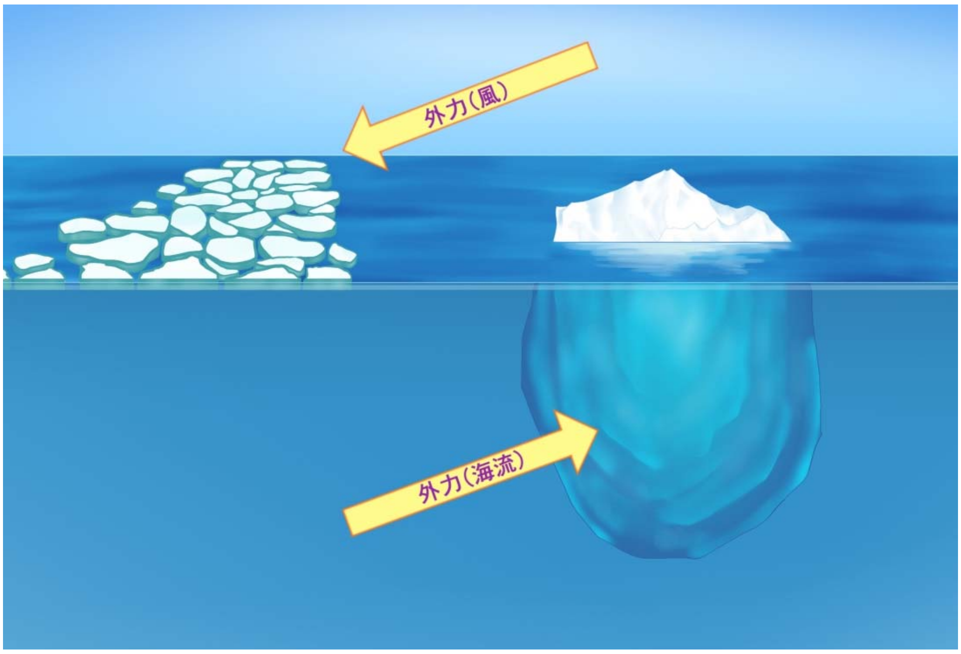


Fig. 3-5: Influence of external forces on ice

- It is dangerous to maneuver against ice direction when ice floes are moving quickly. Vessels should wait until such movement subsides.
- The movement speed of ice floes varies depending on their size and shape. Find ice floes with comparatively slower speeds and navigate in their vicinity.
- It is dangerous to navigate in sea ice areas where waves are rough with ice jostling around with other ice. Avoid this at all costs.

Advice: When ice floes are moving quickly, wait until the speed subsides!

3.1.6 Distance with ice

When ice-strengthened ships are steering to avoid ice floes, a sufficient distance from ice should be maintained for safety.

3.1.7 Heaving to

Ice-strengthened ships should heave to until safety has been confirmed, when there are concerns about ship handling due to narrow fields of vision, nighttime, stormy weather, etc. Heaving to refers to the method of ship handling at the lowest speed at which vessel steering can be maintained, and waiting at a particular location until the weather passes, with the ship positioned so that waves hit the bow diagonally from the front. This limits the chance of ice damage more effectively than completely cutting the propeller. The following points should be noted with regards to heaving to.

- While it is preferable to heave to in safe sea areas such as open waters, if it unavoidably has to be done in sea ice areas, this should be in the areas with the lowest possible ice concentration.
- Always anticipate the direction of movement of sea ice areas and maintain as adequate a distance from the ice as possible when heaving to in sea ice areas.

3.1.8 Protection of the propeller and rudder

The propeller and rudder are the two most delicate parts on the hull when collisions with ice occur. When ice-strengthened ships are entering or approaching sea ice areas, ship handling to prevent damage to the propeller or rudder from contact with ice should be employed. The following points should be noted with regards to protecting the propeller and rudder.

- Damage to the propeller and rudder can easily occur when going astern in sea ice areas. When ordering to run the main engine astern, diligent attention should be maintained to prevent contact between the propeller and rudder with ice, and the rudder should always be amidships when moving in reverse. Recklessly turning the rudder from side to side when going astern could result in contact of the rudder or propeller with ice, leading to a serious accident.
- To prevent contact of the propeller or rudder with ice when going astern in sea ice areas, you should orient the ship approach in advance in a direction other than the ice floes, and attempt to retrace your lead to reach open water or water with relatively little ice.

Advice: The propeller and rudder must be protected above all else!

3.1.9 Prevention of besetment

Ice-strengthened ships approaching or entering sea ice areas should note the following points with regard to preventing the vessel from becoming beset.

- Never stop the ship when there is the risk of dangerous situations such as hull compression due to besetment. Always continue to move even if this movement is at a low speed.

Advice: Continuous movement is essential to avoid the risk of becoming beset!

- There is always a weak point somewhere in a sea ice area even if a vessel is completely encircled by ice in the surroundings, with paths of retreat closed off. Endeavour to maneuver so as to find this as quickly as possible and use that as a breach point to quickly retreat to open waters or safe sea areas with low ice concentration.

- Hummocks or ridges found in a sea ice area are dangerous because they are hard and ice formations are compressed against each other (ice under pressure). Attempting to steer a passage through such areas risks the vessel becoming beset, and thus should be avoided at all costs. If an area with hummocks or ridges, etc. is approached unavoidably and the course is blocked off, be aware that there is a chance that you will have no choice but to idle on standby until the compression subsides.
- Complacency could lead to a vessel becoming beset even when navigating in open waters, due to ice being carried into the surroundings by prevailing winds, etc. Ice-strengthened ships with low ice class (and non-ice-strengthened ships) are particularly susceptible and can fall into a beset with surprising ease when surrounded by ice concentration above a certain threshold. Ice-strengthened ships should always remain vigilant to the possibility of a beset when winds are strong, even if navigating in open waters, and should promptly give a wide berth to any sea ice areas with high ice concentration.
- The ice load on the hull which results from being surrounded by a mixture of first-year ice and second-year ice or multi-year ice, is considerably higher than a sea ice area with only first-year ice. For this reason, the risk of falling into a beset tends to be higher in sea areas with a mixture of multi-year ice, etc. If a vessel encounters a sea ice area with a mixture of multi-year ice, etc. with first year ice, it should promptly give this a wide berth.

Advice: There is always a weak point in a sea ice area, so find it quickly!

Pic.3-9: Ice floes under extreme pressure with a mixture of second-year ice and first-year ice (courtesy of Kazutaka Tateyama)

Pic. 3-10: Aerial panorama of sea ice area (courtesy of Hajime Yamaguchi)

- To prevent an ice-strengthened ship becoming beset when navigating in sea ice areas, in addition to monitoring ice conditions in front of the ship, do not neglect to post a lookout at the stern to confirm ice conditions behind the ship. The ice in the sternwards direction diffuses and forms a lead when navigating sea ice areas. Normally, this temporarily diffused ice will gradually begin to cluster, and the lead will close up. However, as seen in Fig. 3-6, ice is under pressure in sea ice areas where there is potential for a vessel to become beset, meaning that after the ship's passage, the temporarily diffused ice clusters more quickly and a lead will tend to close in short periods of time. When navigating in sea ice areas, post a lookout at the stern to monitor for indications of becoming beset, and handle ship while continually confirming the extent to which a rear lead has closed.

- As shown in Fig. 3-7, leads between the fast ice connected to the shore and the sea ice area, or leads between the coast and a sea ice area are easily subject to external forces, and tend to close more easily than other leads. When navigating these leads, ice-strengthened ships should maintain a pre-emptive grasp of indications of becoming beset by constantly monitoring changes in the wind and wave conditions.

Advice: Leads in a sea ice area with heavy ice load close quickly!

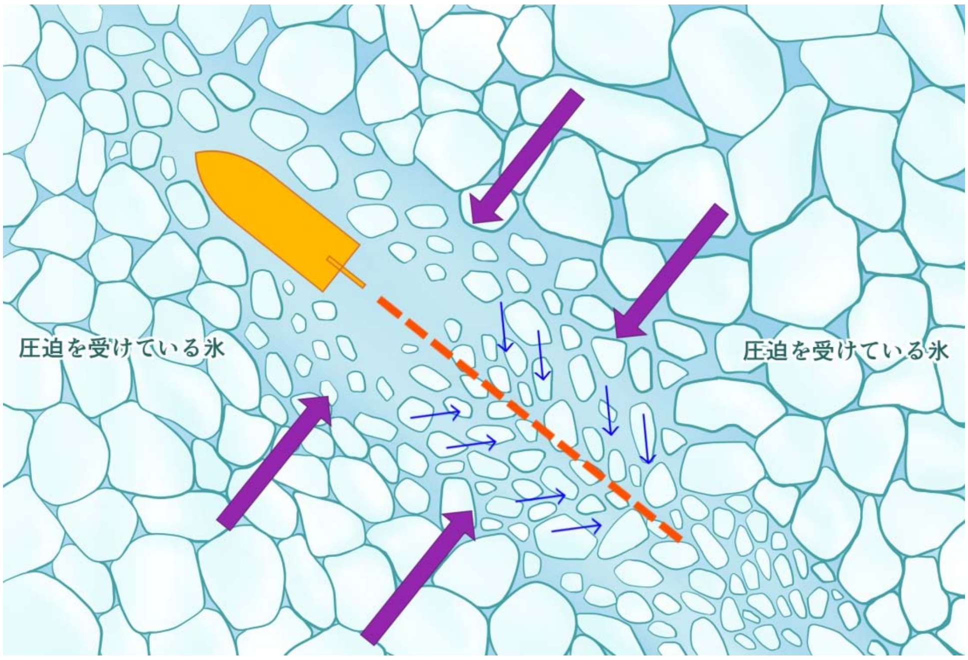


Fig. 3-6: Closing of a lead in sea ice area under pressure

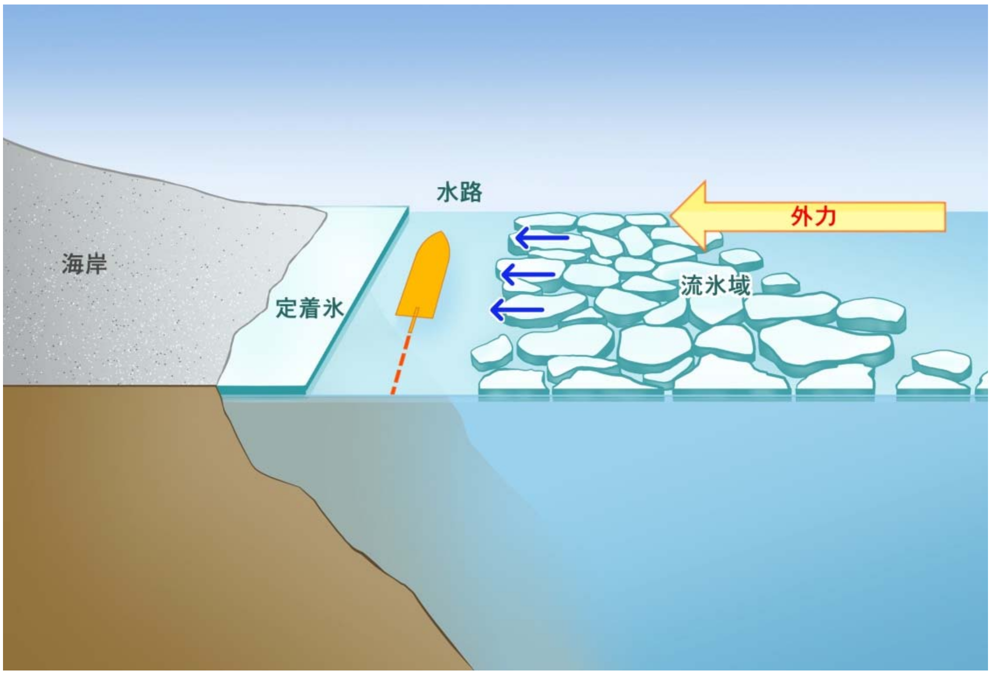


Fig. 3-7: Blocking of a lead between fast ice and sea ice area

3.2 Continuous-mode icebreaking

The ship handling method employed by ice class ships navigating in sea ice areas involving continuously breaking apart or pushing through ice while maintaining a constant low speed and without stopping is referred to as continuous-mode icebreaking.

Icebreakers are the main ice class ships which employ continuous-mode icebreaking. However, if a suitable diversion is not found, and navigation support such as guidance by icebreaker has not arrived on time, there may also be cases in which ice-strengthened ships cannot avoid entering sea ice areas. Also, in sea ice areas with relatively low ice concentration and when the ice thickness is thin, even ice-strengthened ships may sometimes expect to perform continuous-mode icebreaking. In these cases, ice-strengthened ships may implement continuous-mode icebreaking by availing of instruction from the NSRA or a service control station commissioned by the NSRA or advice from ice pilots, while awaiting the arrival of icebreakers or evacuating to safe sea areas such as open waters.

Continuous-mode icebreaking by ice-strengthened ships is presumed on the capacity to withstand ice conditions in sea ice areas, and certain criteria must thus be fulfilled, including the ship operator having ship handling capabilities above a certain level; the main engine and steering apparatus being fully functional; and appropriate ship handling carried out at a safe speed.

This section describes the points which must be noted with regards to continuous-mode icebreaking and ship handling techniques mainly from the perspective of ice-strengthened ships.

3.2.1 Approaching sea ice areas

The points to note and ship handling techniques when approaching sea ice areas for continuous-mode icebreaking are as follows.

- As shown in Fig. 3-8, attempt to find the sea ice area with the lowest possible concentration and use this as a breach when commencing continuous-mode icebreaking. Pay attention not just to the immediate sea ice area but all the sea ice areas within view, and find the entrance passageway with the least resistance.

- When approaching a sea ice area for continuous-mode icebreaking, chart a course which is at an approximate right angle to the ice edge. Investigate the lead which will exert the minimal impact on the ship, and choose it depending on the situation.
- Ice floes around the ice edge are easily affected by rough seas or swells. Pay attention to movement of ice floes due to external forces when approaching the sea ice area for continuous-mode icebreaking.
- Avoid at all costs entering with acute angle or large rudder turns when the ice floes around the ice edge are in extreme upheaval due to rough seas or swells, as this will lead to damage.
- To minimize the ice load on the bow when approaching ice floes for continuous-mode icebreaking, reduce speed to the lowest level at which steering can be maintained. However, maintain awareness that excessive speed reductions can potentially lead to dangerous situations when steering cannot be maintained and the ship loses control.

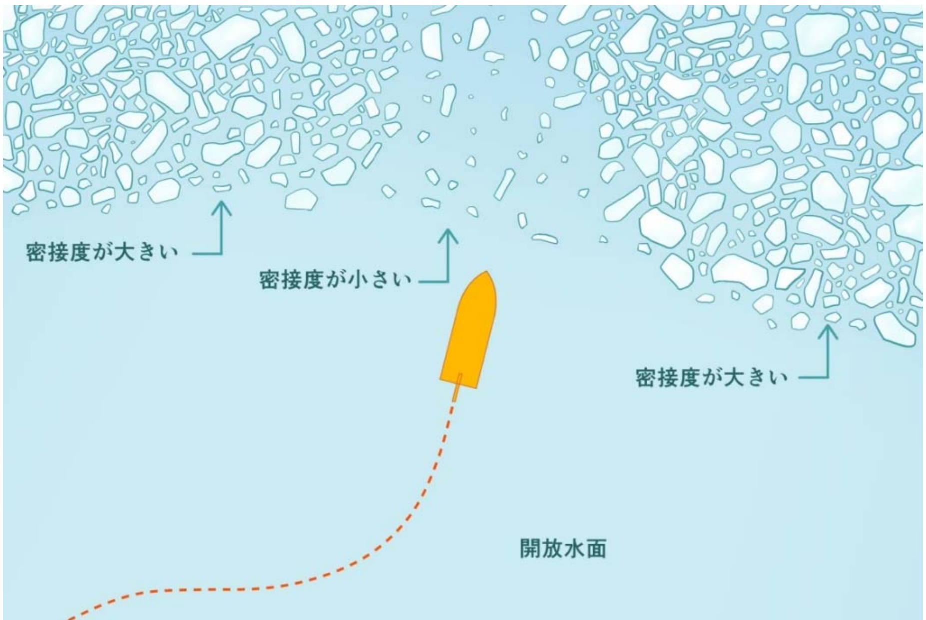


Fig. 3-8: Breach in sea ice area of low concentration

Advice: It is essential to find an area with low ice concentration and approach at low speed!

3.2.2 Contact with ice floes

The points to note and ship handling techniques when coming into contact with ice floes during continuous-mode icebreaking are as follows.

- When the hull is first brought into contact with ice floes during initiation of continuous-mode icebreaking, do so at a right angle to the ice floe, and at as low a speed as possible, to avoid an excessive impact on the hull. Also remain aware that an excessively low speed will result in loss of steerability.
- If everything appears normal when a ship is first brought into contact with ice floes during initiation of continuous-mode icebreaking, maintain control of the hull position and gradually increase the ship speed while checking safety, after confirming that the hull has penetrated and settled into the ice.

3.2.3 Initiating icebreaking

The points to note and ship handling techniques when initiating continuous-mode icebreaking are as follows.

- Ensure to maintain the ship position to encourage a clear stern to protect from damage to the propeller or hull due to contact with ice.
- Ships with side thrusters should appropriately deploy them when implementing continuous-mode icebreaking to improve the effectiveness of icebreaking and maintain position.

- As shown in Fig. 3-9, maneuver with external forces (sea currents and wind) coming from the stern direction whenever possible.

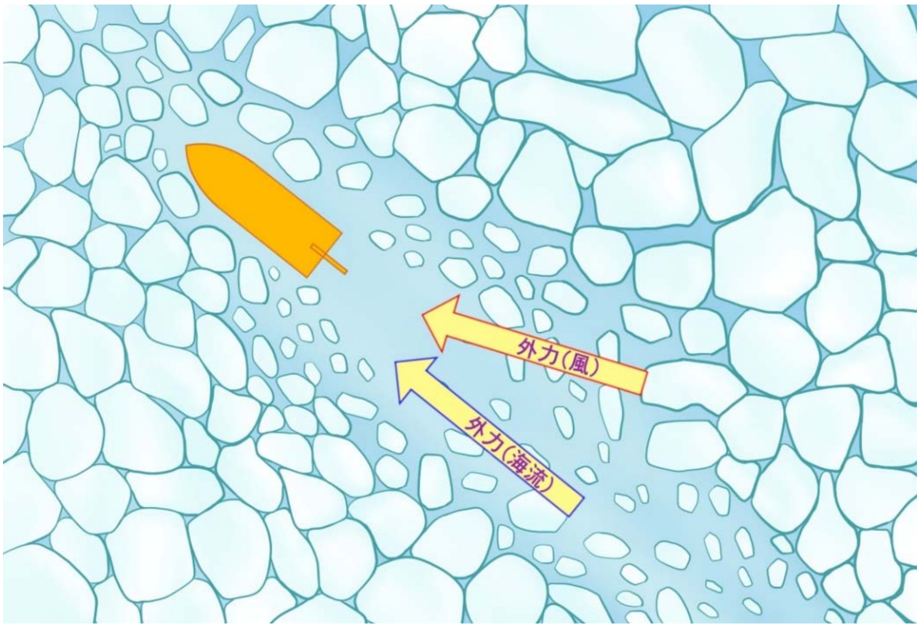


Fig. 3-9: Ideal direction of external forces during continuous-mode icebreaking

3.2.4 Safe speed

The points to note and ship handling techniques with regards to safe speed during continuous-mode ice-breaking are as follows.

- Always maintain a safe speed during continuous-mode icebreaking. There is a tendency for reckless speed increases in sea areas with thin or soft ice, or those with low ice concentration. Vigilance should be maintained to the possible presence of second-year ice mixed in with the other ice.
- Table 3-4 offers estimates of acceptable speeds of ice class ships in line with ice conditions when carrying out continuous-mode icebreaking in open ice, namely sea areas with 4/10 (0.4) to 6/10 (0.6) concentration. However, these should only be thought of as estimates, and it is necessary to base any decision on an integrated assessment of the ice conditions, the capacities of your vessel and ship handling ability, and so on.

Table 3-4: Estimates for acceptable speeds for ships with ice lass in differing ice conditions

(*Only when ice is soft)

氷の密接度	許容速力(ノット)の目安	
	砕氷船	耐氷船
2/10(0.2)未満	12以上	
～3/10(0.3)	10～12	7～8
～4/10(0.4)	6～7	4～5
～5/10(0.5)	5～6	3～4
～6/10(0.6)	5	3(＊)
～7/10(0.7)	3	

- If there are frequent collisions of small ice cakes with the ship bottom, propeller and rudder, etc., or ship vibrations are frequently perceived during continuous-mode icebreaking, this means that the speed is too high. Immediately reduce speed.
- Speed changes during continuous-mode icebreaking should be precisely deployed based on an integrated decision on the concentration, thickness, hardness or size of ice, or the circumstances within the field of vision, vessel capacities, ship handling ability, and so on.

Advice: Use precision speeds during continuous-mode icebreaking!

3.2.5 Course

The points to note and ship handling techniques with regards to course during continuous-mode icebreaking are as follows.

- When carrying out continuous-mode icebreaking, beat a zig-zag course while aiming for open waters by finding an open lead in sea ice areas, a sea ice area with low concentration, a sea ice area with only small ice, or a sea ice area with comparatively thin and soft ice, etc.
- When you encounter a sea ice area with high concentration during continuous-mode icebreaking, give it a wide berth from the windward side.

3.2.6 Sidewall effect

When a vessel navigates approaching a sidewall, a difference in the water pressure distributions on the left and right of the ship occurs, and course keeping becomes difficult due to both an attractive force pulling the ship to the sidewall, and a turning moment exerted on the bow which turns it in the opposite direction. This phenomenon is known as a sidewall effect. As shown in Fig. 3-10, a sidewall effect may arise when a vessel approaches an ice floe during continuous-mode icebreaking. The points to note and ship handling techniques with regards to sidewall effect are as follows.

- In general, the impacts of sidewall effect will be limited to those on maneuverability, when the approach distance to an ice floe is less that 1L (L is the ship length).
- When course keeping becomes difficult due to sidewall effect during continuous-mode icebreaking, be aware that it may be possible to recover by purposely steering into the ice floe side, and adjusting the turning momentum.

Advice: Steer into the ice floe side when course keeping becomes difficult due to sidewall effect!

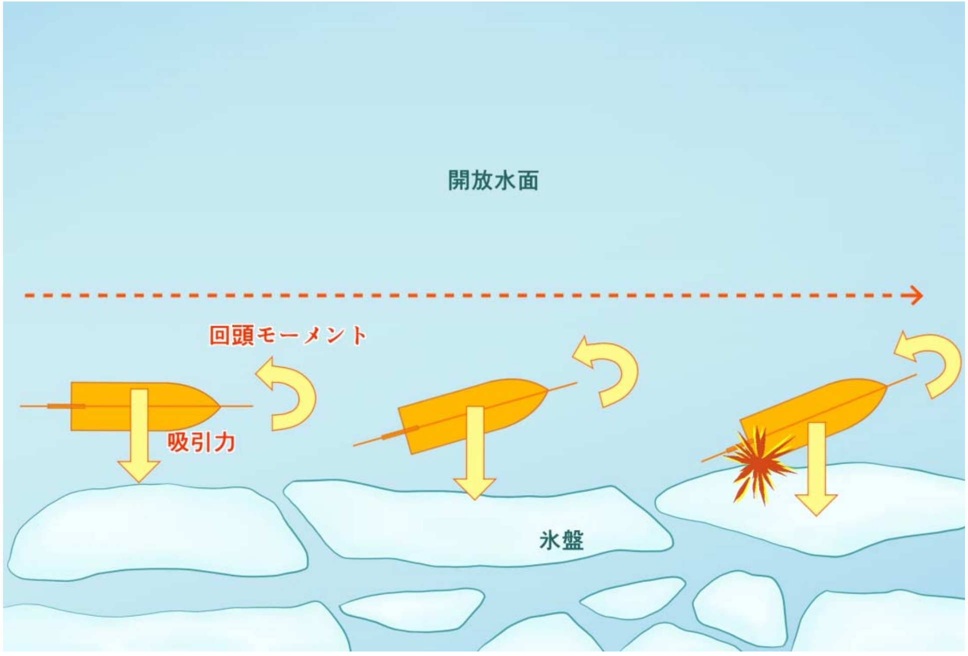


Fig. 3-10: Sidewall effect from ice floe

3.2.7 Suspension of icebreaking

It is necessary to suspend continuous-mode icebreaking until safety is confirmed when there are concerns about ship handling due to narrow field of vision, at night or during stormy weather when implementing continuous-mode icebreaking.

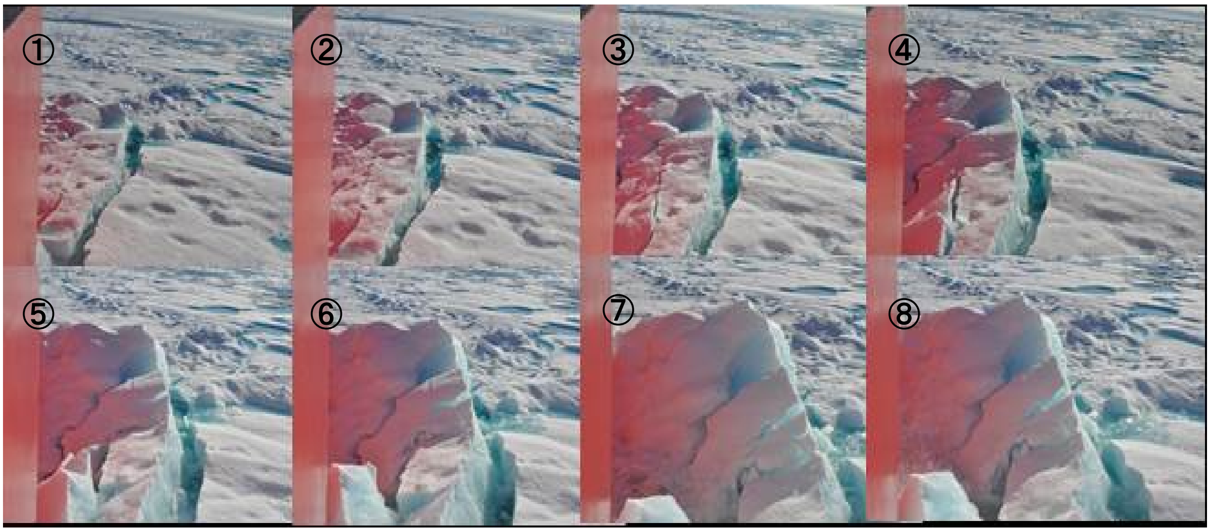
On these occasions, you should heave to in place while slowly running the propeller. This is because damage from ice can more easily occur if you completely halt the propeller.

3.2.8 Maintaining course, etc. during icebreaking

The points to note and ship handling techniques with regards to maintaining course, etc. during continuous-mode icebreaking are as follows.

- Be aware that considerable difficulties can occur in maintaining and changing course when compared to ship handling in open waters during continuous-mode icebreaking, due to, for example, increased resistance from the compromising effects of ice contact on the hull, on course retention and course changing functions, etc.

- The ship tends to be naturally led along the lead, etc. with the least resistance from ice during continuous-mode icebreaking. Accordingly, course keeping or course changes at acute angles may not be the most appropriate strategy, as these increase resistance on the hull or rudder due to loss of steerability. One strategy to reduce resistance is to disregard minor course changes, and maintain the rudder in the amidship position while navigating at the mercy of the elements.



Pic. 3-11: Ice floe movement at the bow during continuous-mode icebreaking by an icebreaker (courtesy of Hiroki Shibata)

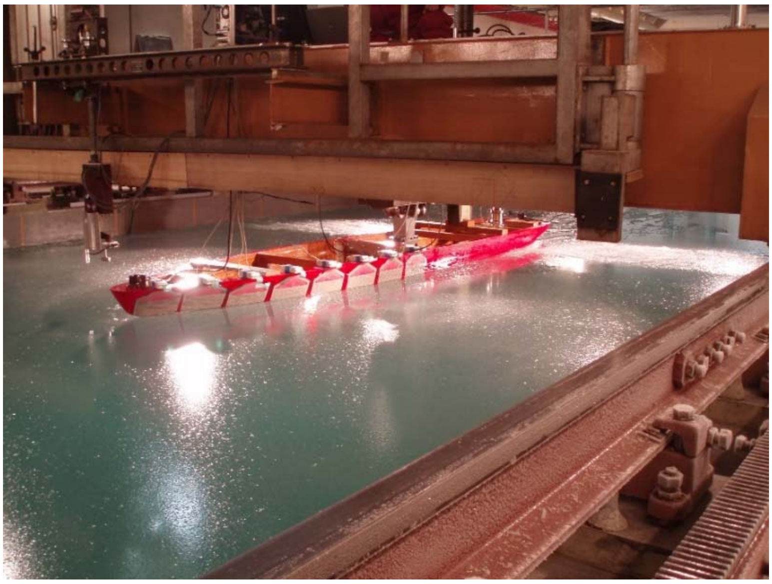
Pic. 3-12: Ice cake passing portside of icebreaker after being broken (courtesy of Hiroki Shibata)

3.2.9 Turning during icebreaking

Turning in sea ice areas for large angle course changes during continuous-mode icebreaking carries an increased risk of damage to the propeller, rudder or hull due to contact with ice, and this should be avoid whenever possible. If you unavoidably have to turn, do so in accordance with the following points and ship handling techniques.

- Turn in safe seas such as open waters, or those with low ice concentration or thin ice whenever possible.
- When you have turned in sea ice areas, while the ice load will only act on the bow part of the ship side in which the rudder is turned, ice load will be experienced on the opposite side over almost the entire length of the ship with a focus on the stern portion. Be aware that turning performance in sea ice areas is considerably worse when compared to open waters, due to this kind of ice load.

- Allow for the significantly compromised turning performance when turning in sea ice areas, take care to avoid excessive turns of the rudder, and ensure to maneuver early in sea areas with ample room on either side.
- Worsening of turning performance in sea ice areas tends to become more pronounced as ice thickness increases. Depending on conditions such as ice thickness and ship type, etc., the tactical diameter for turns can reach tens of times that of turns carried in open waters. For example, as the tactical diameter can be as much as 2 to 3 times that for the vessel turning in open waters depending on particular conditions such as the ship type even in sea ice areas with ice thickness of around 30 centimeters, caution should be maintained.



Pic. 3-13: Performance test for an ice class ship using a sea ice water tank (courtesy of National Maritime Research Institute. Resistance for navigating at constant speed in a uniform ice sheet was measured. The eight sheets hung on the ship sides are special sensors to measure pressure distributions from ice.)

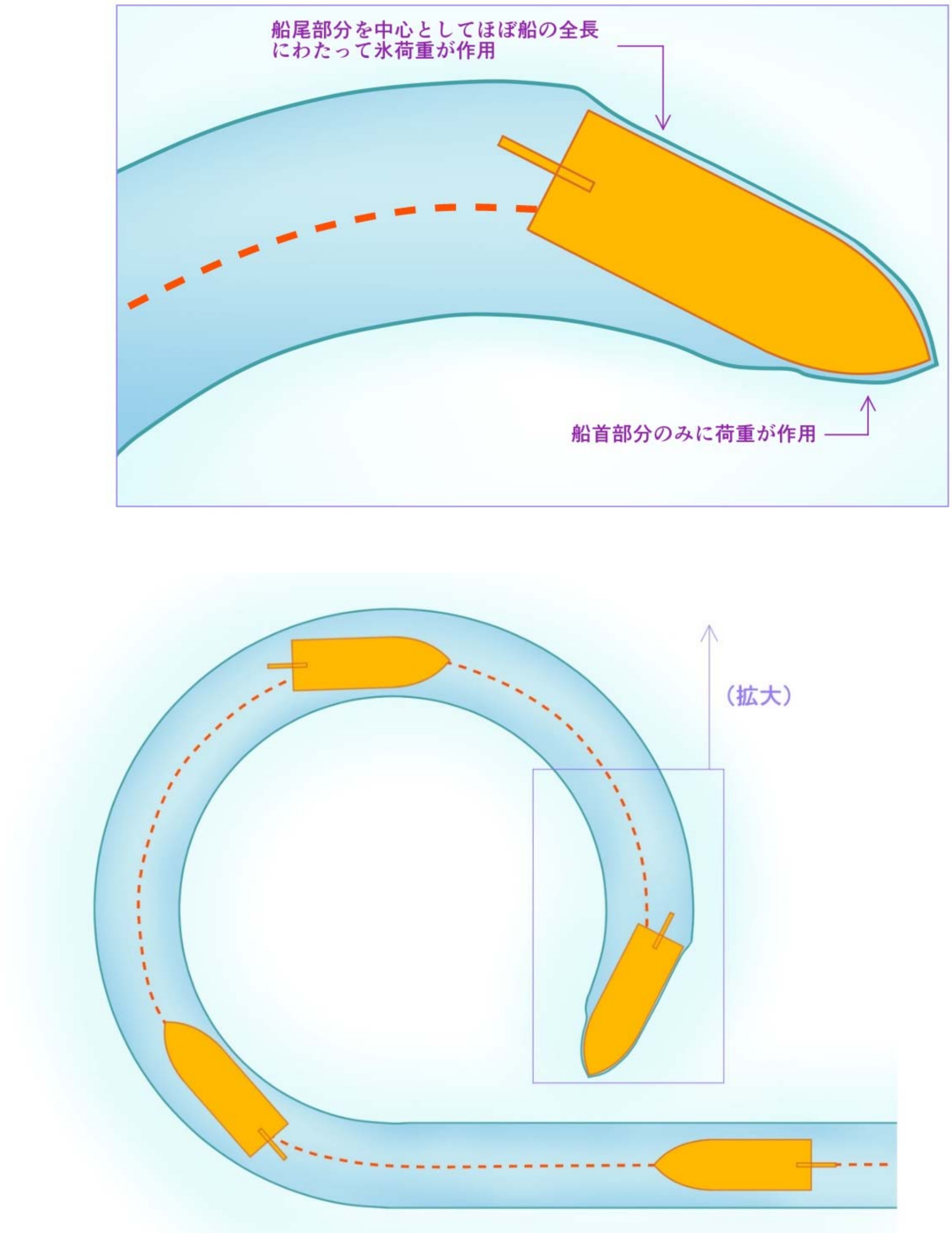


Fig. 3-11: Turning and load during icebreaking

3.2.10 Direction changes during icebreaking

As turning performance worsens considerably in sea ice areas during continuous-mode icebreaking, the chance that you will be unable to complete a turn without sufficient space on either side should be borne in mind, even when a large angle course change is necessary.

In these circumstances, a steering technique which repeatedly combines forward and reverse and side to side movements using the main engine, like the technique of turning a car steering wheel quickly in one direction then the other to change direction in limited space, is sometimes used. As shown in Fig. 3-12, when the locus of this sequence of ship direction changes is seen from above, it resembles a star (or asteroid) so it is called a star maneuver.

Note that a star maneuver is a ship handling technique which involves extremely high risk, with regards to damage to the propeller or rudder from contact with ice. Accordingly, it should only be used in unavoidable circumstances, and by a person proficient in ship handling in sea ice seas.

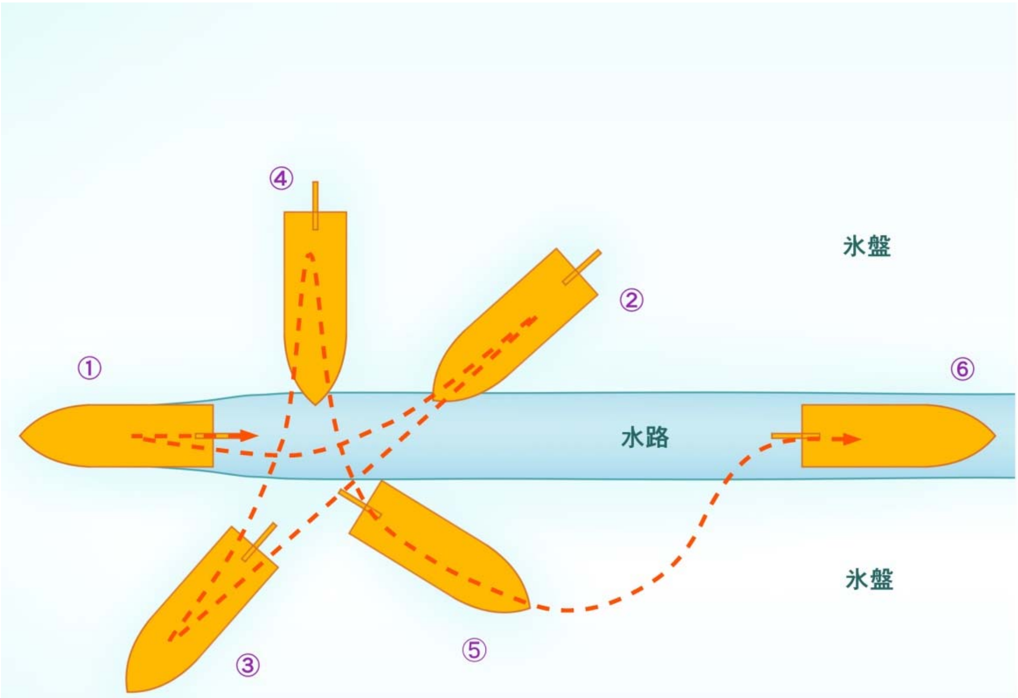


Fig. 3-12: Star maneuver

Advice: Turning performance is significantly worse during icebreaking!

3.2.11 Going astern during icebreaking

You should not put the engine in reverse to go astern during continuous-mode icebreaking, excluding emergencies where it is otherwise unavoidable. This is because it can lead to damage and accidents such as those to the propeller or rudder from contact with ice cakes.

When using the engine in astern during continuous-mode icebreaking unavoidably, you should in principle proceed at dead slow astern, that is reverse at an extremely low speed, as shown in Fig. 3-13, with the rudder amidships (central position) when you have reverse momentum. The steersmen should preferably be instructed to immediately set the rudder amidships when going astern, independently and as a matter of course, without waiting for a helm command.

Advice: Extremely slow speed and rudder amidships are essential when going astern in sea ice areas!

Always ensure to post a lookout at the stern when you unavoidably have to use the engine in astern during continuous-mode icebreaking, to prevent damage to the propeller or rudder, etc. due to contact with ice floes.

Advice: Always post a lookout at the stern when using the engine in astern!

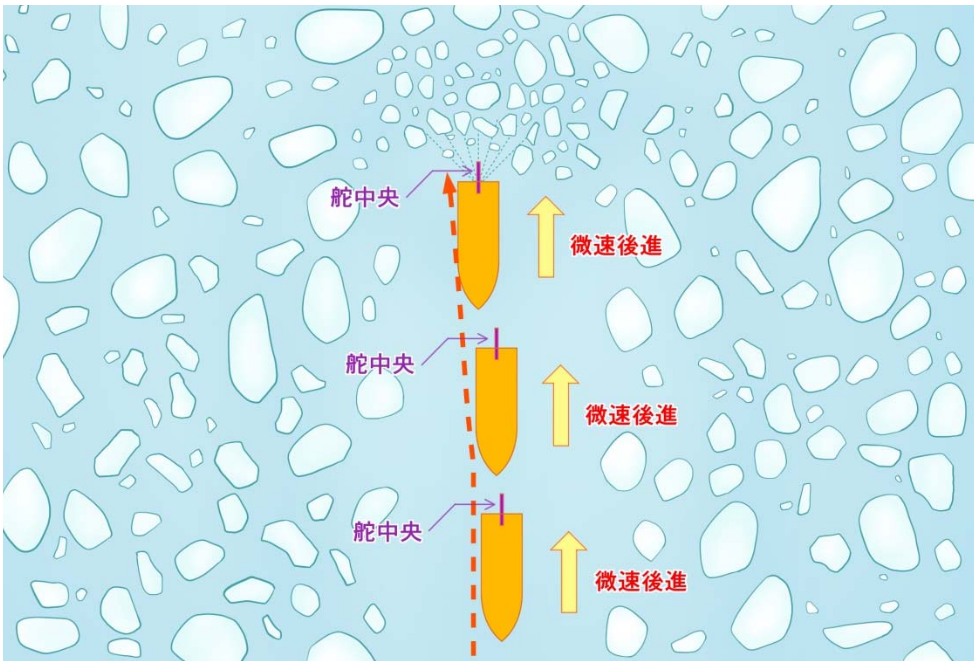


Fig. 3-13: Extremely slow speed and rudder amidships are essential when going astern during icebreaking

There is a further steering technique when you are obliged to use the engine in astern during continuous-mode icebreaking, whereby an extremely short high powered forward burst immediately before going astern is used to clear the ice cakes floating in the propeller stream to prevent damage to the propeller or stern, etc., from contact with ice floes. When using this ship handling technique, ensure to avoid collisions with ice floes astern by maintaining close contact with the stern lookout.

3.2.12 Ship handling during besetment

When an ice-strengthened ship falls or begins to fall into a beset during continuous-mode icebreaking, it is necessary to initiate emergency contact with the NSRA or a service control station commissioned by the NSRA, and request assistance from an icebreaker, etc. In these circumstances, the following points and ship handling techniques should be followed.

- Bear in mind that, due to the gap created between the ship and the ice, you may be able to escape or reduce the ice load following beset, by filling or draining the ballast water in the ballast tank or adjusting its position when you have begun to fall into a beset.
- In cases where you cannot escape becoming beset even by filling, draining or moving the ballast water, it is preferable to ultimately fill the ballast water, and deepen the ship draft. There is a chance that the propeller or rudder will be damaged from contact with ice during assistance when the draft is in a shallow position. It is not particularly common for the assisting icebreaker to request adjustments to the trim or heel.
- As shown in Fig. 3-14, another ship handling technique which is sometimes used when a ship is becoming beset is to complete repeated forward and reverse bursts at full speed in a short period of time while alternately turning the rudder in starboard and portside directions, to disperse the surrounding ice floes and free the ship from besetment. This is made possible by using the principle of lever with the entire ship against the ice floes.
- Another ship handling technique used when a biaxial ship is falling into a beset, is to alternate every few minutes between full steam ahead with one axel and full speed astern with the other, in order to disperse the surrounding ice floes and escape besetment. This too employs the principle of lever with the entire ship against the ice floes.
- The two ship handling techniques which use the principle of lever should only be used in emergencies as both carry an extremely high risk of damage to the propeller or rudder from contact with ice. Pay due heed that there is a danger of collision of the stern with other ice floes, when a

ship has gone out of a sea ice area at full steam astern and lost control of the vessel with astern momentum.

- When employing the two ship handling techniques which use the principle of lever, adjust the draft and the heel as necessary by filling the ballast water, both to prevent damage to the propeller of rudder, and for the most effective angle of contact between the bow part and the ice floes.

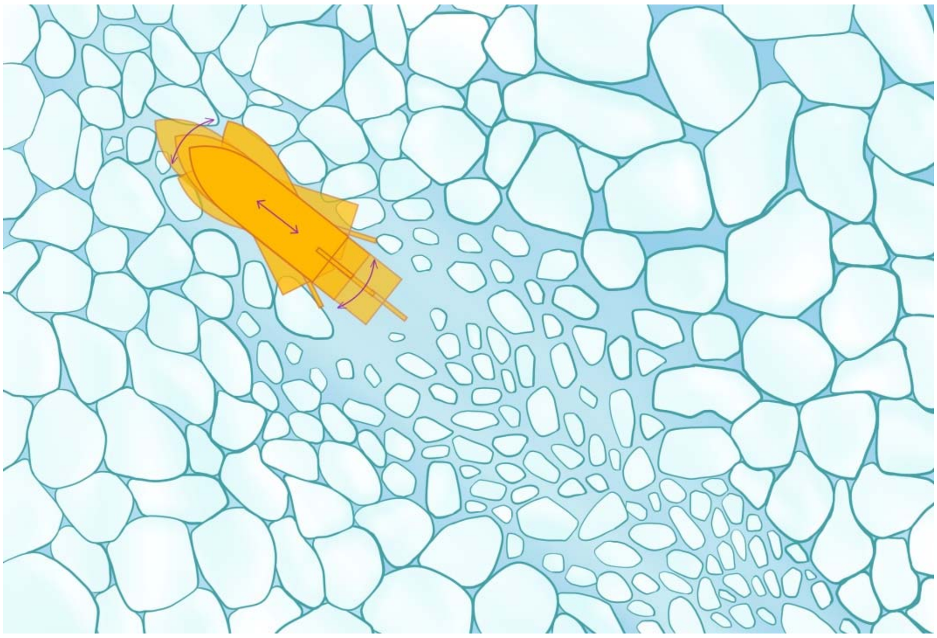


Fig. 3-14: Ship handling with the principle of lever to avoid besetment

Pic. 3-14: Patrol vessels to assist fishing vessels surrounded by ice floes in seas around Japan (courtesy of 1st Regional Coast Guard Headquarters)

Advice: Evade besetment risks with the principle of lever!

3.2.13 Ship handling techniques for assisted vessels

When an ice-strengthened ship has fallen into a beset and cannot escape unaided during continuous-mode icebreaking, the essential method by which an icebreaker will assist is to allow the assisted vessel sail under its own power and lead it to safe waters by having created a lead by removing the ice surrounding the assisted vessel.

Once assistance by an icebreaker has been initiated, preparations should be made so the ice-strengthened ship under assistance is primed to resume autonomous maneuvering at any time. In addition, the following points and ship handling techniques should be followed by assisted vessels.

- As shown in Fig. 3-15, in normal circumstances, an icebreaker will approach an assisted vessel from behind using the engine in forward. It will then pass along either the starboard or portside of the assisted vessel, proceeding at a diagonal angle of around 20 to 30 degrees from stern to bow of the assisted vessel, and break and clear the ice around the ship to open up a lead. Be aware that, depending on the ice conditions, an icebreaker may open up a lead around the entire circumference of the assisted vessel.

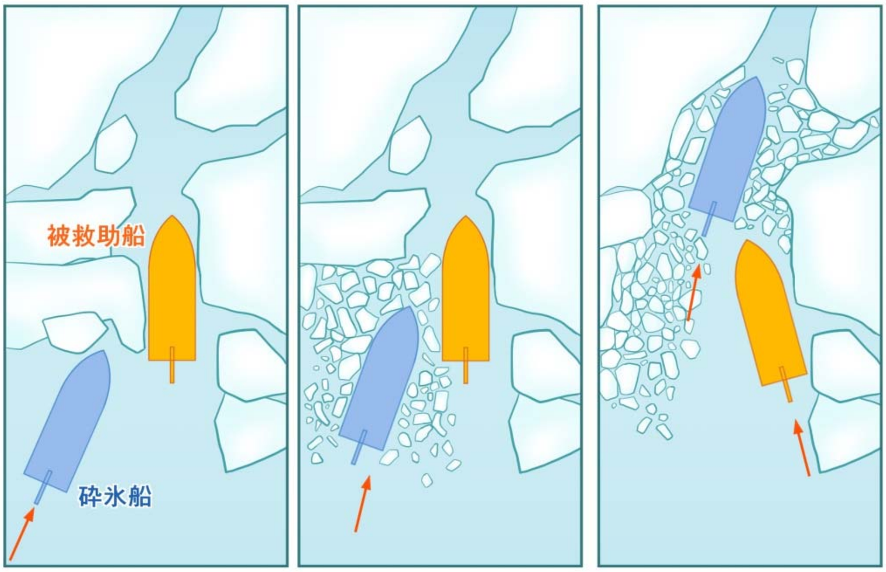


Fig. 3-15: Rescue by forward approach

(during independent passage of assisted vessel)

- Be aware that if the ship under assistance is a large vessel, the icebreaker will also open up a path of retreat, and this may take some time.
- Note that the distance between vessels during guidance by icebreaker for assisted vessels to safe waters is extremely short. Measures must be taken to ship handle to prevent a rear-end collision or other accident involving the icebreaker and the assisted vessel, with accurate information exchange and ensuring mutual understanding.
- Keep in mind that the rescue method whereby an icebreaker tows a distressed vessel is a last resort.

3.3 Ramming icebreaking

Ramming, which is also referred to as charging, is a ship handling method employed when thick ice or hard ice impervious to continuous-mode icebreaking is encountered, whereby an icebreaker either retreats before accelerating into the ice in order to use the force of the impact from the collision to break it, or gets on top of the ice to use the weight of the ship to crush it.

A ram was a protuberance, so-called beak, fitted below the waterline on the bow of warships and used to attack other vessels in antiquity or Middle Ages Europe. A naval ram was equipped to inflict grave damage to enemy vessels during battles, and was found on many warships in Europe before the invention of heavy firearms. The icebreaking method came to be called ramming as the way in which the hull purposely impacts the ice floes at speed resembles this past technique of inflicting damage through bodily impact on an enemy vessel.

Ramming is an icebreaking method which is chiefly used by icebreakers. In normal circumstances, ice-strengthened ships are not designed with ramming in mind, and very rarely carry out ramming, excepting times when it is used to avoid emergency situations such as sea accidents. Ships with a bulbous bow are particular vulnerable to damage if they carry out ramming.

However, ramming may be frequently required depending on the ice conditions when an icebreaker guides an assisted vessel. As such, ice-strengthened ships under assistance must have a basic knowledge of the technique being used by the icebreaker in front. The points and ship handling techniques to be heeded during ramming are described below, mainly from the perspective of icebreakers.

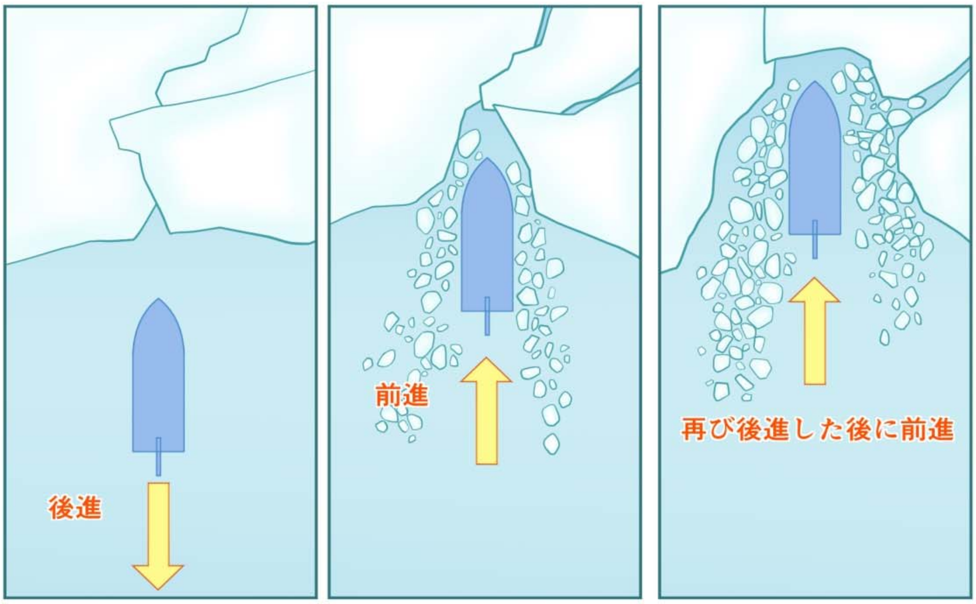


Fig. 3-16: Ramming

3.3.1 Basic policy

The basic policy applied by an icebreaker carrying out ramming is as follows.

- Under no circumstances should vessels with a bulbous bow carry out ramming.
- Ramming is a ship handling method which should, rather than attempting to break up the ice floes all at once by accelerating into them, emphasize slow speeds and repeated forward and reverse movements to gradually eliminate the ice floes and open up a lead.
- The maximum ice thickness at which ramming by an icebreaker is possible is called the maximum icebreaking performance. Maximum icebreaking performance increases as the propulsion power of the propeller increases. Maintain awareness that the larger the vessel displacement the more momentum increases during collision with ice floes, resulting in increased maximum icebreaking performance.
- Both ramming and continuous-mode icebreaking are important ship handling techniques for icebreakers. Icebreakers should appropriately

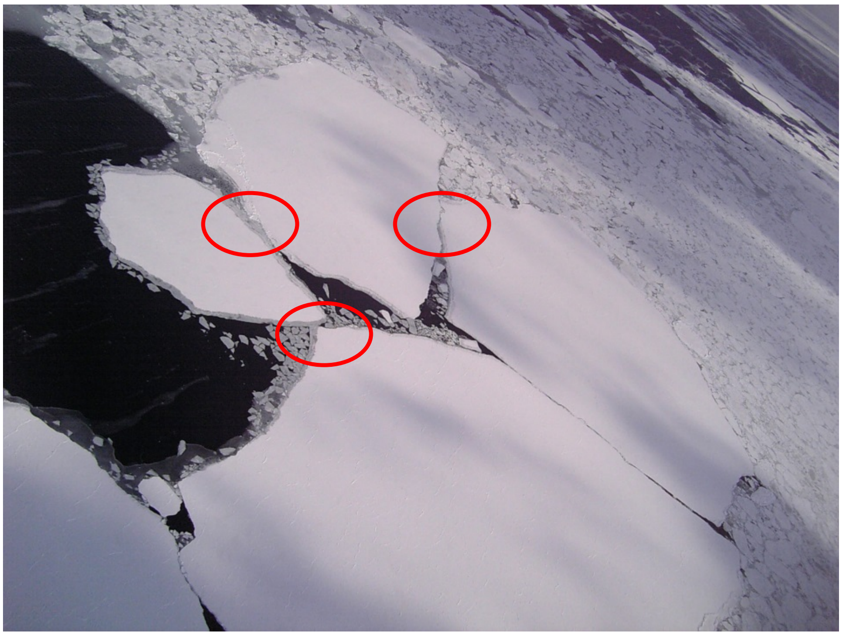
deploy ramming and continuous-mode icebreaking after ascertaining ice conditions and assessing their own ship functions and steering performance.

- Ramming should whenever possible be limited to sea ice areas with thin or soft ice. Excessive ramming against hard ridges or multi-year ice requires caution as it invites the risk of difficult passages or damage to the hull, etc. even for icebreakers.
- Ridges are easily formed at the points where different ice floes are in contact with each other. Avoid ramming in these places whenever possible.
- Merchant vessels place great importance on the transport of cargo within a pre-decided timeframe. Accordingly, in cases where icebreakers are merchant vessels, ramming takes a lot of time and should not be considered an appropriate strategy. In fact, most icebreaking merchant vessels constructed to date, place more emphasis on continuous-mode icebreaking performance than maximum icebreaking performance. Rather than persevering with attempts at forward progress through ramming, vessels should make a priority of ship handling which retraces the route navigated and turn 180 degrees without heaving to, when directly confronted with a dangerous situation such as hull compression after becoming beset.

Pic. 3-15: Damage to a bulbous bow from ice load (Source: Website of the Canadian Coast Guard)

Advice: Ramming by General Ships and bulbous bow vessels is forbidden!

Advice: Beware of ramming against ridges or thick ice!



Pic. 3-16: Ridges formed at the contact points of edges of different ice floes (courtesy of Seiji Shigehara)

3.3.2 Safe speed

When icebreakers are in ramming mode, the force of the impact on the hull is considerably greater than that experienced during continuous-mode icebreaking, and is accompanied by extremely high risk with regard to damage to the hull, etc. from ice impacts. Damage can easily occur even if an icebreaker is considerably sturdier than an ice-strengthened ship, when the hull is subject to an impact greater than the load design.

A ramming icebreaker should always proceed with even more care than usual and ensure a safe speed; and only after having taken full consideration and having intimate knowledge of their vessel's icebreaking performance. Low speeds which err on the side of caution are essential, and vessels must exercise absolute vigilance against excessive speeds.

Advice: Ramming must be done at a safe low speed, and an excessive speed is absolutely forbidden!

3.3.3 Approach run distance

The essence of ship handling for ramming icebreakers is to decide exactly what position to which the vessel should retreat using the engine to go astern for an approach before accelerating with the engine in forward to collide with ice. Indeed, it would not be remiss to say that the question of optimum approach run distance for ramming is a repeated trial and error process. Attention should always be given to ensure ship handling with a consideration to the optimum approach run distance.

The optimum approach run distance when carrying out ramming, means the best distance at which the maximum forward run can be achieved with the shortest use of the engine going astern. The specific distance will vary depending on ice conditions and vessel capacities, but, as shown in Fig. 3-17, a range of 0.5 to 1.0L (L is the ship length) is generally said to be the most appropriate.

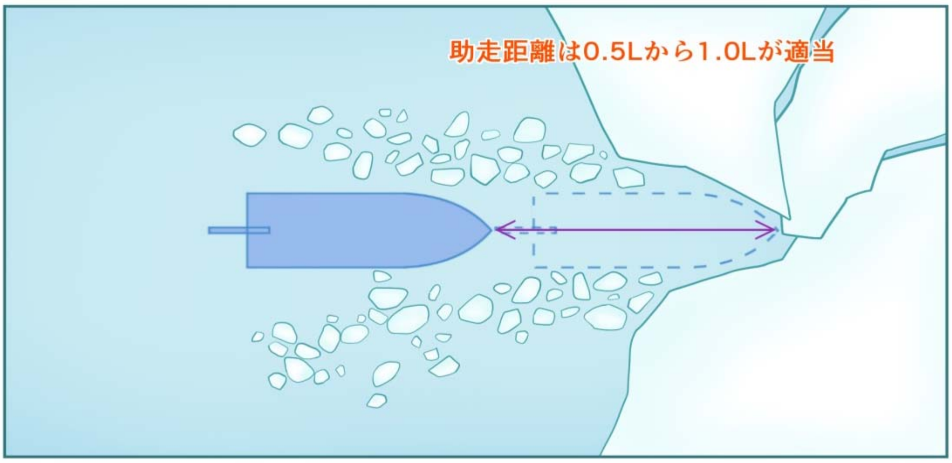


Fig. 3-17: Approach run distance for ramming

3.3.4 Going astern

An icebreaker in the process of ramming must always ensure that the rudder is amidships (central position) when going astern engine, with the engine in reverse, or when there is astern momentum. Also, an icebreaker must always ensure that the rudder is amidships both when using the engine going forward, and when there is no forward momentum.

Steersmen should preferably be instructed to immediately set the rudder amidships, independently and as a matter of course, without waiting for a helm command when going astern or when there is no forward momentum.

Advice: Rudder should also be amidships when there is no forward momentum!

Pic. 3-17: Icebreaker going temporarily astern for ramming

(courtesy of Seiji Shigehara)

Pic. 3-18: Icebreaker going temporarily astern for ramming

(courtesy of Koji Shimada)

3.3.5 Wide-mode ramming

Should icebreakers open a narrow lead approximate in width to the ship beam through one-directional ramming with the hull in sea areas with extremely bad ice conditions, they may quickly find themselves enclosed by ice in the vicinity. If the lead is blocked and it cannot go astern, this may ultimately result in an icebreaker falling into a beset.

In order to avoid this situation, an icebreaker sometimes implements this special ramming technique as shown in Fig. 3-18 in order to open a wider lead.

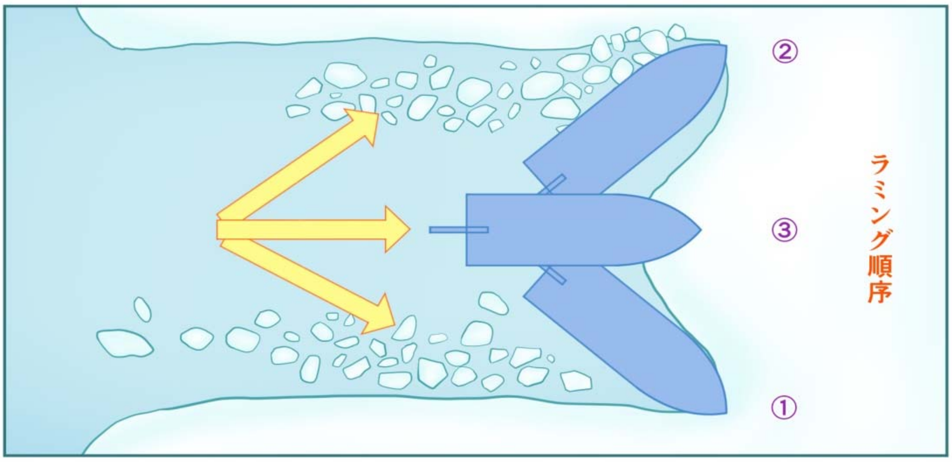


Fig. 3-18: Wide-mode ramming

4. Ship handling under the guidance by icebreaker

When an ice-strengthened ship (or a non-ice-strengthened ship) is approaching or entering sea ice areas on the Northern Sea Route, they must avail of navigation support such as guidance by icebreaker in line with the instructions of the NSRA, according to the ice conditions in the navigated sea area, the ice class of the vessel, and so on. Assisted vessels, such as ice-strengthened ships, under the guidance by icebreaker, must ship handle with heed to the following points.

4.1 Basic principles

Guidance by icebreaker is a type of team play involving multiple vessels. Accordingly, it is important that this team aims for excellent mutual communication, with the related ships maintaining close contact and exchanging information in order to prevent accidents at sea involving ships, collisions with ice, and so on. Assisted vessels must also accurately comply with the moment-to-moment icebreaker instructions relating to the distance between vessels, the course, speed, etc., at all times. The basic principles for ship handling for assisted vessels such as ice-strengthened ships during the guidance by icebreaker are as follows.

4.1.1 Rendezvous

The basic principles with regards to rendezvous with icebreakers are as follows.

- Comply with the instructions of the NSRA or icebreakers with regards to the place, time, and so on of rendezvous with icebreakers.
- If assisted vessels arrive at the rendezvous point before the icebreaker, they should always wait at that location until the icebreaker arrives. Assisted vessels should not enter sea ice areas independently. While

there may be a tendency to think that you can always turn around and go back even when entering sea ice areas independently, this thinking can result in situations which require the kind of hard toil and powers of perseverance greater than a vessel and its crew have ever before experienced.

- Assisted vessels waiting at the rendezvous point should reduce speed to the lowest level at which steering can be maintained, and effectively employ ship handling to maintain position or heave to with the bow positioned to receive waves diagonally from ship front.
- At the time of rendezvous with the icebreaker, avoid, whenever possible, heaving to in a sea area near the sea ice, to avoid the dangers of collision with the ice edge or entering the sea ice area and becoming beset, etc. It is important that assisted vessels heave to in a place which is at a sufficiently large safety distance from the sea ice area, as shown in Fig. 3-19.
- Changes in the prevailing weather or ice conditions at the time of rendezvous with the icebreaker could result in a vessel becoming unexpectedly enclosed by ice and rendered immobile even if that vessel heaves to in a place which is at a sufficiently large safety distance from the sea ice area. Assisted vessels awaiting the arrival of the icebreaker should continually monitor weather and ice conditions, and always anticipate the movement direction and speed of ice floes during this wait. Moreover, if it seems that there is a risk that a vessel will draw particularly near a sea ice area, it should immediately suspend heave to and move towards safe open waters.

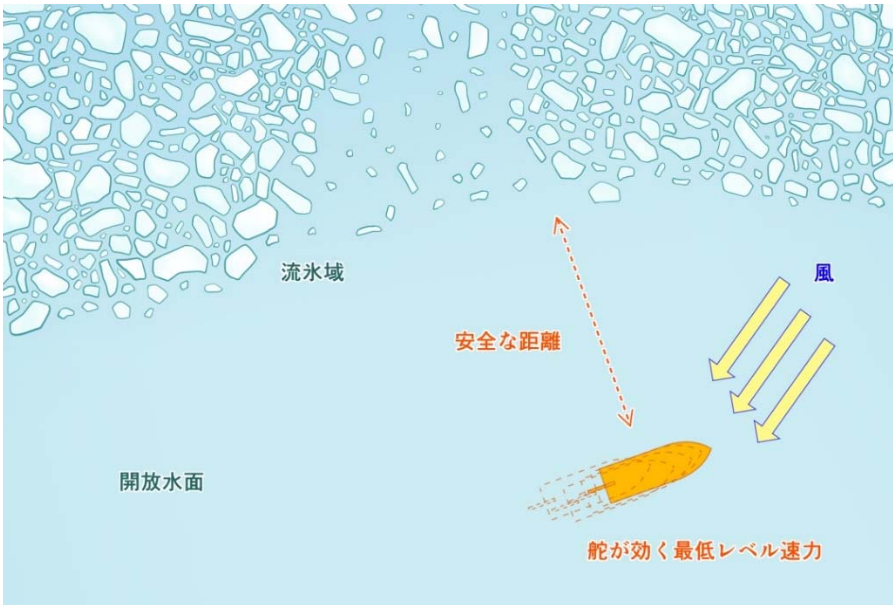


Fig. 3-19: Heave to during rendezvous

4.1.2 Telecommunications

The basic principles with regards to telecommunications with icebreakers, etc., are as follows.

- Assisted vessels must always secure the means of telecommunications between all relevant vessels when under guidance by icebreaker.
- In normal circumstances, telecommunications among all relevant vessels when under guidance from icebreakers are mainly conducted using international VHF radio channels. In addition to 16ch, the channel which is generally used for call and response, listen to any channels indicated by the NSRA or icebreaker. Radiotelephone “Medium Frequency” (MF) *2182 kHz* should also be monitored. Also monitor any surrounding radiotelephone AM bands indicated by the NSRA or icebreaker.
- If telecommunications by both international VHF and radiotelephone AM frequencies go down during guidance by icebreaker, or if instructed by the icebreaker, contact between all relevant ships should be conducted

using the “Single letter signals between icebreaker and assisted vessels” in the International Code of Signals.

- “Single letter signals between icebreaker and assisted vessels” in the International Code of Signals are single or double letter combinations or numbers which are used to convey a particular meaning. They are conveyed by means of flag signals using the International Code of Signals; light signals such as Morse signaling using signal lamp; or audio signals such as whistles or sirens using Morse. The meanings of the roman numerals or numbers used for instructions or responses are shown in the table below. There are four additional single-letter signals indicated for use during guidance operations by icebreakers in the International Code of Signals. These signals are indicated in the table after the next.

Pic. 3-19: Sea ice area as seen from the bridge of an icebreaker

(courtesy of Hajime Yamaguchi)

Table 3-5: Letter signals between icebreaker and assisted vessels
(Source: International Code of Signals)

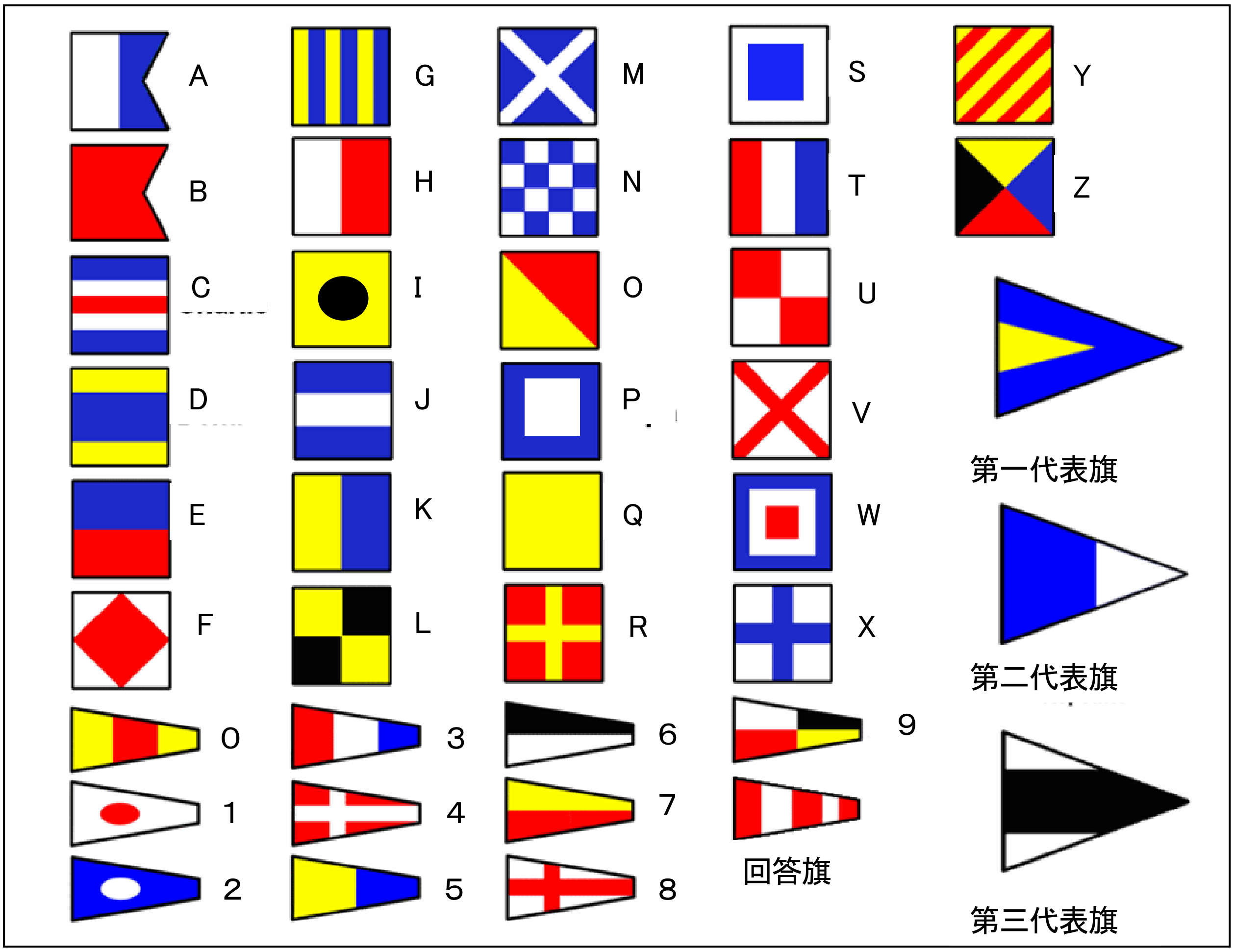
文字	砕氷船からの指示(英語・日本語)	被援助船の応答(英語・日本語)
WM	Icebreaker support is now commencing. Use special icebreaker support signals and keep continuous watch for sound, visual, or radiotelephony signals. 砕氷船による援助を今から始める。砕氷船援助の特別信号を使用し、音響、視覚、又は無線電話の聴取のための当直を続けよ。	
A	Go ahead (proceed along the ice channel). 前進せよ(氷間水路を進行せよ)。	I am going ahead. (I am proceeding along the ice channel) 本船は前進している(本船は氷間水路を進行している)。
G	I am going ahead, follow me. 本船は前進している。本船に続航せよ。	I am going ahead. I am following you. 本船は前進している。貴船に続航している。
J	Do not follow me (proceed along the ice channel). 本船に続航するな(氷間水路を進行せよ)。	I will not follow you (I will proceed along the ice channel). 本船は貴船に続航しない(氷間水路を進行しよう)。
P	Slow down. 減速せよ。	I am slowing down. 本船は減速しつつある。
N	Stop your engines. 機関を止めよ。	I am stopping my engines 本船は機関を止めつつある。
H	Reverse your engines. 貴船の機関を逆転せよ。	I am reversing my engines. 本船は機関を逆転しつつある。
L	You should stop your vessel instantly. 貴船はすぐに停船せよ。	I am stopping my vessel. 本船は停船しつつある。
4	Stop. I am icebound. 停船せよ。本船は氷に閉ざされた。	I am stopping my vessel. 本船は停船しつつある。
Q	Shorten the distance between vessels. 船間距離をつめよ。	I am shortening the distance. 本船は船間距離をつめつつある。
B	Increase the distance between vessels. 船間距離を増せ。	I am increasing the distance. 本船は船間距離を増しつつある。
Y	Be ready to take (or cast off) the tow line. 曳航索を受け取る(放す)準備をせよ。	I am ready to take (or cast off) the tow line. 本船は曳航索を受け取る(放す)準備をした。
FE	Stop your headway (given only to a ship in an ice channel ahead of an icebreaker). 貴船の行き脚を止めよ(氷間水路で砕氷船の前方の船にのみ使用する)。	I am stopping headway. 本船は行き脚を止めている。
WO	Icebreaker support is finished. Proceed to your destination. 砕氷船による援助は終わった。貴船は目的地に進行せよ。	
5	Attention. 注意せよ。	Attention. 注意せよ。

Table 3-6: Additional single-letter signals indicated for use during guidance operations by icebreakers (Source: International Code of Signals)

文字	砕氷船からの指示（英語･日本語）	被援助船の応答（英語･日本語）
E	I am altering my course to starboard. 私は針路を右に変えている。	I am altering my course to starboard. 私は針路を右に変えている。
I	I am altering my course to port. 私は針路を左に変えている。	I am altering my course to port. 私は針路を左に変えている。
S	My engines are going astern. 本船は機関を後進にかけている。	My engines are going astern. 本船は機関を後進にかけている。
M	My vessel is stopped and making no way through the water. 本船は停船している。行き脚はない。	My vessel is stopped and making no way through the water. 本船は停船している。行き脚はない。

* The signal “K” by sound or light may be used by an icebreaker to remind assisted vessels of their duty to continuously monitor their radio.

Table 3-7: List of International Flags and Pennants (Source: International Code of Signal)



4.1.3 Basic compliance rules

The basic compliance rules for assisted vessels such as ice-strengthened ships during guidance by icebreaker are as follows.

- During guidance by icebreaker, the icebreaker will make a decision on an appropriate distance between vessels, as well as course and speed, based on a consolidated assessment of the ice conditions, the visibility, the weather conditions, functions or steering performance of own vessel and assisted vessels, handling capacities of assisted vessels, and so on. Assisted vessels should fully comply with those instructions.
- Assisted vessels under guidance by icebreaker should not neglect to observe developments and continuously monitor the icebreaker in front.
- Assisted vessels under guidance by icebreaker should in no circumstances overtake the icebreaker. The assisted vessels should in no circumstances increase speed, stop or reduce speed without instruction from the icebreaker.
- Assisted vessels under guidance by icebreaker should deploy a lookout at the stern to confirm the degree to which the astern lead has closed.

Advice: Post a lookout at the stern during guidance by icebreaker!

4.1.4 Additional compliance rules during convoy navigation

There are cases when guidance by icebreaker is conducted with one icebreaker and two or more assisted vessels following to make a single-file (column) fleet. This form of guidance by icebreaker is known as a convoy. The level of difficulty for both the icebreaker and the assisted vessels in a convoy markedly increases when compared to guidance with a single icebreaker and single assisted vessel.

Additional compliance rules for assisted vessels such as ice-strengthened ships during a convoy are as follows.

- During a convoy, all of the ships must ensure clear communication by close contact and information exchange, and work together under the lead of icebreaker.

Advice: Guidance by icebreaker is team play - all ships must ensure to maneuver by working together!

- During a convoy, the icebreaker will decide the number of assisted vessels, the overall length of the fleet, the fleet order, and so on, taking into consideration a consolidated assessment of the ice conditions around the icebreaker, the visibility, the weather, the ship functions and steering performance of the icebreaker and assisted vessels, or the ship handling capacities of the operators of assisted vessels, and so on. Any and all instructions should be fully complied with.

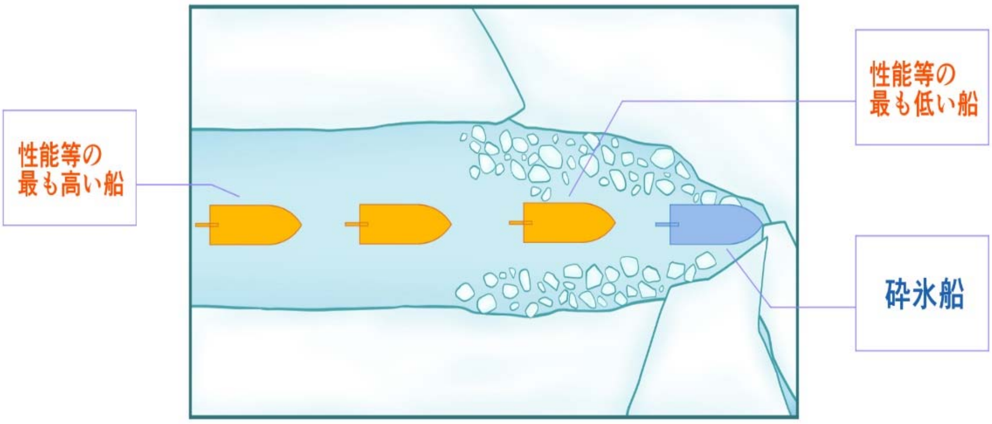
Advice: An icebreaker is the team manager, so follow its orders!

- While this also depends on the ice conditions, the number of ships under assistance which a single icebreaker can lead during a convoy is usually 2 to 3. If it is necessary to guide more vessels at a single time, there may be times when an auxiliary icebreaker will participate besides the main icebreaker in the lead. An auxiliary icebreaker is most often positioned in the middle of the single-file fleet. When an auxiliary icebreaker has been added to the fleet, all ships should comply with both the instructions of the main icebreaker and auxiliary icebreaker.
- Maintain awareness that during convoy, if assisted vessels with different

ship functions or ship handling capacities or steering performance are involved, the icebreaker normally orders the assisted vessel with the weakest overall capacities to be in second position in the fleet (directly behind the lead icebreaker), and the assisted vessel with the greatest capacities to be at the rear of the fleet, as shown in Fig. 3-20.

- Maintain awareness that during convoy, if the ships which assembled have commensurate ship functions, handling capacities or steering performance, etc., the icebreaker normally orders the assisted vessels to line up behind in order of their beam width from widest to narrowest, as shown in Fig. 3-21.
- During convoy, the assisted vessels should not neglect to observe developments and continuously monitor the icebreaker as well as the other assisted vessels both in front and behind.
- During convoy, no ship under assistance should at any time overtake any of the other assisted vessels. Also, no assisted vessel should in any case increase speed, stop or reduce speed without instruction from the icebreaker.
- During convoy, each ship under assistance should deploy a lookout at the stern, to monitor the ships behind or confirm the degree to which the astern lead has closed.

Advice: Overtaking or unpermitted ship stops are forbidden when in convoy!



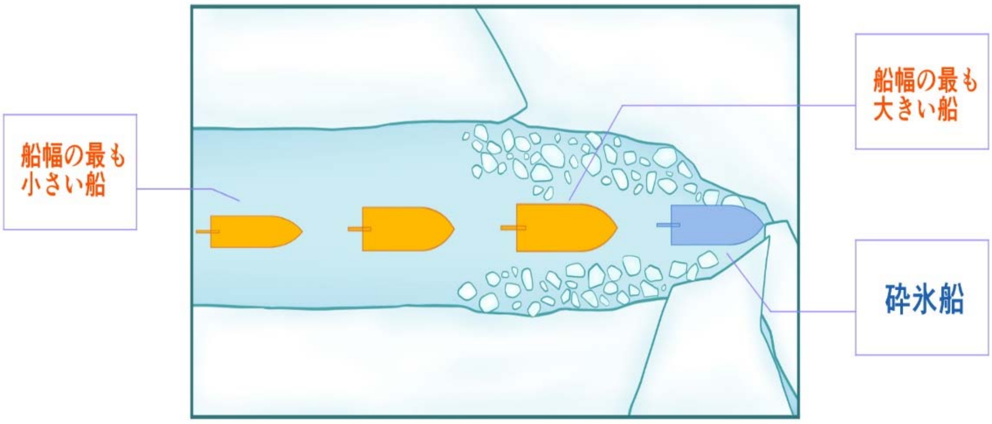


Fig. 3-20: Example (1) of fleet arrangement during convoy (top),

Fig. 3-21: Example (2) of fleet arrangement during convoy (bottom)

4.2 Ship handling methods when under assistance

There is a constant necessity during guidance by icebreaker for assisted vessels to maintain ship handling to ensure that the assisted vessel does not collide with the icebreaker, etc., in front; to appropriately follow the movements of the icebreaker, etc. in front; and to ensure a safe passage while the lead which the icebreaker has opened remains open. For this reason, the icebreaker will give constant instructions to the assisted vessels on appropriate course and distance between vessels, the feet overall length, as well as its speed, to ensure that this kind of ship handling is completed both safely and manageably.

These instructions take into consideration a consolidated assessment of the ice conditions around the icebreaker, the visibility, the weather, the ship functions and ship handling capacities of the assisted vessels, and so on. The assisted vessels must then appropriately comply with all of the moment-to-moment instructions issued by the icebreaker. For successful guidance by icebreaker, all of the assisted vessels in the fleet must comply with the icebreaker instructions, and ensure to diligently work together as a team with every member cooperating. Should even one ship in the fleet deviate, this will have an impact on all the other ships.

The points to note and ship handling techniques for assisted vessels during guidance by icebreaker are described as follows.

4.2.1 Accurate tailing

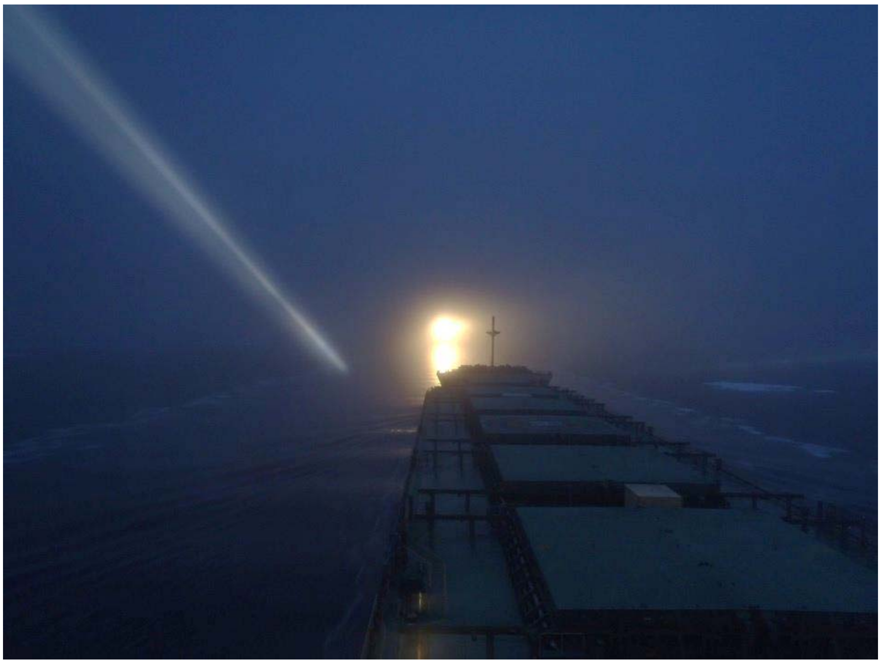
The following are the points to note and the ship handling techniques, etc., with regards to accurate tailing for assisted vessels during guidance by icebreaker.

- When an assisted vessel following (tailing) an icebreaker or other assisted vessels in front (hereafter, icebreaker, etc.) becomes unsure of its course, it may veer outside the lead, which could result in the risk of accidents such as collision with the adjacent ice edge. To ensure that a vessel accurately follows the course of the icebreaker, etc., and to achieve a consistent vessel course, it is advisable to get into the wake of the icebreaker, etc., and tail from there.
- To minimize frictional resistance between the ice and the hull and make icebreaking easier, the icebreaker sometimes deploys a sprinkler device (water jet). Be aware that in such cases this makes it easier to maintain visual confirmation of the icebreaker wake.

Advice: For accurate tailing, follow the ship's wake!

- When navigating in narrow fields of view, at night or in darkness, the icebreaker will expose the assisted vessels behind to a searchlight which should be used to anticipate the tail course. Maintain awareness that if the searchlight is viewed head on, glare may be induced, and this can delay discovery of obstacles such as ice.
- Assisted vessels should always observe the developments of the icebreaker, etc. using a lookout. To ensure accurate tailing, ship handling should reflect continuous monitoring using radar and Doppler Speed Log (ship speed measurement), of the distance between, and speed of, the icebreaker, etc.

Advice: Observe and continuously monitor the developments of other ships!



Pic. 3-20: Ice-strengthened cargo ship tailing icebreaker searchlight (center of image) (courtesy of Jin Saijo)

* The light radiating from the left towards the bottom of the image is the cargo ship searchlight

4.2.2 Course, distance between vessels, fleet overall length, and speed

The following are the points to note and the ship handling techniques, etc,. with regards to course, distance between vessels, fleet overall length, and speed for assisted vessels such as ice-strengthened ships.

- Assisted vessels should quickly and accurately comply with the moment-to-moment instructions of the icebreaker with regards to course, distance between vessels, fleet overall length, and speed.
- In normal circumstances, the distance between vessels during guidance by icebreaker in sea ice areas exceeds a minimum of around 3 times the length of the icebreaker, equivalent to a distance of 2.5 cables (approximately 460 meters). The speed during guidance by icebreaker in sea ice areas is at least in excess of around 3 knots, which is the lowest limit at which steering can be maintained, and at most within 10 to 12 knots.
- In sea areas where ice conditions are comparatively poor, such as close ice areas, that is ice areas of 7/10 (0.7) to 8/10 (0.8) concentration or sea ice areas under pressure, the temporarily dispersed ice closes up quickly in the icebreaker wake, and leads tend to close quickly. Awareness should be maintained that the icebreaker may issue instructions to the assisted vessels for generally shorter distance between vessels and for low speed, to address such circumstances, as shown in Fig. 3-22 (top image).

Advice: You will be instructed to adopt a low speed and short distance between vessels when ice conditions are poor!

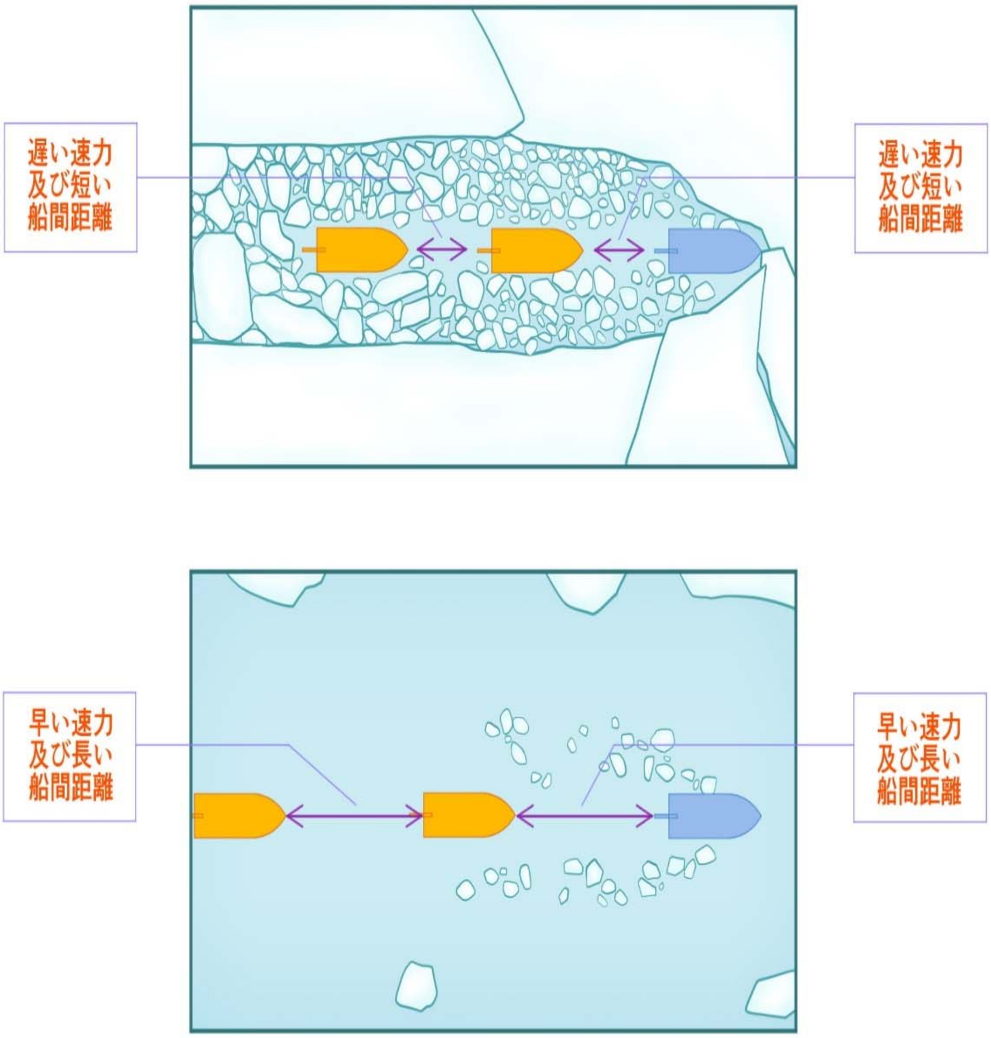


Fig. 3-22: Guidance by icebreaker when ice conditions are poor (top image) and when ice conditions are good (bottom image)

- In sea ice areas with particularly bad ice conditions, for example very close ice of 9/10 (0.9) to 10/10 (1.0) concentrations or sea ice areas which are strongly under pressure, it should be noted that instructions may be issued from the icebreaker to assisted vessels for a short distance between vessels of less than 2.5 cables (around 460 meters) and dead slow speed to address such circumstances.

- In sea ice areas with extremely poor ice conditions, for example compact ice or consolidated of 10/10 (1.0) concentrations, or sea ice areas which are under extreme pressure, be aware that there is a possibility that guidance by icebreaker itself will become unsustainable. Even in cases where it may be possible to continue, the icebreaker may issue instructions to the assisted vessels in the fleet to maintain extremely short fleet overall length and distance between vessels when compared with normal circumstances. In particular, it should be noted that the assisted vessel taking up the rear may be instructed to maintain an extremely short interval of 0.5 cables (approximately 93 meters).
- For sea areas with relatively good ice conditions, such as those with low concentrations of ice or sea ice areas accompanied by polynya, or brash ice channels packed with small ice cakes, the closing of the temporarily dispersed ice in the wake of the icebreaker is slow and it tends to take a long time for the lead to close. In these cases, it should be noted that the icebreaker may issue instructions to the assisted vessel fleet to maintain a relatively longer distance between vessels and higher speed to address such circumstances, as shown in Fig. 3-22 (bottom).

Advice: When ice conditions are extremely poor, you will be instructed to maintain extremely short fleet overall length!

Advice: When ice conditions are good, you will be instructed to maintain a faster speed and longer distance between vessels!

- Assisted vessels should always maintain the distance between vessels instructed by the icebreaker. If for any reason a vessel cannot maintain the instructed distance, it should immediately contact the icebreaker and defer to its advice. In an emergency, send a warning signal such as light signals using signal lamp or audio signals such as whistles or sirens to the icebreaker and other assisted vessels as necessary.

- If for any reason an assisted vessel has unavoidably come significantly close to the ship in front, any ice in the lead may act as a fender pile, and this should be reflected in ship handling.
- Speed control by assisted vessels based on the instructions of icebreaker should involve continual monitoring of the distance between vessels, etc., to employ precision methods such as minute adjustments of the wheel notch to control the engine rotations, rather than use of general full steam ahead, half ahead, dead slow ahead, and so on with the engine telegraph.

Advice: Always keep the distance as instructed by the icebreaker!

4.2.3 Opening a lead

The points to note and ship handling techniques with regards to opening a lead are as follows.

- Be aware that instructions to assisted vessels on the distance between vessels and speed by the icebreaker may also be influenced by the width of the lead opened by the icebreaker.
- Note also that the width of the lead opened by the icebreaker may be influenced by ice conditions. The lead will become wider when the proportion of the sea area occupied by open water is large, as the ice through which it has pushed is easily moved to a distance. Meanwhile, the lead will become narrower when the proportion of the sea area

occupied by open water is small, as the movement of the ice through which it has pushed will be obstructed.

- The width of the lead opened by the icebreaker will be influenced by the icebreaker ship type, and its speed and icebreaking performance. With the icebreaker proceeding at a low speed to break through thick ice, in normal circumstances the width of the lead will be approximately 30% to 40% greater than the icebreaker beam, as shown in Fig. 3-23. Meanwhile, with the icebreaker proceeding at high speed to break through thin ice, in normal circumstances the width of the lead will expand to as much as 3 times that of the icebreaker beam.
- When the icebreaker carries out icebreaking with ice floes touching both sides of the hull, the ice cakes which the icebreaker has broken and pushed through with the bow parts will be distributed on either side of the ship. This ice tends to move towards the outer side of the lead which has been opened. Meanwhile, be aware that when an icebreaker breaks ice with ice floes touching only either the left or right side of the hull, the ice cakes which the bow parts have broken and pushed through, may enter the opened lead.

Advice: Beware of ice cakes entering the lead!

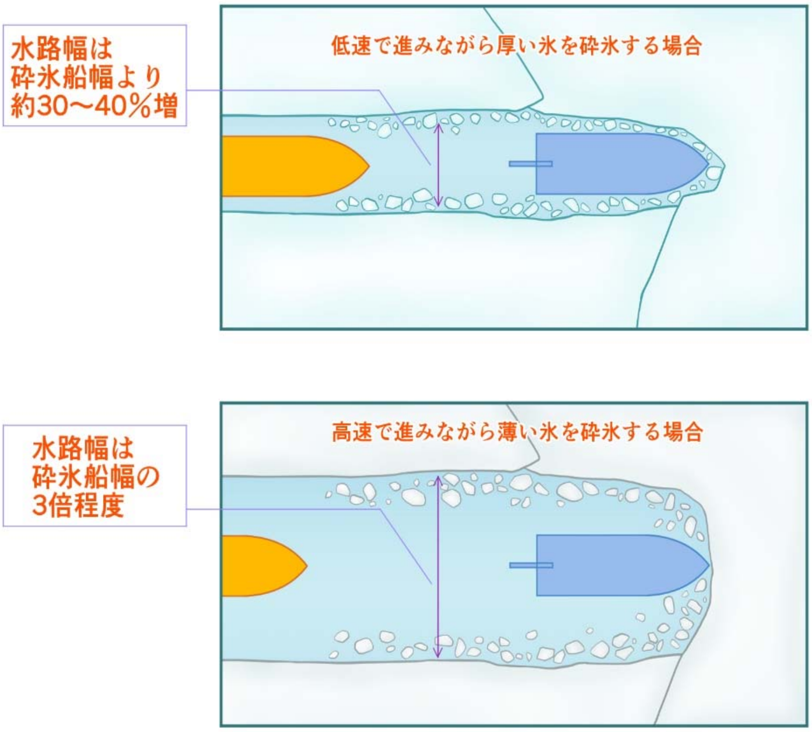


Fig. 3-23: Width of lead opened by icebreaker

・ In normal circumstances, various ice cakes of different sizes are left behind in the lead opened by an icebreaker. While an icebreaker endeavors to reduce the impact of ice on the assisted vessels which follow by carefully breaking ice into as fine sizes as possible, nevertheless, large ice cakes will sometimes enter the lead. Maintain awareness that collisions with large ice cakes, in particular when under guidance at high speed, may lead to ship hull damage.

4.2.4 Preventing expansion of distance between vessels and fleet overall length

The points to note and ship handling techniques with regards to preventing expansion of distance between vessels and fleet overall length are as follows.

- An increase of the distance between vessels and the fleet overall length can invite navigation difficulties or decreased navigation speeds for assisted vessels which accompany the closing of leads. In particular when in convoy, awareness must be maintained that an increase in distance can have a snowball effect on the ships in the fleet, with the rear assisted vessel experiencing the most severe repercussions.

Advice: Know that increases in distance build and build and the rear ship experiences the most serious repercussions!

- ・Repercussions of excessive increases in distance between vessels or fleet overall length do not stop at navigation difficulties or reduced navigation speeds for assisted vessels which accompany blocked leads. It can also lead to dangerous situations such as interrupted or suspended assisted vessel operations or guidance by icebreaker, or in worst cases an assisted vessel falling into a beset and under ice pressure, and must therefore be avoided at all costs.
- Be aware that it is surprisingly difficult for assisted vessels to maintain a constant distance as instructed by the icebreaker. Assisted vessels which are unaccustomed to sea ice areas are particularly wary of collisions with the ship in front, and tend to unconsciously lengthen the distance beyond that instructed by the icebreaker. For example, in a convoy with an icebreaker guiding three assisted vessels, if each ship opens an extra distance of a mere 60 meters, the fleet overall length will lengthen by nearly 200 meters.
- Maintain awareness that a typical mistake during guidance by icebreaker is to invite the blocking of a lead due to an increase in the distance between vessels or the fleet overall length. This can lead to suspended

operation of assisted vessels or cause them to fall into a beset. Conversely, if the distance is excessively shortened, while it cannot be claimed that collisions with ships in front never occur, it is said that the risk of a collision accident occurring is not as great as might be assumed, as long as the icebreaker determines an appropriate speed to correspond to the distance between vessels, and each assisted vessel having a steering performance above a certain level complies with the instructions of the icebreaker to work together as a single unit. The risk of accidents such as vessel crippling occurring from the blockage of a lead is greater.

Advice: Know that a typical mistake during guidance by icebreaker is an excessive distance between vessels!

4.2.5 Dealing with speed reductions

The points to note and ship handling techniques with regards to dealing with reductions in speed are as follows.

- When there is an order from the icebreaker to reduce speed during guidance by icebreaker, assisted vessels should comply immediately.
- When there is an order from the icebreaker to reduce speed during guidance by icebreaker, assisted vessels, excluding unavoidable circumstances, should never completely stop the propeller, or use the engine to go astern. If the propeller is completely stopped, there is a danger of the lead around the stern closing up. If the engine is used to go astern, there is a chance of damage to the propeller or rudder from contact with ice.
- When there is an order from the icebreaker to reduce speed during guidance by icebreaker, assisted vessels should deal with this by means

such as precision adjustments of the wheel notch to control the engine rotations, while continuing to run the engine to go forward.

- When there is an order from the icebreaker to reduce speed during guidance by icebreaker, assisted vessels should monitor developments of the ships in front and behind by means of a lookout, and consolidate continuous monitoring of the distance between vessels and speed with the navigational instruments.
- When there is an order from the icebreaker to reduce speed during guidance by icebreaker, assisted vessels should broadly swing the rudder to alternate sides as necessary to increase hull resistance and facilitate effective speed reduction, as long as they have forward momentum.
- When the distance between vessel in front has dropped below a certain level while reducing speed, an assisted vessel should swing the bow to either the left or right to assume a position to avoid a direct collision with the stern of the ship in front.

Advice: Never completely cut the propeller or go astern; when instructed to reduce speed, always do so with the engine going forward!

4.2.6 Dealing with stops, etc.

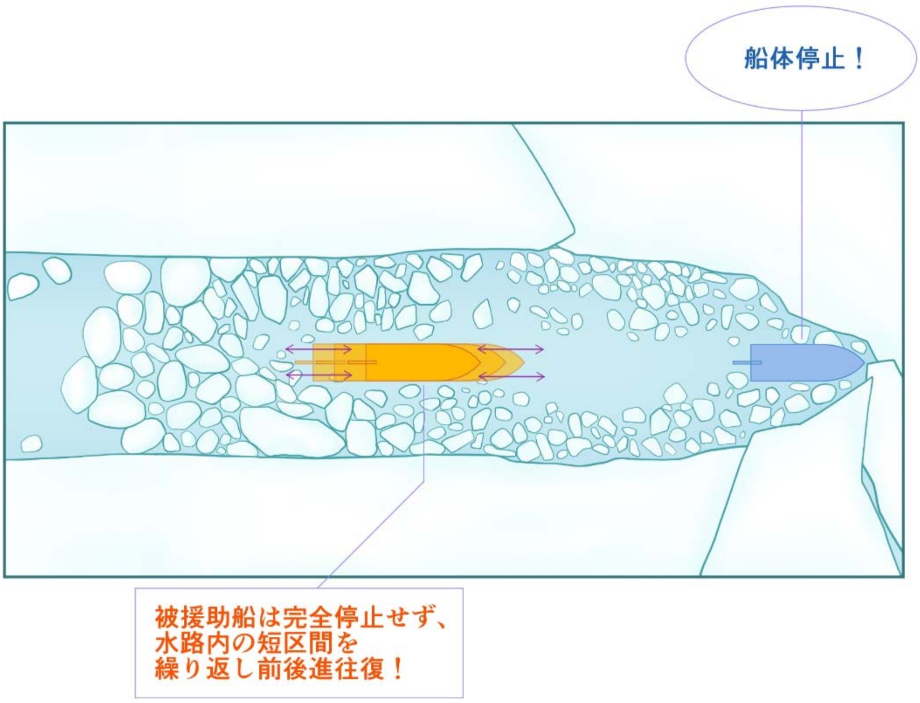
The points to note and ship handling techniques with regards to dealing with stops, etc., are as follows.

- In normal circumstances during guidance by icebreaker, an icebreaker will never stop or rapidly reduce speed (hereafter, stops, etc.) of the fleet. Nevertheless, be aware that there may be cases where, for example, an icebreaker has unexpectedly encountered severe ice conditions and it takes some time to break the ice, so unavoidable stops, etc. of the fleet will be necessitated.

- In normal circumstances, when the icebreaker stops, etc. the fleet, it will contact assisted vessels by international VHF, and any such commands should be complied with. If emergency stops, etc. are required, be aware that the icebreaker will send a warning signal such as light signals using signal lamp or audio signals such as whistles or sirens to the icebreaker and other assisted vessels as necessary.
- When there is a contact or signal from the icebreaker for fleet stops, etc., assisted vessels should consolidate monitoring of developments of the ships in front and behind by means of a lookout, and continuous monitoring of the distance between vessels and speed with the navigational instruments. They should also strive towards full consensus and mutual understanding by means of close contact and information exchange using international VHF, and so on.
- When there is a contact or signal from the icebreaker for fleet stops, etc., each assisted vessel should use its engine going astern, and immediately begin all preparations to stop. At times of stops, etc., assisted vessels, as long as they have forward momentum, should strive to broadly swing the rudder to alternate sides as necessary to increase hull resistance and reduce the stopping distance. Position the rudder amidships (central position) when forward momentum is lost and immediately before reverse movement begins, and take due care to prevent damage to the propeller, rudder, and so on from collisions with ice cakes.
- During fleet stops, etc., assisted vessels should not completely stop. If vessels completely stop, closing of the lead will gradually progress, which in worst cases could lead to a vessel being enclosed by ice and

falling into a beset, with the risk that navigation will not be able to restart without the assistance of an icebreaker. As shown in Fig. 3-24, do not stop completely, but endeavor to remain in the same place, going repeatedly forward and astern, by short interval back-and-forth movements within the lead to prevent the vessel becoming beset.

- During fleet stops, etc., should a long time pass with the assisted vessels repeating forward and reverse maneuvers to stay in place, the lead in front may finally close and the vessels will be unable go forward. In such cases, even with no possibility of going forward, it is preferable that an assisted vessel should continue to gently use the engine in forward while in contact with ice floes by its bow. This is to reduce the possibility of damage to the propeller, rudder, and so on from collision with ice cakes, along with controlling the closing of the lead towards the stern using the propeller discharge stream.



3-24: Stop method while under guidance by icebreaker

Advice: Never cut the propeller, and alternate forward and reverse movements when commanded to stop!

- During guidance by icebreaker, stops, etc. may be caused by assisted vessels in cases where the lead closes up due to too broad distance between the assisted vessels, resulting in suspended operations. If unavoidable stops, etc., are necessary, assisted vessels should immediately contact the icebreaker and defer to its instructions. During emergencies, vessels should send warning signals such as light signals using signal lamp or audio signals such as whistles or sirens as necessary to the icebreaker and other assisted vessels.
- When there is a contact or signal from an assisted vessel for stops, etc., the other assisted vessels should consolidate monitoring of developments of the ships in front and behind by means of a lookout, and continuous monitoring of the distance between vessels and speed with the navigational instruments. They should also strive towards full consensus and mutual understanding by means of close contact and information exchange using international VHF, and so on.
- When there is a contact or signal from an assisted vessel for stops, etc., the other assisted vessels should comply with the instructions of icebreaker, and make immediate preparations for stops, etc. using the engine in forward. During stops, etc., assisted vessels should continue to broadly swing the rudder to alternate sides as necessary to increase hull resistance and reduce the stopping distance as long as they have forward momentum. Position the rudder amidships (central position) when forward momentum is lost and immediately before reverse movement begins, and take due care to prevent damage to the propeller, rudder, and so on from collisions with ice cakes.

- If for any reason an assisted vessel is unable to prevent forward momentum during stops, etc., and begins to draw near to the ship in front, it should send a warning signal immediately, and assume a position to avoid the stern of the ship in front, by swinging its bow to either left or right.
- If for any reason an assisted vessel is unable to prevent forward momentum during stops, etc., and is extremely close to the ship in front, it should send a warning signal immediately, and take all measures in order to avoid a collision such as emergency full steam astern, dropping anchor, or turning. If a collision with the ship in front is inevitable, swing its bow to either left or right to avoid a direct collision with the stern of the ship in front. Be aware that getting on top of the ice cakes in the lead along the opposite broadside while swinging the bow can have the ice serve as a fender pile, and may reduce damage from collisions.

Advice: Swing the bow to avoid collisions, and get on top of the ice to reduce damage!

- If for any reason the ship behind is unable to prevent forward momentum during stops, etc., and has drawn close to your vessel, send a warning signal immediately, and cooperate to avert a collision by moving forward when the lead in front is open. Be aware that, if the lead in front is closed and a collision with the ship behind is inevitable, use of engine in full steam ahead with the bow in contact with ice floes may help to avert a direct collision with the stern, by reducing forward momentum of the ship behind with the propeller stream, or encouraging a change in the bow course of the ship behind.

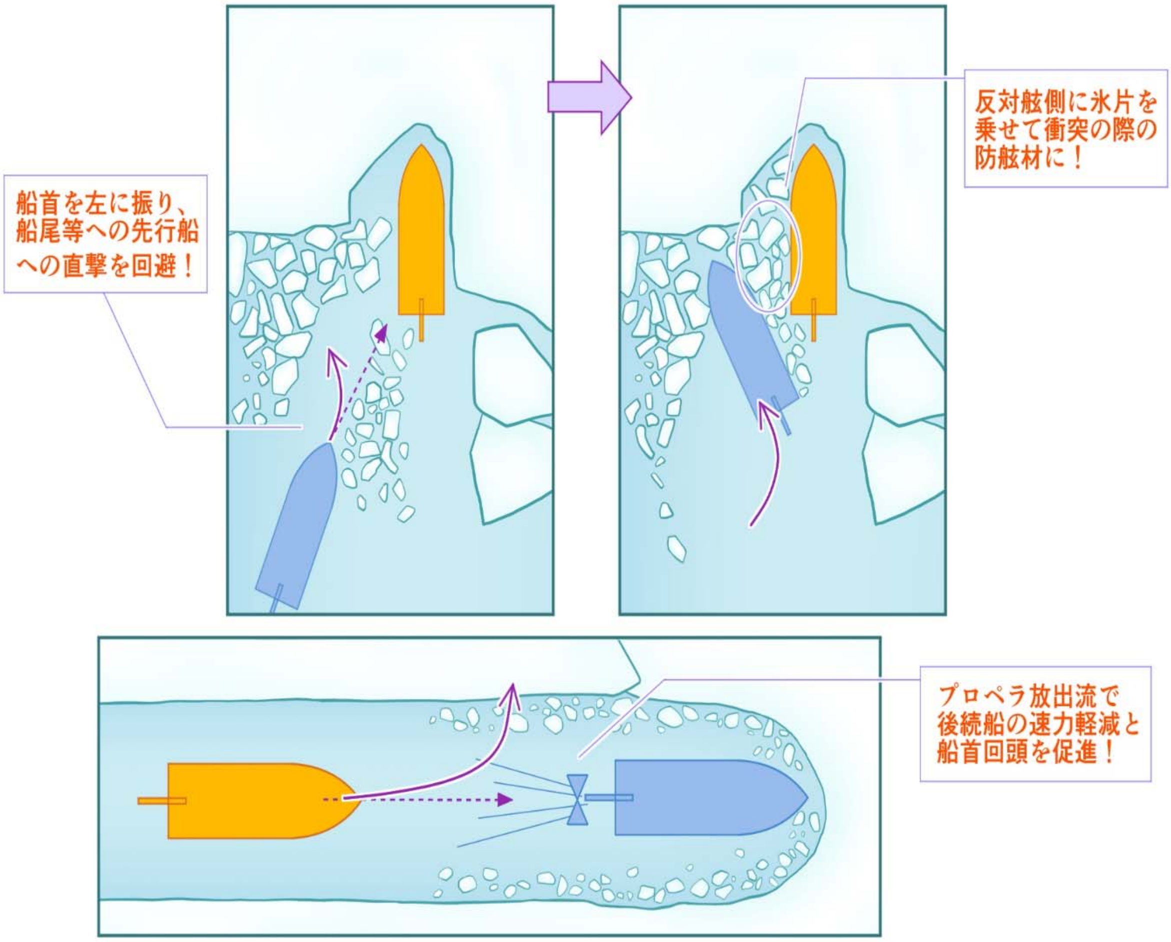


Fig. 3-25: Ship handling to avoid or reduce damage from collisions

4.3 Ship handling of assisted vessel

Icebreakers are not only responsible for opening leads and guiding assisted vessels but also perform rescue operations if an assisted vessel is unable to maneuver (crippled) or has fallen into a beset, or when there is a high chance of either. The points to note with regards to rescue methods for assisted vessels from icebreakers and ship handling of assisted vessels when they are being rescued are described as follows.

4.3.1 Assisted vessel handling for unassisted escape

If the area in front of an assisted vessel is choked with ice and there are navigation difficulties during guidance by icebreaker, or the ship is becoming beset, it should immediately contact the icebreaker and defer to its instructions.

The assisted vessel should attempt to escape unassisted by maneuvering to repeatedly go forward and astern in short bursts at full steam while turning the rudder to alternate sides.

The points to note with regards to ship handling for assisted vessels to escape under their own power are as follows.

- If the assisted vessel is biaxial, it should attempt an unassisted escape by ship handling to disperse the surrounding ice, by alternating short bursts going full steam ahead on one axel and full steam astern on the other, to alternate between forward and reverse movements on each axel.
- Beware that attempts at unassisted escapes by assisted vessels involve extremely high risk with regards to damage to the propeller or rudder, and so on, from contact with ice. When using the engine at full steam astern, pay due caution to collisions with ice floes or the vessel behind.
- An assisted vessel which has failed to escape under its own power and become unable to maneuver should immediately contact the icebreaker, and defer to its instructions. When required by emergencies, send a warning signal such as light signals using signal lamp or audio signals such as whistles or sirens to the icebreaker and other assisted vessels.

Advice: If you encounter navigation difficulties during guidance by icebreaker first attempt to escape under your own power!

4.3.2 Method of rescue by icebreaker and ship handling of assisted vessels

If an assisted vessel is unable to maneuver or has fallen into a beset during guidance by icebreaker, or there is a high chance of either, or if the ship has failed to escape unassisted, the main icebreaker leading the fleet or an auxiliary icebreaker may separate from the fleet, and head towards the assisted vessel for rescue operations.

The main icebreaker or the auxiliary icebreaker, when separating from the fleet and heading towards an assisted vessel behind it, will in normal circumstances do so going astern, as shown in Fig. 3-26. It will then pass in reverse along either the port or starboard of the assisted vessel from the bow to the stern of the assisted vessel, and remove the ice in its surroundings to open a lead.

In cases where the auxiliary icebreaker separates from the fleet to rescue an assisted vessel in front, in normal circumstances, it will approach the assisted vessel from behind using its engine going forward. It will then proceed diagonally at an angle of around 20 to 30 degrees along either the port or starboard of the assisted vessel from the direction of the stern towards the bow direction of the assisted vessel, to carry out operations to finely break up the ice around the assisted vessel and open a lead (see Fig. 3-15). Depending on ice conditions, the icebreaker may open a lead around the entire circumference of the assisted vessel.

The points to note with regards to ship handling of an assisted vessel being rescued by an icebreaker are as follows.

- When the icebreaker is going astern to pass along the broadside of an assisted vessel, in normal circumstances, the ice in front of the assisted vessel will temporarily disperse to open a lead. At the same time, a command to proceed towards that lead will be issued from the icebreaker to the assisted vessel. That lead is temporary and the ice will often assemble, causing the lead to close in a very short time. Particularly in circumstances where ice is under pronounced pressure, the lead can close in a mere 2 to 3 minutes. The assisted vessel cannot afford to hesitate to complete its escape by the timing indicated. Be prepared in advance to commence ship handling at any time in line with the instructions of icebreaker.

- Maintain awareness that when an assisted vessel is going forward in the lead in compliance with the instructions of icebreaker, the icebreaker will overtake the assisted vessel from its flank at full steam ahead, and before the assisted vessel arrives at the end of the lead which has just been opened, the icebreaker will return to the head of the convoy to attempt a restart of guidance by icebreaker.

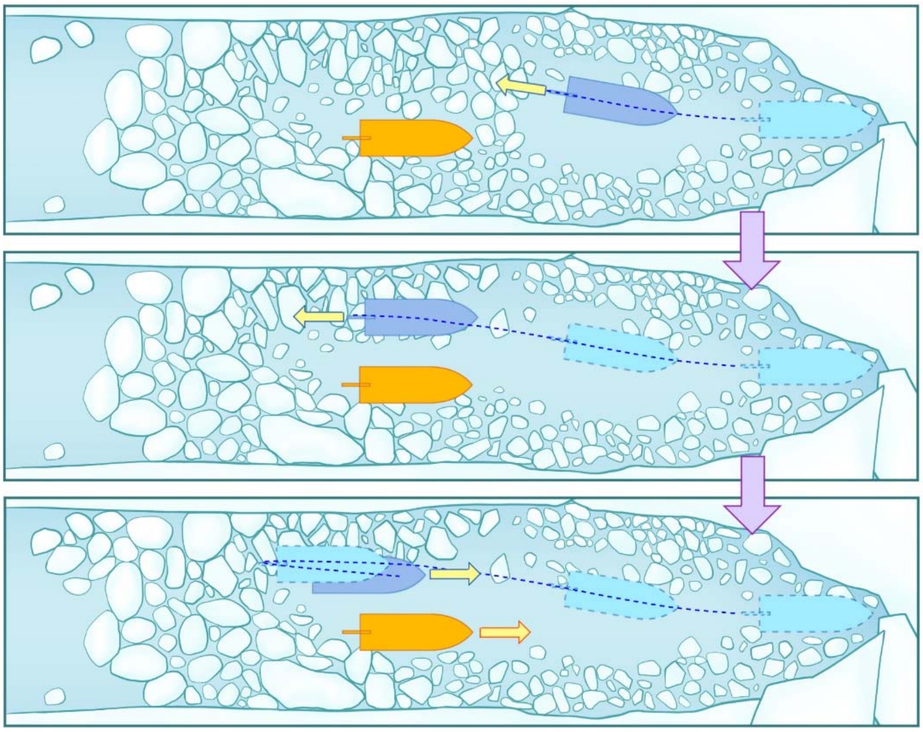


Fig. 3-26: Rescue by sternway approach (during guidance by icebreaker)

- Be aware that if the assisted vessel again becomes unable to maneuver, the icebreaker will come astern to pass along the broadside of the assisted vessel and again go forward to open a lead repeatedly until guidance by icebreaker is made possible.

- The basic principle of rescue by icebreaker is to facilitate unassisted maneuvering by an assisted vessel under its own power, and thus resume guidance by icebreaker. Be aware that the rescue method whereby the assisted vessel is towed by the icebreaker is only used as a last resort.

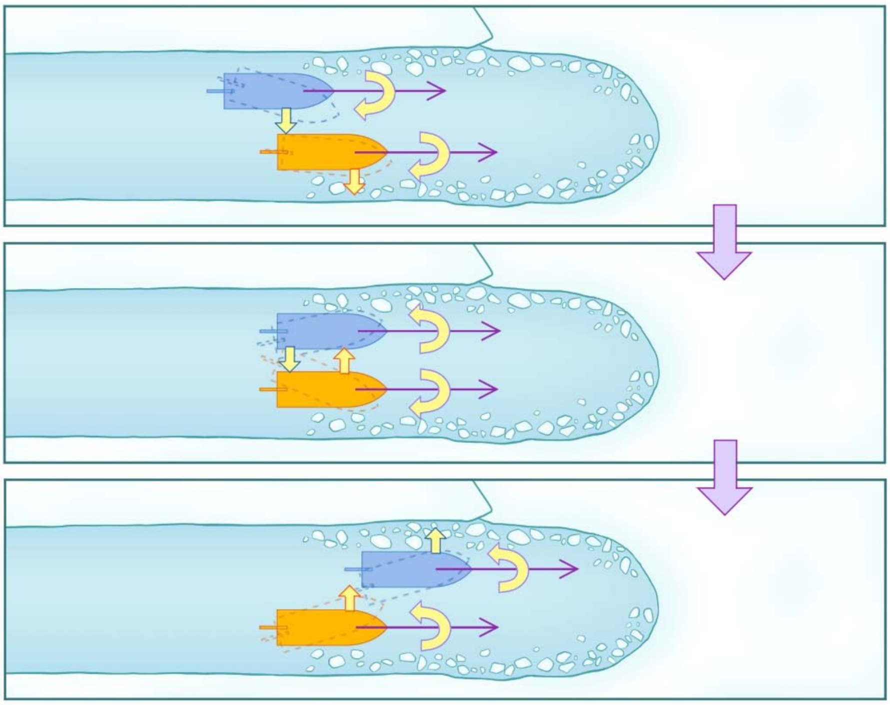


Fig. 3-27: Interaction between two vessels

4.3.3 Interaction between two vessels

When two vessels are navigating for an approach or one vessel is overtaking a stopped vessel at close range, an attractive or repellent force similar to side-wall effect occurs, due to the change of flows around the ship hull. For this reason, a turning moment is generated and phenomena whereby course keeping becomes difficult or vessels turn inadvertently may occur. This phenomenon is called an interaction between two vessels.

Be aware that there is a chance that contact or collision accidents may occur due to the interaction between two vessels during rescue of an assisted vessel by an icebreaker, as shown in Fig. 3-27. In addition, ice cakes, etc., that the icebreaker has broken and pushed through, can encroach on the flanks of the assisted vessel due to the interaction between two ships, which can also lead to damage to the propeller, rudder, etc., of the assisted vessel. Be aware in particular, that this can easily occur when the icebreaker is maneuvering at high speed.

5. Special ship handling techniques

For ship handling techniques in sea ice areas, this chapter has so far described ship handling methods for ice-strengthened ships during independent navigation, continuous-mode icebreaking methods for ice-strengthened ships, ship handling methods for icebreaker ramming, and ship handling methods for ice-strengthened ships under guidance by icebreaker. These are the most popular ship handling methods used by ice class ships in sea ice areas, and it is necessary for all navigators using the Northern Sea Route to have a prior understanding of these as basic, foundational knowledge. At the same time, additional special ship handling techniques such as ship handling for towing or anchoring may be carried out in sea ice areas. This section describes special ship handling techniques in sea ice areas mainly from the perspective of ice-strengthened ships.

5.1 Towed ship handling methods

When ice conditions are extremely poor, including sea ice areas with high concentrations of ice such as compact ice or consolidated ice, or sea ice areas under extreme pressure, assisted vessels including ice-strengthened ships may repeatedly find themselves unable to maneuver due to the closing of leads, etc., during icebreaker assistance. This can ultimately lead to a situation where the continuation of guidance by icebreaker is endangered.

At times such as this, the icebreaker may resort to towing, as a final resort to ensure the success of guidance by icebreaker for assisted vessels. Towing in sea ice areas requires both advanced ship handling and highly determined mutual operations and understanding from both the vessel towing and the ship being towed. It should be noted that towing involves high risk of a collision accident if they are not perfectly coordinated and in step with one another.

Towing in general seas is in normal circumstances used for rescue due to maritime accidents, namely when damage such as that occurring to the engine, propeller or rudder necessitates the rescue of a vessel which is no longer able to navigate unassisted. Of course such scenarios, whereby towing becomes necessary due to engine damage of an assisted vessel also occur during guidance by icebreaker, similarly to such accidents in general waters where a ship can no longer proceed unassisted.

However, in practice, most of the towing which is carried out on the Northern Sea Route is not motivated by rescue from a maritime accident, but implemented as one of the means to ensure successful guidance by icebreaker. For this reason, in contrast to towing for accident rescue, the main engine and the propeller of the assisted vessel are often in normal operation, and the assisted vessel such as an ice-strengthened ship actually uses them in compliance with the instructions of the icebreaker. This is quite characteristic of towing in sea ice areas. Towing carried out in sea ice areas can be thought of as an icebreaking ship handling method carried out in unison between the icebreaker and the assisted vessel such as an ice-strengthened ship.

The towing methods for an assisted vessel by an icebreaker, the points to note and ship handling techniques for assisted vessels such as ice-strengthened ships during towing are as follows.

5.1.1 Basic compliance rules

The compliance rules which form the basis during assisted towing are as follows.

- The towing method, the type and length of towline, tow course and tow speed, and so on during towing are decided by the icebreaker after a consolidated assessment with consideration to the ice conditions around the icebreaker, the visibility, the weather, the ship functions and steering performance of the icebreaker and the assisted vessel, the ship handling capacities of the assisted vessel, and so on. The assisted vessel should accurately comply with the relevant instructions.

- During towing, the icebreaker and the assisted vessel should facilitate perfect coordination of the operation to a level exceeding that during normal guidance by icebreaker, by means of even closer contact and information exchange to ensure that the icebreaker and the assisted vessel handle in unison with one another.
- During towing, the assisted vessel should not neglect to observe developments and continuously monitor the towing icebreaker.

Advice: Towing by an icebreaker is a last resort solution!

5.1.2 Towing method

There are following two methods of towing by an icebreaker in sea ice areas for assisted vessels such as ice-strengthened ships.

[Interval towing]

In sea ice areas, just as in general waters, a towing method is used whereby an icebreaker tows an assisted vessel using a towline while maintaining a constant interval (hereafter, interval towing).

[Close-contact towing]

A special towing method may be used in sea ice areas, whereby an icebreaker leads an assisted vessel with both ships in close contact, using a special notched device installed on the stern (stern notch) of the icebreaker (hereafter, close-contact towing), as shown in Fig. 3-28.

Close-contact towing is also called close-coupled towing, fork towing, or notch towing, and is only implemented in extremely harsh ice conditions in winter such as those found on the Northern Sea Route of the Russian coast and the Baltic Sea.

It is said that close-contact towing can be more relied on for effective navigation, as ice conditions are more uniform.

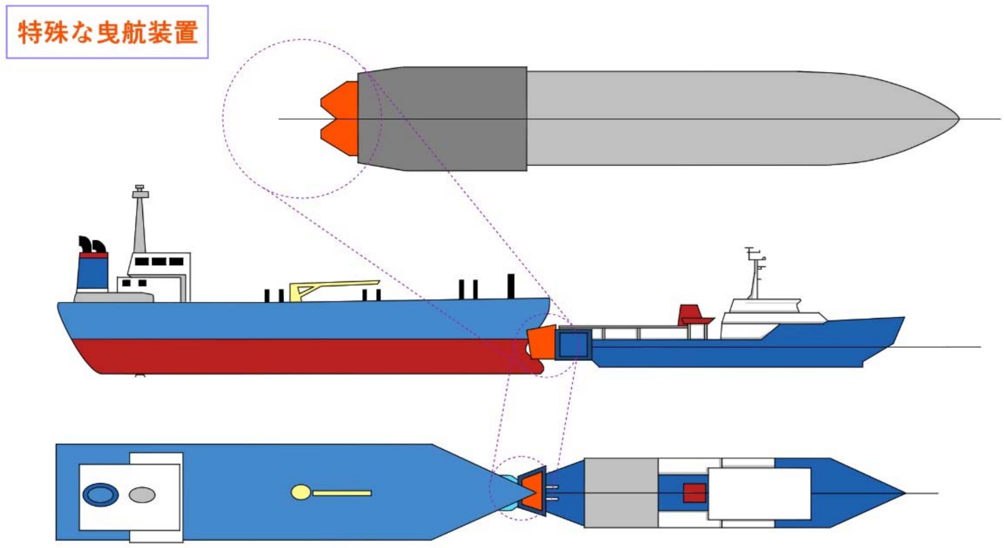


Fig. 3-28: Close-contact towing schema

5.1.3 Use of the main engine

The points to note and ship handling techniques with regards to use of the main engine of assisted vessels such as ice-strengthened ships are as follows.

- During towing, an assisted vessel with a fully functional main engine should use that main engine in compliance with the instructions of the icebreaker. The assisted vessel should under no circumstances use the engine on its own, in particular to go forward, during interval towing, from the viewpoint of preventing collisions with the icebreaker, unless special instructions from the icebreaker to do so are issued.
- The assisted vessel must be prepared to use the main engine to go astern at any time during towing.
- There will often be instructions from the icebreaker to the assisted vessel

for precision deployment of the main engine during interval towing, to ensure that a constant distance is maintained to prevent a collision between the icebreaker and the assisted vessel, to prevent cutting of the towline, or to prevent the lead opened by the icebreaker from closing. Maintain awareness that, in contrast to towing in general waters, the assisted vessel is more likely to use its main engine.

- During close-contact towing, the assisted vessel may be instructed to have its engine going forward and at times be instructed to go full steam ahead, to complement the engine output of the icebreaker and facilitate improved icebreaking capacity. Be aware that close-contact towing, in contrast to interval towing, is strongly associated with integrated icebreaking work by the icebreaker and the assisted vessel.
- In normal circumstances, speeds during towing are within a few knots. Be aware that the change in speed of the assisted vessel increases as towing speed increases, which can invite the risk of accidents such as collisions with the icebreaker or cutting of the towline.

Advice: Deploy the main engine in compliance with the instructions of icebreaker during towing!

5.1.4 Dealing with speed reductions

The points to note and ship handling techniques with regards to dealing with speed reductions during towing for assisted vessels such as ice-strengthened ships are as follows.

- When there is an instruction from the icebreaker to reduce speed during towing, the assisted vessel running the engine in forward should immediately comply.
- When there is an instruction from the icebreaker to reduce speed during

towing, the assisted vessel running the engine in forward should not completely cut the propeller or use the engine going astern, excepting cases when this is unavoidable, in order to prevent closing of the lead around the ship stern.

- When there is an instruction from the icebreaker to reduce speed during towing, the assisted vessel running the engine in forward should deal with this by means such as minute adjustments of the wheel notch to adjust engine speed by continuing to run its engine in forward.
- When there is an instruction from the icebreaker to reduce speed during towing, the assisted vessel running the engine in forward should consolidate monitoring of developments of the icebreaker in front by means of a lookout, and continuous monitoring of the distance between vessels and speed with the navigational instruments.
- When there is an instruction from the icebreaker to reduce speed during towing, as long as there is forward momentum, the assisted vessel running the engine in forward should swing the rudder broadly to alternate sides to increase hull resistance and improve retarding effect, as necessary.
- When the distance between the icebreaker in front shortens to less than a certain level as a result of an instruction from the icebreaker to reduce speed during towing, the assisted vessel should swing the bow of the vessel to either left or right to assume a position to avoid a collision with the stern of the vessel in front.

5.1.5 Dealing with stops, etc.

The points to note and ship handling techniques for dealing with stops, etc. by assisted vessels such as ice-strengthened ships are as follows.

- In normal circumstances, when an icebreaker executes a stop or a rapid speed reduction during towing (hereafter, stops, etc.), it will contact the assisted vessel by international VHF, and the assisted vessel should comply with these instructions. Be aware that, when required by emergency, the icebreaker may send warning signals such as light signals using signal lamp, or audio signaling such as whistles or sirens.
- When there is a contact or signal from the icebreaker for stops, etc., during towing, the assisted vessel should consolidate monitoring of developments of the icebreaker by means of a lookout, and continuous monitoring of the distance between vessels and speed with the navigational instruments, and ensure good communication by means of close contact and information exchange using international VHF, and so on.
- When there is a contact or signal from the icebreaker for stops, etc., during towing, the assisted vessel should use its engine going astern, and immediately begin all preparations to stop. At times of stops, etc., the assisted vessel, as long as it has forward momentum, should strive to broadly swing the rudder to alternate sides to increase hull resistance and reduce the stopping distance. Position the rudder amidships (central position) when forward momentum is lost and immediately before reverse movement begins, and take due care to prevent damage to the propeller, rudder, and so on from collisions with ice cakes.
- The master of the assisted vessel who has judged that a collision with the icebreaker cannot be avoided during towing should put the engine in reverse under his own initiative to avoid a collision without waiting for instructions from the icebreaker.
- The assisted vessel, excepting circumstances where it is otherwise

unavoidable, should not completely cut the propeller during stops, etc., when being towed, in order to prevent the closing of a lead around the stern.

5.1.6 Lookout

The points to note with regards to lookout by assisted vessels such as ice-strengthened ships are as follows.

- During towing, the assisted vessel should also deploy lookout at the bow to assign duties such as monitoring of developments of the icebreaker and confirmation of the towline status.
- The bow lookout should carefully monitor for signs of towline abnormalities, etc., in particular when towing is begun and until the designated speed is reached.
- The bow lookout must not neglect to position the friction resistant mat, etc., at the point of contact of the towline and the ship, and apply lubricating grease.

Advice: Post an additional lookout at the bow during towing!

5.1.7 Towline length

An estimate of towline length for interval towing in general waters *S*(*m*) is said to be around 1.75 times the sum of the towing ship length *L1(m)* and the towed ship length *L2(m)*.

$$S = 1.75\,(L1 + L2)$$

An icebreaker with an overall length of 160 meters, towing a Handymax Bulk

Carrier with an overall length of 185 meters, would have a towline length of 604 meters.

Meanwhile, instructions for the towline length for interval towing in sea ice areas are often considerably shorter when compared to general waters. This is because there is a chance that, if the towline is too long, a lead that the icebreaker has opened will close before the assisted vessel passes through.

The points to note with regards to the towline length are as follows.

- The towline length for interval towing in sea ice areas is greatly influenced by the surrounding ice conditions, in particular the ice concentration. In sea ice areas with high concentrations of sea ice such as compact ice or consolidated ice of 10/10 (1.0) concentrations, or sea ice areas under extremely strong pressure, instructions for extremely short towline of around 0.5 cables (around 93 meters) may be issued, as a lead will close rapidly in such areas.
- In sea ice areas with low concentrations of sea ice such as open ice of 4/10 (0.4) to 6/10 (0.6) concentration or very open ice of 1/10 (0.1) to 3/10 (0.3) concentrations, instructions for towline of between 0.5 cables (around 93 meters) and 1.5 cables (around 278 meters) may be issued, as a lead will close slowly in such areas.
- For open waters, instructions for towline length approximately the same as that used in general waters may be issued.

Advice: Remember that the towline length is shorter in sea ice areas than in general waters!

5.1.8 Towline configuration and combination

The towline used for interval towing generally consists of a towing wire and towing chain, and these are connected with a joining shackle, as shown in Fig.

3-29. The points to note with regards to the configuration and combination of towlines are as follows.

- A towline should be sturdy and its length is easily adjustable.
- Be aware that a towing hawser (fiber towline) or fuse wire (thin diameter wire standing in for towing wire) may be deployed in the central part of the towline for their buffering or incisory effect during exponential tensile force.
- A towline is generally secured on a bollard, etc., in the bow of the assisted vessel with a wire rope.

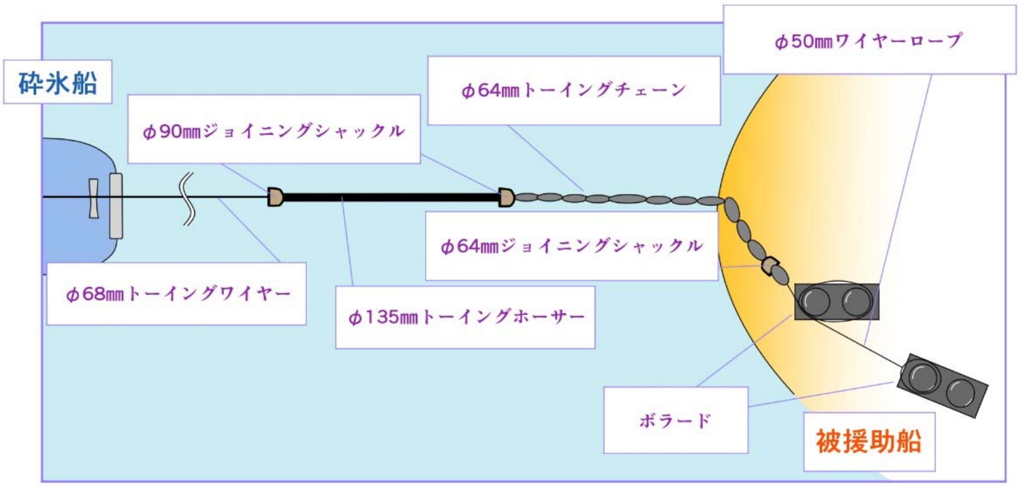


Fig. 3-29: Example of towline configuration and combination

5.1.9 Catenary

The towline during towing hangs down under its own weight in a catenary curve, and may be submerged in the sea partially, as shown in Fig. 3-30. The relationship between the towline length *S(m)*, the drooping towline mass *d(m)*, the droop angle *φ(°)*, the weight of 1 meter of towline *w(kg)*, and the towed vessel resistance *R(kg)* is expressed by the following formula.

$$S = 2\sqrt{d\left(d + \frac{2R}{w}\right)} \quad d = \frac{R(\sec\varphi - 1)}{w}$$

Generally, the towline will not easily snap even if exponential tensile force is exerted when the towline is long, as the catenary curve expands and the drooping towline mass increases. However, if the towline is too long, there is an increased risk of difficulties such as severing due to contact with ice cakes or passing through the underside of ice floes, as the portion submerged in the sea increases.

Advice: When the towline is too long, it could be severed by ice!

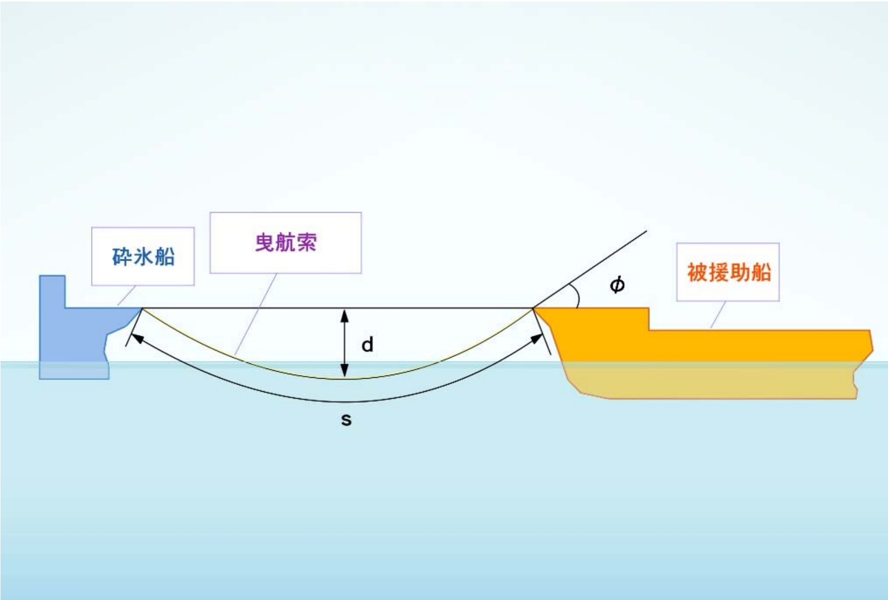


Fig. 3-30 Towline droop

5.1.10 Tensile force of towline

Factors contributing to load on the towline during towing in sea ice areas include both the resistance force of the towed vessel and the impact forces which accompany the speed difference between the towed vessel and the icebreaker, and the impact forces which accompany sudden acceleration needed for icebreaking and stops, etc. For this reason, the loads exerted on the towline tend to be greater when compared with towing in general waters. It is necessary to pay due caution to accidents involving towline severance.

5.2 Ship handling for anchorage and moorage

Ice-strengthened ships mooring on ice floes or anchoring in sea ice areas will be confronted with dangers such as impact with ice floe or hull compression accompanying besetment, require advanced ship handling techniques and long-term operation beyond expectation. Such operations should, for these and other reasons, be avoided, except in cases where such anchorage or moorage is otherwise unavoidable.

In order to avoid maritime accidents, etc., when mooring on ice floes or anchoring in sea ice areas for unavoidable reasons, ice-strengthened ships should carry out ship handling with reference to the following points to note and techniques.

Advice: Moorage to ice floes or anchorage in sea ice areas is forbidden barring unavoidable circumstances!

5.2.1 Selection of sea ice area

The points to note with regards to the selection of sea ice area for moorage or anchorage are as follows.

- Excepting unavoidable circumstances, ice-strengthened ships or non-ice-strengthened ships should never enter fast ice areas connected to the shoreline for the purpose of moorage or anchorage.

- Sea ice area with no iceberg or glacier on the periphery should be selected for moorage or anchorage, to avoid the danger of hull damage from impacts.
- Sea ice area with polynya or open water on the windward side, or sea ice area with the lowest possible ice concentration on the windward side should be selected, to avoid dangers such as hull compression accompanying besetment or collisions with ice floes. These polynya or open water should preferably be of sufficient extent to allow plenty of leeway for turning or maneuvering for course change.

Advice: Select sea ice area with polynya or open water on the windward side!

- Sea ice areas in stormy weather should not be selected as locations for moorage or anchoring, as there is a significant danger of propeller, rudder, or hull damage due to collisions with ice floes. If a sea ice area is entered in stormy weather, immediate evacuation to safe sea areas along the ice edge or finding and heaving to in a location at a sufficiently safe distance from the sea ice area or open water is recommended.
- There is a risk of propeller, rudder or hull damage due to collisions with ice floes in sea ice areas with big swells, meaning that they should not be selected as locations for moorage or anchoring. Meanwhile, it is said that sea ice areas where swells are barely perceptible have a comparatively low danger of besetment.
- There is considerable danger of hull compression accompanying besetment in sea ice areas around the ice edge of fast ice, and hard hummocks or ridges form easily in these areas, meaning that they should not be selected as locations for moorage or anchorage.

- Select sea ice areas with the shallowest depths possible for anchorage.

Advice: Avoid sea ice areas where stormy weather is developing and sea ice areas around the ice edge of fast ice!

5.2.2 Selection of ice floe

The points to note with regards to selecting an ice floe for moorage by ice-strengthened ships are as follows.

- Select a sturdy ice floe with a stable form and a width and thickness above a certain level.
- Select an ice floe with as straight and level an ice edge as possible. Also, select the one which rises deep and sheer to the submerged part, and with as little as possible of the protruding part in the sea.
- When mooring on an ice floe to avoid stormy weather, select the one with a positional aspect to bear the brunt of the worst possible ongoing forecast gales in the direction of the bow.

Advice: Select a sturdy ice floe with a stable form and a straight and level ice edge for moorage!

5.2.3 Ship handling for moorage

The points to note and techniques with regards to ship handling for moorage by ice-strengthened ships are as follows.

- When implementing ship handling for the purpose of mooring on an ice floe, the ice floe should be approached from the bow parts, and maneuvering should be done to achieve a course as perpendicular to the ice edge as possible.
- When the bow parts first make contact with the ice floe, this should be at the lowest speed possible to avoid excessive impact. Take due care not

to collide with the ice floe in situations where you cannot maintain steerage due to excessive speed reduction.

- If it appears that the bow parts have successfully made contact with the ice floe, continue to quietly run the engine going forward while pressing the bow parts against the ice floe. The mooring cable should be let out with the hull settled perpendicular to the ice edge. Continue to maintain this hull position until the locking of the bow mooring cable is completed.
- When locking of the bow mooring cable to the ice floe is completed, use the engine and the rudder to go forward and astern as needed, and complete a 90 degree turn with the moor point as the fulcrum, to carefully make the ship parallel and adhere with the ice floe. Any ice cakes between the floe and the hull should preferably be eliminated at this time using the stream from the propeller whenever possible.

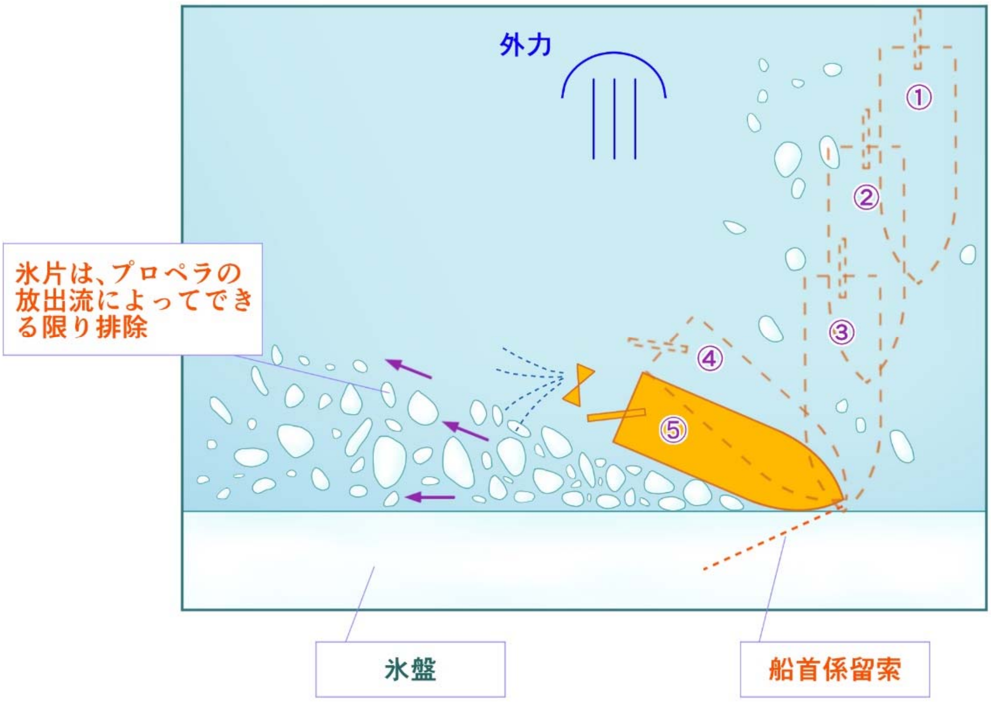


Fig. 3-31: Ship handling method to moor to ice floe

Advice: Approach at a 90 degrees angle of passage to the ice floe!

- When ship handling for mooring, ensure to maintain a hull position to keep the stern clear, in order to protect the propeller and the rudder from damage due to contact with ice.
- When ship handling for mooring, ships reserving side thrusters should appropriately and effectively deploy them for effective ship handling or maintaining hull position.
- When ship handling for mooring, take the brunt of external forces (sea currents and wind) from the stern direction of the ship, as far as this is feasible.

Pic. 3-21: Canadian Coast Guard icebreaker moored to an ice floe

(courtesy of Kazutaka Tateyama)

5.2.4 Moorage tools

When locking the moorage cable to an ice floe, a small portable anchor called an ice anchor is deployed especially for this purpose. A device called a deadman may also be used. A deadman is a self-assembled moorage tool using timbers, wire rope, etc., in the deck.

In normal circumstances, a rectangular hole is cut in the ice, and a sturdy timber baulk on which the wire rope, etc., is wound (this is originally referred to as the deadman) is buried in this hole. Water is then poured into this hole to freeze the deadman in place. After it has completely frozen in place, the wire rope, etc., extending from the deadman, is threaded through a nylon cable, toggle and link, and when this is attached to the mooring cable extending from the ship, the operation is complete.

The toggle has an emergency release rope called a toggle cable. This configuration ensures that the mooring cable can be reeled off in emergency situations where it becomes necessary to abandon ice floe moorage. The toggle cable is pulled from the deck to release the toggle, and the knot of the nylon cable unravels without anyone having to get out on the ice.

Advice: Make a deadman for moorage to an ice floe!

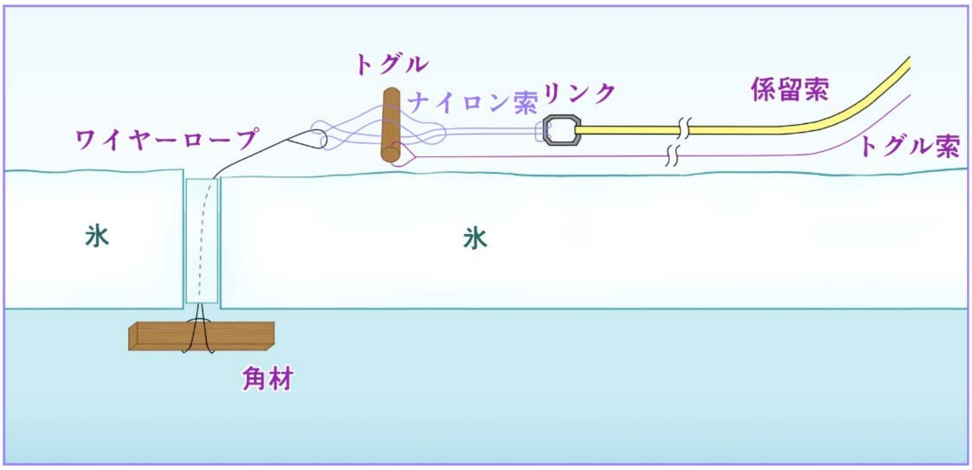


Fig. 3-32: Deadman configuration

5.2.5 Ship handling for anchorage

The points to note and techniques with regards to ship handling for anchorage by ice-strengthened ships are as follows.

- During ship handling for anchorage, there is a possibility of damage to the propeller or rudder from contact with ice cakes, etc., meaning that you should not use the engine to go astern whenever possible.
- If you unavoidably have to use the engine to go astern during ship handling for anchorage, in principle, go dead slow astern, that is only go astern at incremental speeds, and ensure that the rudder is amidships (central position) when you have astern momentum.
- If you unavoidably have to use the engine to go astern during ship handling for anchorage, an effective ship handling technique to prevent damage to the propeller or rudder due to contact with ice cakes, is to use the engine to go forward in short bursts at high power immediately before going astern, in order to dispel ice cakes floating in the vicinity of the stern using the propeller stream. When using this ship handling technique, maintain close contact with the stern lookout, and pay intimate care not to crash the stern into the ice floe behind.
- During ship handling for anchorage, ensure to maintain a hull position to keep the stern clear, in order to protect the propeller and the rudder from damage due to contact with ice.
- Anchor chain should be made as short as possible. If it is too long, when an emergency arises and it becomes necessary to abandon anchor, you may not be able to deal with this rapidly.
- When the water depths are too great to be favorable to anchorage, a vessel should also consider drifting along in the sea ice area with the ice without dropping anchor, only if given conditions are met with regards to

the weather and hydrographic conditions, the ice conditions, the visibility, and ship function and steering performance, etc., and when it can be judged that there is a low risk of collisions with ice or besetment.

Advice: Make the anchor chain as short as possible when anchoring in sea ice areas!

5.2.6 Precautions during moorage or anchorage

Points to note during moorage or anchorage for ice-strengthened ships are as follows.

- During moorage to an ice floe or anchorage in a sea ice area, strictly assign a person for anchor watch, to pay close attention for any signs of besetment or hull compression, etc., changes in the surrounding ice conditions, sudden changes in the weather, etc.
- During moorage to an ice floe or anchorage in a sea ice area, do not neglect to acquire and analyze the latest information on weather and ice conditions, and try to have a grasp of at least the general characteristics of the weather, hydrographic conditions and ice conditions in the vicinities of the sea area, the position and circumstances of the ice edge, and forecast changes in the weather, hydrographic conditions and ice conditions for the forthcoming several days.
- During moorage to an ice floe or anchorage in a sea ice area, alert for main engine standby and be prepared to use it at any time.
- There is a risk of polar bear attacks during ice floe moorage, so no one should in principle go ashore unless the vessel has a bearwatcher onboard. Note that a polar bear is the most formidable beast of prey found on land, and around 22,000 make their habitat in the Arctic Ocean and surroundings. Males are 2 to 3 meters tall, with a body weight

reaching 300 to 800 kilograms, prey on seals, reindeers, beluga (white whales), and move over broad expanses of the ice in the Arctic Ocean. They are more dangerous than brown bears and also attack humans.

- During moorage to an ice floe or anchorage in a sea ice area, the windlass or the mooring winch should be idling to ensure usability at any time. That is, they should be kept running at low speed and not completely stopped, with each part kept warm.

Advice: never go onto the ice floe unprepared - polar bears will attack!

Pic. 3-22: Polar bear which has approached alongside an icebreaker

(courtesy of Hiroki Shibata)

Pic. 3-23: Canadian bearwatcher equipped with rifle (courtesy of Koji Shimada)

5.3 Ship handling in stormy weather

In the past during the peak season for passages in summer, the weather of the Northern Sea Route was comparatively mild, and passages rarely encountered stormy weather. However, in recent times, navigating vessels often encounter stormy weather in the seas around the Northern Sea Route. This situation is caused by a temperature difference between the warmer sea surfaces and the ice due to the decrease of ice, which develops clouds in vertical direction, resulting in the occurrence of low pressures. The more pronounced the decline trend of ice is, the more intense the low pressure activity becomes in summer, and vessels may at times encounter stormy weather on a level with typhoons. Vessels navigating the Northern Sea Route should pay due heed to this possibility.

Ice-strengthened ships encountering stormy weather in sea ice areas or their vicinities should maneuver with reference to the following points.

- In principle, evacuate to safe waters along the ice edge, or find open waters and heave to, when stormy weather is encountered in sea ice areas or their vicinities. Ice in sea ice areas acts to buffer from wind and calm waves, with the result that conditions are often milder when compared to those in open waters, even in stormy weather. Accordingly, if given conditions are met with regards to the weather and hydrographic conditions, the ice conditions, the visibility, and ship function and steering performance, etc., and it can be judged that there is a low risk of collisions with ice or besetment in sea ice areas, vessels should also consider the measure of entering sea ice areas to retreat from stormy weather.

- When heaving to after encountering stormy weather, reduce speed to the lowest level at which steering can be maintained, and effectively employ ship handling to maintain position with the bow positioned to receive waves diagonally from ship front.
- Heaving to in a sea area in the vicinity of a sea ice area after encountering stormy weather should be avoided whenever possible, as there is a danger of a collision with ice edges or becoming beset by entering a sea ice area. Heave to should always be completed in a location at a sufficiently safe distance from the sea ice area, while continually anticipating its direction of movement.

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Published by: The Japan Association of Marine Safety (JAMS)
Isomura Building 6F, Toranomon 1-1-3
Minato-ku, Tokyo 105-0001 Japan
TEL: +81 3 (3502) 2231, FAX: +81 3 (3581) 6136