Ice Reinforcement Selection in Different World Navigation Areas

September 2013

Guidance Note
NI 543 DT R01 E

Marine Division
92571 Neuilly sur Seine Cedex – France
Tel: +33 (0)1 55 24 70 00 – Fax: +33 (0)1 55 24 70 25
Marine website: http://www.veristar.com
Email: veristarinfo@bureauveritas.com

BUREAU VERITAS

MARINE & OFFSHORE DIVISION

GENERAL CONDITIONS

ARTICLE 1

1.1. - BUREAU VERITAS is a Society the purpose of whose Marine & Offshore Division (the "Society") is the classification (" Classification ") of any ship or vessel or offshore unit or structure of any type or part of it or system therein collectively hereinafter referred to as a "Unit" whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

The Society:

- "prepares and publishes Rules for classification, Guidance Notes and other documents (" Rules ");
- "issues Certificates, Attestations and Reports following its interventions (" Certificates ");
- "publishes Registers.

1.2. - The Society also participates in the application of National and International Regulations or Standards, in particular by delegation from different Governments. Those activities are hereafter collectively referred to as " Certification ".

1.3. - The Society can also provide services related to Classification and Certification such as ship and company safety management certification; ship and port security certification, training activities; all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board.

1.4. - The interventions mentioned in 1.1., 1.2. and 1.3. are referred to as " Services ". The party and/or its representative requesting the services is hereinafter referred to as the " Client ". **The Services are prepared and carried out on the assumption that the Clients are aware of the International Maritime and/or Offshore Industry (the "Industry") practices.**

1.5. - The Society is neither and may not be considered as an Underwriter, Broker in ship's sale or chartering, Expert in Unit's valuation, Consulting Engineer, Controller, Naval Architect, Manufacturer, Shipbuilder, Repair yard, Charterer or Shipowner who are not relieved of any of their expressed or implied obligations by the interventions of the Society.

ARTICLE 2

2.1. - Classification is the appraisement given by the Society for its Client, at a certain date, following surveys by its Surveyors along the lines specified in Articles 3 and 4 hereafter on the level of compliance of a Unit to its Rules or part of them. This appraisement is represented by a class entered on the Certificates and periodically transcribed in the Society's Register.

2.2. - Certification is carried out by the Society along the same lines as set out in Articles 3 and 4 hereafter and with reference to the applicable National and International Regulations or Standards.

2.3. - **It is incumbent upon the Client to maintain the condition of the Unit after surveys, to present the Unit for surveys and to inform the Society without delay of circumstances which may affect the given appraisement or cause to modify its scope.**

2.4. - The Client is to give to the Society all access and information necessary for the safe and efficient performance of the requested Services. The Client is the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out.

ARTICLE 3

3.1. - **The Rules, procedures and instructions of the Society take into account at the date of their preparation the state of currently available and proven technical knowledge of the Industry. They are a collection of minimum requirements but not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.**

Committees consisting of personalities from the Industry contribute to the development of those documents.

3.2. - **The Society only is qualified to apply its Rules and to interpret them. Any reference to them has no effect unless it involves the Society's intervention.**

3.3. - The Services of the Society are carried out by professional Surveyors according to the applicable Rules and to the Code of Ethics of the Society. Surveyors have authority to decide locally on matters related to classification and certification of the Units, unless the Rules provide otherwise.

3.4. - **The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not in any circumstances involve monitoring or exhaustive verification.**

ARTICLE 4

4.1. - The Society, acting by reference to its Rules:

- "reviews the construction arrangements of the Units as shown on the documents presented by the Client;
- "conducts surveys at the place of their construction;
- "classes Units and enters their class in its Register;
- "surveys periodically the Units in service to note that the requirements for the maintenance of class are met.

The Client is to inform the Society without delay of circumstances which may cause the date or the extent of the surveys to be changed.

ARTICLE 5

5.1. - **The Society acts as a provider of services. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty.**

5.2. - **The certificates issued by the Society pursuant to 5.1. here above are a statement on the level of compliance of the Unit to its Rules or to the documents of reference for the Services provided for.**

In particular, the Society does not engage in any work relating to the design, building, production or repair checks, neither in the operation of the Units or in their trade, neither in any advisory services, and cannot be held liable on those accounts. Its certificates cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

5.3. - **The Society does not declare the acceptance or commissioning of a Unit, nor of its construction in conformity with its design, that being the exclusive responsibility of its owner or builder.**

5.4. - The Services of the Society cannot create any obligation bearing on the Society or constitute any warranty of proper operation, beyond any representation set forth in the Rules, of any Unit, equipment or machinery, computer software of any sort or other comparable concepts that has been subject to any survey by the Society.

ARTICLE 6

6.1. - The Society accepts no responsibility for the use of information related to its Services which was not provided for the purpose by the Society or with its assistance.

6.2. - **If the Services of the Society or their omission cause to the Client a damage which is proved to be the direct and reasonably foreseeable consequence of an error or omission of the Society, its liability towards the Client is limited to ten times the amount of fee paid for the Service having caused the damage, provided however that this limit shall be subject to a minimum of eight thousand (8,000) Euro, and to a maximum which is the greater of eight hundred thousand (800,000) Euro and one and a half times the above mentioned fee. These limits apply regardless of fault including breach of contract, breach of warranty, tort, strict liability, breach of statute, etc.**

The Society bears no liability for indirect or consequential loss whether arising naturally or not as a consequence of the Services or their omission such as loss of revenue, loss of profit, loss of production, loss relative to other contracts and indemnities for termination of other agreements.

6.3. - All claims are to be presented to the Society in writing within three months of the date when the Services were supplied or (if later) the date when the events which are relied on of were first known to the Client, and any claim which is not so presented shall be deemed waived and absolutely barred. Time is to be interrupted thereafter with the same periodicity.

ARTICLE 7

7.1. - Requests for Services are to be in writing.

7.2. - **Either the Client or the Society can terminate as of right the requested Services after giving the other party thirty days' written notice, for convenience, and without prejudice to the provisions in Article 8 hereunder.**

7.3. - The class granted to the concerned Units and the previously issued certificates remain valid until the date of effect of the notice issued according to 7.2. here above subject to compliance with 2.3. here above and Article 8 hereunder.

7.4. - The contract for classification and/or certification of a Unit cannot be transferred neither assigned.

ARTICLE 8

8.1. - The Services of the Society, whether completed or not, involve, for the part carried out, the payment of fee upon receipt of the invoice and the reimbursement of the expenses incurred.

8.2. - **Overdue amounts are increased as of right by interest in accordance with the applicable legislation.**

8.3. - **The class of a Unit may be suspended in the event of non-payment of fee after a first unfruitful notification to pay.**

ARTICLE 9

9.1. - The documents and data provided to or prepared by the Society for its Services, and the information available to the Society, are treated as confidential. However:

- "Clients have access to the data they have provided to the Society and, during the period of classification of the Unit for them, to the **classification file** consisting of survey reports and certificates which have been prepared at any time by the Society for the classification of the Unit ;
- "copy of the documents made available for the classification of the Unit and of available survey reports can be handed over to another Classification Society, where appropriate, in case of the Unit's transfer of class;
- "the data relative to the evolution of the Register, to the class suspension and to the survey status of the Units, as well as general technical information related to hull and equipment damages, may be passed on to IACS (International Association of Classification Societies) according to the association working rules;
- "the certificates, documents and information relative to the Units classed with the Society may be reviewed during certificating bodies audits and are disclosed upon order of the concerned governmental or inter-governmental authorities or of a Court having jurisdiction.

The documents and data are subject to a file management plan.

ARTICLE 10

10.1. - Any delay or shortcoming in the performance of its Services by the Society arising from an event not reasonably foreseeable by or beyond the control of the Society shall be deemed not to be a breach of contract.

ARTICLE 11

11.1. - In case of diverging opinions during surveys between the Client and the Society's surveyor, the Society may designate another of its surveyors at the request of the Client.

11.2. - Disagreements of a technical nature between the Client and the Society can be submitted by the Society to the advice of its Marine Advisory Committee.

ARTICLE 12

12.1. - Disputes over the Services carried out by delegation of Governments are assessed within the framework of the applicable agreements with the States, international Conventions and national rules.

12.2. - Disputes arising out of the payment of the Society's invoices by the Client are submitted to the Court of Nanterre, France, or to another Court as deemed fit by the Society.

12.3. - **Other disputes over the present General Conditions or over the Services of the Society are exclusively submitted to arbitration, by three arbitrators, in London according to the Arbitration Act 1996 or any statutory modification or re-enactment thereof. The contract between the Society and the Client shall be governed by English law.**

ARTICLE 13

13.1. - **These General Conditions constitute the sole contractual obligations binding together the Society and the Client, to the exclusion of all other representation, statements, terms, conditions whether express or implied. They may be varied in writing by mutual agreement. They are not varied by any purchase order or other document of the Client serving similar purpose.**

13.2. - The invalidity of one or more stipulations of the present General Conditions does not affect the validity of the remaining provisions.

13.3. - The definitions herein take precedence over any definitions serving the same purpose which may appear in other documents issued by the Society.

BV Mod. Ad. ME 545 L - 7 January 2013

Contents

1. INTRODUCTION

1.1. Purpose of the document

This Guidance Note on the ice reinforcement selection in different world areas is aimed to provide advice on the Ice Class or Polar Class notation to be adopted for the navigation in areas such as the Canadian Arctic, the Greenland waters, the Russian Arctic, the Baltic Sea, the Antarctic and some other locations in Central and Eastern Europe. Based on the climatic conditions in a given area at a specific time of the year and the local legislation where applicable, this Note allows identifying the most appropriate additional class notation for navigation in ice.

1.2. Ice Class and Polar Class notations

To operate in ice environment, ships need suitable reinforcements, relying on the additional class notation assigned for navigation in ice.

The additional class notations for navigation in ice are divided into two categories:

- the **Ice Class notations** [1] for navigation in first-year ice environment,
- the **Polar Class notations** [2] for navigation in Arctic and Antarctic waters, where multi-year ice might occur

These notations provide requirements for both hull strengthening and propulsion, but they do not provide any requirements concerning special fittings or equipments, which are covered by the **COLD** notation [3].

Ice Class notations range decreasingly from ICE CLASS IA SUPER to ICE CLASS IC, and are based on the *Finish-Swedish Ice Class Rules* [4]. They are appropriate for first-year ice conditions, which mean that the ice is accumulated during one winter season. These conditions are typical of the Baltic Sea or the Saint Lawrence Gulf.

These Rules give an estimation of the ice-going capabilities of each of the Ice Class notations, as indicated in Table 1.

Ice Class notations	Ice description
ICE CLASS IA SUPER	First-year ice thickness 1.0 m
ICE CLASS IA	First-year ice thickness 0.8 m
ICE CLASS IB	First-year ice thickness 0.6 m
ICE CLASS IC	First-year ice thickness 0.4 m

Table 1: Ice description for the Ice Class notations

Polar Class notations range decreasingly from POLAR CLASS 1 to POLAR CLASS 7 and are based on *IACS Unified Requirements concerning Polar Class* [5]. They are appropriate for Arctic ice conditions, which can vary from thick first-year ice to multi-year ice.

These Rules give a gross estimation of the ice-going capabilities of each of the Polar Class notations, as indicated in Table 2.

The ice description in Table 2 is based on the *Sea ice nomenclature of the World Meteorological Organization* [6]. Namely the approximate ice thicknesses can be added as the Polar Class notations usually reflect the ice capability of the ice-going ships. The table thus becomes the following one:

Polar Class notations	Ice description	Typical ice thickness
POLAR CLASS 1	Year-round operation in all polar waters	> 3.0 m
POLAR CLASS 2	Year-round operation in moderate multi-year ice conditions	3.0 m
POLAR CLASS 3	Year-round operation in second- year ice which may include multi-year ice inclusions	2.5 m
POLAR CLASS 4	Year-round operation in thick first-year ice which may include old ice inclusions	1.2 m
POLAR CLASS 5	Year-round operation in medium first-year ice which may include old ice inclusions	1.0 m
POLAR CLASS 6	Summer/autumn operation in medium first-year ice which may include old ice inclusions	0.7 m
POLAR CLASS 7	Summer/autumn operation in medium first-year ice which may include old ice inclusions	< 0.7 m

Table 2: Ice description and ice thickness for the Polar Class notations

1.3. Selection of a suitable ice class notation

The ice thickness only gives a rough estimation of the ice-going capabilities of the Polar Class ships and the selection of a suitable ice class notation should take into account various parameters. Some of these parameters deal with the physical capacity of the ship:

- area of navigation,
- time of the year at which the navigation is intended,
- operational conditions (independent, channel or icebreaker convoy navigation).

Some other parameters concern the economical aspects of the ship operation, where a balance is to be found between these different parameters:

- reduction of the icebreaking fees,
- additional steel weight for the reinforcements,
- additional cost for sufficient power propulsion,
- additional oil consumption.

And last but not least, the local authorities' requirements and legislation have a major influence on the choice of the proper ice class notation.

The prevailing parameter is usually the environmental conditions, which give the minimum requirements to ensure permissible operations of the ship.

This Guidance Note deals with the environmental conditions in Antarctic and in almost all the regions of the North hemisphere where ships might encounter ice, namely the Canadian Arctic, the Greenland waters, the Russian Arctic, Baltic Sea and some other locations such as Sakhalin Island, the Black and Caspian Seas and the Saint Lawrence River and Seaway.

The regional descriptions presented in this Guidance Note are meant to provide to the interested parties an overview of the climatic conditions of the regions considered but are not meant to provide design parameters. These conditions concern air and water main parameters as well as ice cover main characteristics. Unless otherwise specified, they usually reflect the harshest conditions that may be encountered in each area. The areas of the world for which environmental conditions are provided in this Guidance Note are indicated in Figure 1.

The Guidance Note also gives, where applicable, the local legislation to be applied for navigation.

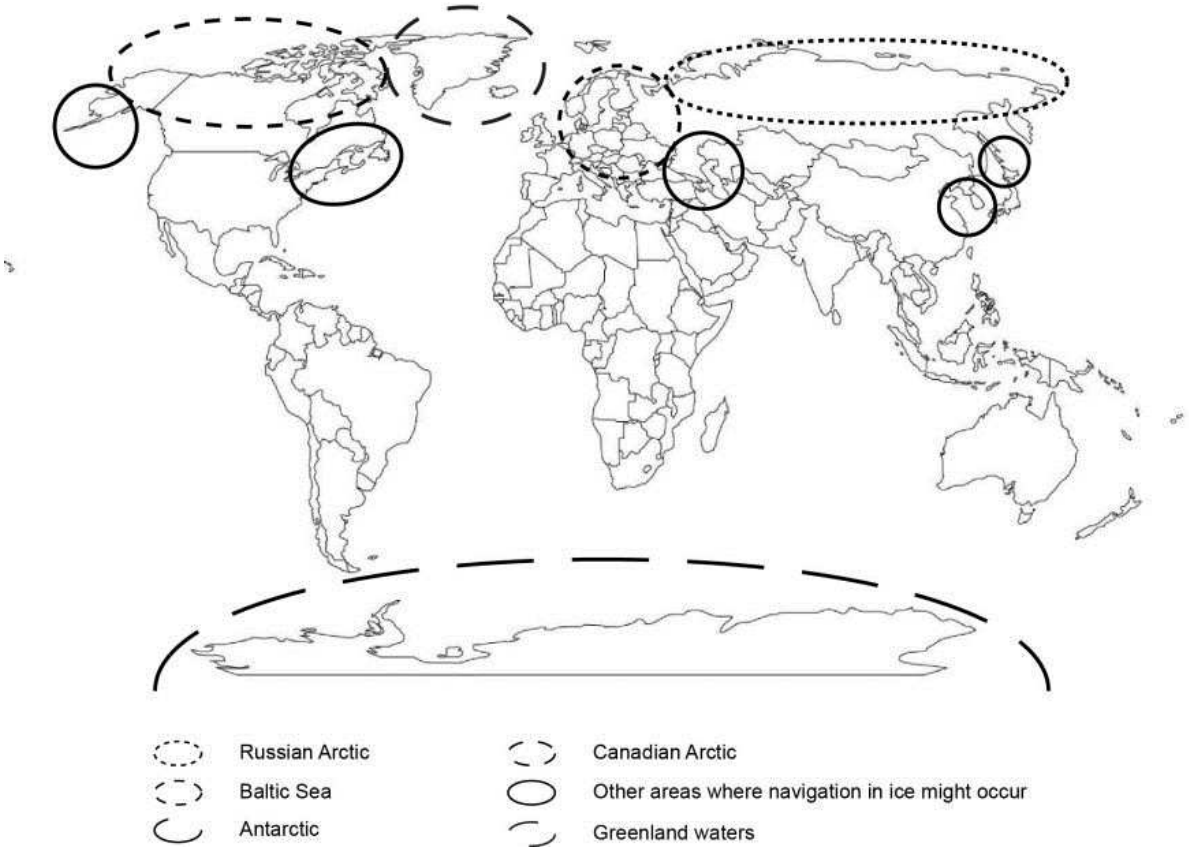

Figure 1: Areas of the world covered in this Guidance Note

To obtain the latest available and most extensive information on a given area, it is recommended to contact the National ice services. They usually provide very useful data on the area, such as the bathymetry, the detailed climatic conditions and the ice conditions with, sometimes, some sets of data recorded over a long period of time.

The ice services for the main areas covered in this Guidance Note are quoted in Table 3.

Another service for ice navigation is the International Ice Patrol that monitors iceberg danger near the Grand Banks of Newfoundland and provides the limits of all known ice to the maritime community. Iceberg sightings and requests for information north of 50°N are to be addressed to the Canadian Ice Service. See Table 4 for contact details.

Important notice:

All the values quoted in this Guidance Note reflect the hard conditions that may be encountered during navigation but they are not to be used for design purpose, as they are averaged on the whole sea regions and local differences might be of importance. Moreover the year-to-year variations are of great importance for all of the quoted parameters, and especially for the ice thickness.

Regional area	Ice service
Greenland	**Danish Meteorological Institute** 3910 Kangerlussuaq, Greenland Phone +299 841022 www.dmi.dk/dmi/en/gronland/iskort.htm
Russian Arctic	**Arctic and Antarctic Research Institute** 38 Bering str, St. Petersburg, 199397, Russia Phone (812)337-3123 Fax (812)337-3241 E-mail aaricoop @ aari.ru www.aari.nw.ru/default_en.asp
Baltic Sea	**Finish Institute of Marine Research** P.O.BOX 304, FI-00181, Helsinki, Finland Phone +358 9 685 7659 Fax +358 9 685 7639 Email ice@fimr.fi www.fimr.fi **Baltic Icebreaking Management** veps.fma.fi/portal/page/portal/baltice/ice_map
Iceland	**Icelandic Meteorological Office** Bústaðavegur 9, 150 Reykjavík, Iceland Phone +354 522 6000 Fax +354 522 6001 en.vedur.is/sea-ice/sea
United States of America	**National Ice Center** Federal Building #4, 4251 Suitland Road, Washington D.C. 20395, USA Phone (301) 817-3911 www.natice.noaa.gov/
Canadian Waters	**Canadian Ice Service** 373 Sussex Drive Block E, Third Floor, Ottawa, Ontario K1A 0H3 Canada www.ec.gc.ca/glaces-ice/
Sea of Okhotsk	**Japan Coast Guard** 2-1-3 Kasumigaseki, Chiyoda-ku, Tokyo, 100-8918, Japan Phone +81 3 3591 9780 www.kaiho.mlit.go.jp/e/index_e.htm

Table 3: Ice services of the main ice-covered areas

Regional area	Ice service
Icebergs, southern of 50°N	**International Ice Patrol** 1082 Shennecossett Road, Groton, Connecticut 06340, USA Phone +1 860 441 2626 Fax +1 860 441 2773 E-mail iipcomms@uscg.mil www.uscg-iip.org/
Icebergs, northern of 50°N	**Canadian Ice Service** 373 Sussex Drive Block E, Third Floor, Ottawa, Ontario K1A 0H3 Canada ice-glaces.ec.gc.ca/App/WsvPageDsp.cfm?ID=1&Lang=eng

Table 4: Ice services for icebergs monitoring

2. NAVIGATION IN THE CANADIAN ARCTIC

2.1. Typical ice conditions

The Canadian Ministry of Transport, in the *Arctic Waters Pollution Prevention Act* [7], defines the so called zone/date system. In this document, Arctic waters are divided into 16 zones (see Figure 2), in which ships are allowed to enter at certain dates, depending on their ice classes.

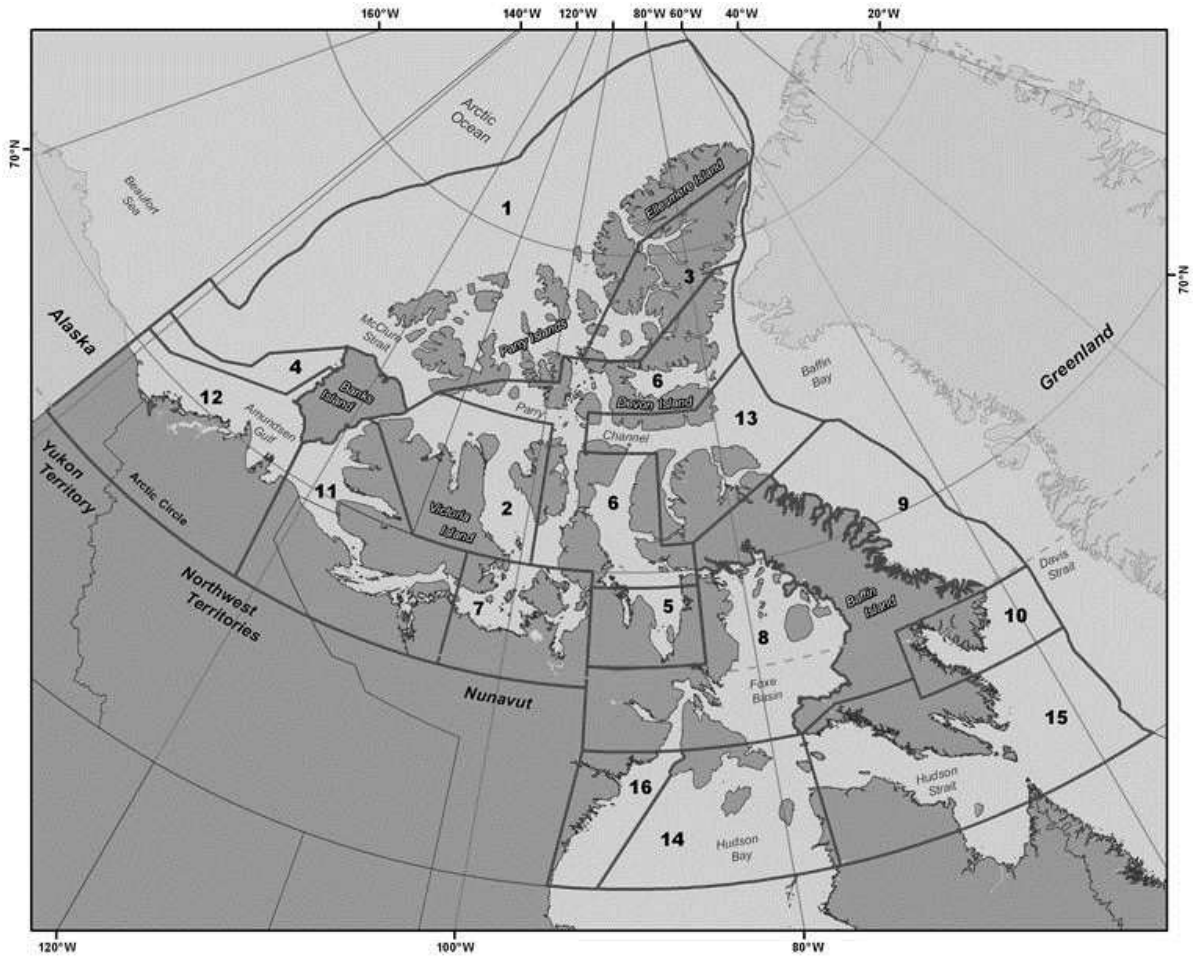

Figure 2: Canadian control zones

To describe the ice conditions encountered in the Canadian Arctic region, measurement stations were selected inside these zones.

Table 5 gives the monthly mean ice thicknesses of these measurement stations.

These ice thickness data are issued by the Canadian Ice Service website [8]. In the ice archive section can be found a whole set of data called *Weekly Ice Thickness and On-Ice Snow Depth Measurements for Canadian Stations.* These data consist of weekly ice thickness measurements for 195 sites, some measurements dating back to 1947 for the first established stations in the Canadian Arctic (Eureka and Resolute). Among those 195 stations, only 24 were selected, when situated inside a control zone. The mean ice thicknesses given in Table 5 were calculated, for each month, from the whole available data (between 1 and 200 values, depending upon the time period where measurements were carried out). Some stations have two measurement sites, one close to the shore and another a bit further, where ice thickness might be more important.

Zone	Station	January	February	March	April	May	June
1	Alert	131.9	153.2	169.0	188.8	198.7	201.7
1	Alert	120.5	141.5	161.5	180.6	193.2	199.7
1	Isachsen	228.8	240.5	251.3	261.4	274.4	251.1
1	Isachsen	130.5	161.3	185.6	204.1	215.5	217.2
1	Mould Bay	126.9	149.1	165.9	179.2	190.0	195.8
3	Eureka	144.8	165.6	189.7	209.5	221.1	221.0
6	Resolute	119.5	140.9	162.2	181.2	190.1	192.3
7	Cambridge Bay	128.8	146.7	177.5	194.2	204.9	189.3
7	Gladman Point	124.5	156.3	181.8	184.2	187.4	182.1
7	Spence Bay	134.7	162.0	186.5	209.2	213.8	187.2
8	Hall Beach	122.9	137.5	169.2	184.6	184.8	191.5
9	Clyde	92.2	114.5	134.3	145.3	155.2	154.8
11	Coppermine	116.4	137.0	155.2	168.1	167.5	151.9
11	Holman Island	122.4	152.5	176.4	197.4	205.6	165.9
11	Lady Franklin Point	130.9	141.0	153.6	174.4	173.5	180.0
12	Cape Parry	108.9	133.7	158.0	174.6	182.4	166.3
12	Inuvik	74.4	90.9	101.3	112.7	113.7	0.0
12	Sachs Harbour	117.3	141.3	161.8	178.3	184.0	165.6
12	Tuktoyaktuk	113.5	159.0	183.1	199.4	196.0	0.0
13	Arctic Bay	90.7	110.2	130.4	139.6	135.1	120.6
13	Pond Inlet	99.0	121.7	138.7	149.9	159.1	153.3
14	Coral Harbour	99.3	125.2	146.4	162.1	169.3	157.2
15	Cape Dorset	82.4	106.8	125.9	133.0	134.0	125.1
15	Iqualuit	92.1	118.2	139.7	154.7	160.1	140.0
15	Quaqtaq	102.6	128.3	140.3	156.0	156.3	147.2
15	Quaqtaq	73.4	94.1	109.1	118.6	118.5	107.9
16	Chesterfield Inlet	105.1	134.2	159.2	176.8	183.5	162.1

Zone	Station	July	August	September	October	November	December
1	Alert	175.5	5.0	32.7	56.3	85.1	108.2
1	Alert	179.0	4.0	21.0	44.3	71.1	97.3
1	Isachsen	232.2	134.8	180.2	165.2	175.2	192.1
1	Isachsen	211.7	0.0	22.0	46.0	76.8	109.1
1	Mould Bay	159.0	0.0	21.4	49.7	75.8	102.7
3	Eureka	128.6	0.0	21.7	46.4	81.7	113.9
6	Resolute	144.3	73.1	15.8	33.3	63.8	92.4
7	Cambridge Bay	121.3	0.0	1.0	30.3	64.2	96.7
7	Gladman Point	0.0	0.0	0.0	32.0	56.2	93.1
7	Spence Bay	118.8	0.0	12.0	33.4	63.1	100.4
8	Hall Beach	172.5	0.0	0.0	27.9	55.3	89.0
9	Clyde	117.1	83.0	0.0	18.4	36.5	65.5
11	Coppermine	0.0	0.0	0.0	20.5	46.4	83.0
11	Holman Island	88.8	0.0	0.0	23.9	52.3	89.2
11	Lady Franklin Point	0.0	0.0	0.0	0.0	55.8	82.9
12	Cape Parry	100.9	0.0	13.0	24.1	47.6	80.0
12	Inuvik	0.0	0.0	0.0	19.1	31.9	54.4
12	Sachs Harbour	168.0	0.0	0.0	29.7	56.2	89.6
12	Tuktoyaktuk	0.0	0.0	0.0	25.8	62.8	91.5
13	Arctic Bay	87.7	0.0	0.0	28.1	49.6	71.9
13	Pond Inlet	98.3	0.0	0.0	29.1	43.9	69.5
14	Coral Harbour	107.5	0.0	0.0	23.7	41.2	71.0
15	Cape Dorset	97.6	0.0	0.0	0.0	35.1	53.4
15	Iqualuit	102.3	0.0	0.0	13.0	36.7	61.2
15	Quaqtaq	151.0	0.0	0.0	19.3	34.3	67.5
15	Quaqtaq	126.0	0.0	0.0	0.0	8.7	50.2
16	Chesterfield Inlet	90.6	0.0	0.0	0.0	33.3	70.1

Table 5: Monthly mean ice thickness (in cm) for the stations of Canadian Arctic

2.2. Selection of the appropriate ice class

The selection of an appropriate ice class is rather easy in the case of the Canadian Arctic as the regulation to be followed in this area is very explicit. In fact, inside the *Arctic Waters Pollution Prevention Act* [7], there are the *Arctic Shipping Pollution Prevention Regulations*, which define the zone/date system. The different zones are shown on Figure 2 and the choice of the minimum ice class is thus guided by the route and the time of the year the ship is to sail, as specified in Table 6. It is to be noticed that this regulation only concerns ships over 100 gross registered tons and carrying more than 453 m^3 of oil.

Some requirements for the design of Arctic Class Ships, from 10 to 1, are also specified in *Arctic Shipping Pollution Prevention Regulations*, while the requirements for the design of Type A to Type E ships are specified by the mean of equivalences with the other Ice Classes, as explained in 2.3.

Category	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Arctic Class 10	All year	All year	All year	All year	All year	All year	All year	All year
Arctic Class 8	July 1 to Oct. 15	All year	All year	All year	All year	All year	All year	All year
Arctic Class 7	Aug. 1 to Sept. 30	Aug. 1 to Nov. 30	July 1 to Dec. 31	July 1 to Dec. 15	July 1 to Dec. 15	All year	All year	All year
Arctic Class 6	Aug. 15 to Sept. 15	Aug. 1 to Oct. 31	July 15 to Nov. 30	July 15 to Nov. 30	Aug. 1 to Oct. 15	July 15 to Feb. 28	July 1 to Mar. 31	July 1 to Mar. 31
Arctic Class 4	Aug. 15 to Sept. 15	Aug. 15 to Oct. 15	July 15 to Oct. 31	July 15 to Nov. 15	Aug. 15 to Sept. 30	July 20 to Dec. 31	July 15 to Jan. 15	July 15 to Jan. 15
Arctic Class 3	Aug. 20 to Sept. 15	Aug. 20 to Sept. 30	July 25 to Oct. 15	July 20 to Nov. 5	Aug. 20 to Sept. 25	Aug. 1 to Nov. 30	July 20 to Dec. 15	July 20 to Dec. 31
Arctic Class 2	No entry	No entry	Aug. 15 to Sept. 30	Aug. 1 to Oct. 31	No entry	Aug. 15 to Nov. 20	Aug. 1 to Nov. 20	Aug. 1 to Nov. 30
Arctic Class 1A	No entry	No entry	Aug. 20 to Sept. 15	Aug. 20 to Sept. 30	No entry	Aug. 25 to Oct. 31	Aug. 10 to Nov. 5	Aug. 10 to Nov. 20
Arctic Class 1	No entry	No entry	No entry	No entry	No entry	Aug. 25 to Sept. 30	Aug. 10 to Oct. 15	Aug. 10 to Oct. 31
Type A	No entry	No entry	Aug. 20 to Sept. 10	Aug. 20 to Sept. 20	No entry	Aug. 15 to Oct. 15	Aug. 1 to Oct. 25	Aug. 1 to Nov. 10
Type B	No entry	No entry	Aug. 20 to Sept. 5	Aug. 20 to Sept. 15	No entry	Aug. 25 to Sept. 30	Aug. 10 to Oct. 15	Aug. 10 to Oct. 31
Type C	No entry	No entry	No entry	No entry	No entry	Aug. 25 to Sept. 25	Aug. 10 to Oct. 10	Aug. 10 to Oct. 25
Type D	No entry	No entry	No entry	No entry	No entry	No entry	Aug. 10 to Oct. 5	Aug. 15 to Oct. 20
Type E	No entry	No entry	No entry	No entry	No entry	No entry	Aug. 10 to Sept. 30	Aug. 20 to Oct. 20

Table 6: Zone/date system [7]

Table 6: Zone/date system [7] (continued)

Category	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13	Zone 14	Zone 15	Zone 16
Arctic Class 10	All year	All year	All year	All year	All year	All year	All year	All year
Arctic Class 8	All year	All year	All year	All year	All year	All year	All year	All year
Arctic Class 7	All year	All year	All year	All year	All year	All year	All year	All year
Arctic Class 6	All year	All year	July 1 to Mar. 31	All year	All year	All year	All year	All year
Arctic Class 4	July 10 to Mar. 31	July 10 to Feb. 28	July 5 to Jan. 15	June 1 to Jan. 31	June 1 to Feb. 15	June 15 to Feb. 15	June 15 to Mar. 15	June 1 to Feb. 15
Arctic Class 3	July. 20 to Jan. 20	July 15 to Jan. 25	July 5 to Dec. 15	June 10 to Dec. 31	June 10 to Dec. 31	June 20 to Jan. 10	June 20 to Jan. 31	June 5 to Jan. 10
Arctic Class 2	Aug. 1 to Dec. 20	July 25 to Dec. 20	July 10 to Nov. 20	June 15 to Dec. 5	June 25 to Nov. 22	June 25 to Dec. 10	June 25 to Dec. 20	June 10 to Dec. 10
Arctic Class 1A	Aug. 10 to Dec. 10	Aug. 1 to Dec. 10	July 15 to Nov. 10	July 1 to Nov. 10	July 15 to Oct. 31	July 1 to Nov. 30	July 1 to Dec. 10	June 20 to Nov. 30
Arctic Class 1	Aug. 10 to Oct. 31	Aug. 1 to Oct. 31	July 15 to Oct. 20	July 1 to Oct. 31	July 15 to Oct. 15	July 1 to Nov. 30	July 1 to Nov. 30	June 20 to Nov. 15
Type A	Aug. 1 to Nov. 20	July 25 to Nov. 20	July 10 to Oct. 31	June 15 to Nov. 10	June 25 to Oct. 22	June 25 to Nov. 30	June 25 to Dec. 5	June 20 to Nov. 20
Type B	Aug. 10 to Oct. 31	Aug. 1 to Oct. 31	July 15 to Oct. 20	July 1 to Oct. 25	July 15 to Oct. 15	July 1 to Nov. 30	July 1 to Nov. 30	June 20 to Nov. 10
Type C	Aug. 10 to Oct. 25	Aug. 1 to Oct. 25	July 15 to Oct. 15	July 1 to Oct. 25	July 15 to Oct. 10	July 1 to Nov. 25	July 1 to Nov. 25	June 20 to Nov. 10
Type D	Aug. 15 to Oct. 20	Aug. 5 to Oct. 20	July 15 to Oct. 10	July 1 to Oct. 20	July 30 to Sept. 30	July 10 to Nov. 10	July 5 to Nov. 10	July 1 to Oct. 31
Type E	Aug. 20 to Oct. 15	Aug. 10 to Oct. 02	July 15 to Sept. 30	July 1 to Oct. 20	Aug. 15 to Sept. 20	July 20 to Oct. 31	July 20 to Nov. 5	July 1 to Oct. 31

An alternative method to the zone/date system, called the *Arctic Ice Regime Shipping System* **[9]** may be used.

This method is based on the Ice numeral, equal to the sum of the products of the ice concentrations, in tenths, of each ice type by the corresponding ice multiplier (see Table 7). When the value obtained is greater than or equal to zero, the ice navigation is allowed.

This method, taking into account the ice conditions in real time, is more flexible and accurate. Its particularity is that it relies on the *Equivalent standards for the construction of arctic class ships* **[10]** which is a Canadian alternative admissible standard that defines the Canadian Arctic Categories 1 to 4, the higher category being CAC 1.

The calculation method is the following.

For each category of ship, the Ice numeral is calculated, multiplying the ice multiplier with the corresponding ice concentration, in tenths, and the result defines whether the ice navigation is permitted.

For example, to know whether a CAC 3 ship is allowed to sail in a sea with 8/10 of thick first-year ice and 2/10 of multi-year ice, the ice numeral is calculated:

Ice numeral = 8 x 2 + 2 x (– 1) = 14

The value obtained being not less than 0, the ship is allowed to sail in these ice conditions.

But, for a Type A ship, the calculation gives, in the same conditions:

Ice numeral = 8 x (– 1) + 2 x (– 4) = – 16

It means that the ship is not allowed to sail in these ice conditions.

It is to be noticed that CAC 1 and CAC 2 ships are supposed to sail in all multi-year ice conditions, with an unrestricted icebreaking mode for CAC 1.

The second point of importance with this system is that it becomes necessary to know quite in advance what ice conditions will be ahead of the ship course. It supposes to have, on board, a system to download and display ice charts forecasts, as well as an experienced officer, called the Ice Navigator, with both the qualifications and the ice experience as mentioned in the requirements.

Category	Open water	Grey ice	Grey/ white ice	Thin first year 1st stage	Thin first year 2nd stage	Medium first year	Thick first year	Second year	Multi year
CAC 3	2	2	2	2	2	2	2	1	– 1
CAC 4	2	2	2	2	2	2	1	– 2	– 3
Type A	2	2	2	2	2	1	– 1	– 3	– 4
Type B	2	2	1	1	1	– 1	– 2	– 4	– 4
Type C	2	2	1	1	– 1	– 2	– 3	– 4	– 4
Type D	2	2	1	– 1	– 1	– 2	– 3	– 4	– 4
Type E	2	1	– 1	– 1	– 1	– 2	– 3	– 4	– 4

Table 7: Ice multiplier [9]

2.3. Equivalences with Bureau Veritas ice class notations

The equivalences with the Bureau Veritas ice class notations are indicated in Table 8.

Ice type descriptions for POLAR CLASS 1 to POLAR CLASS 7 are those of the IACS *Unified Requirements concerning Polar Class* [5]. The typical ice thicknesses, not described in these Unified Requirements, are given here to an informative purpose only. Obtained from the *Sea ice nomenclature* [6] of the World Meteorological Organization, they reflect more or less the maximal ice thickness in which a ship is able to sail.

It is of importance to note that equivalences between ice classes are approximate and given to an informative purpose but are not officially recognized. Differences might appear in those equivalences, depending on the criteria of comparison.

The only officially recognized equivalences by the Canadian authorities are signalled in bold characters and concern the equivalences between the former and recent Canadian Arctic classes as well as the equivalences between the Bureau Veritas ice classes and the Type A to Type E Canadian ice classes. Ships without an explicit Canadian Arctic Category or Arctic Class will be assigned one of them by the authorities, on a case by case basis.

Ice Type	Typical ice thickness	Polar Class notation (BV) [2]	Ice Class notation (BV) [1]	Canada 1995 (ASPPR) [10]	Canada 1972 (ASPPR) [7]
Year-round operation in all polar waters	> 3.0 m	POLAR CLASS 1	–	CAC 1	Arctic Class 10
Year-round operation in moderate multi-year ice conditions	3.0 m	POLAR CLASS 2	–	CAC 2	Arctic Class 8
Year-round operation in second- year ice with old ice inclusions	2.5 m	POLAR CLASS 3	–	CAC 3	Arctic Class 6
Year-round operation in thick first-year ice which may contain old ice inclusions	> 1.2 m	POLAR CLASS 4	–	CAC 4	Arctic Class 3
Year-round operation in medium first-year ice with old ice inclusions	1.2 m - 0.7 m	POLAR CLASS 5, POLAR CLASS 6	ICE CLASS IA SUPER	Type A	Type A
Summer / autumn operation in thin first-year ice with old ice inclusions	0.7 m	POLAR CLASS 7	ICE CLASS IA	Type B	Type B
First-year ice	0.5 m	–	ICE CLASS IB	Type C	Type C
First-year ice	0.4 m	–	ICE CLASS IC	Type D	Type D

Table 8: Equivalences with Bureau Veritas ice classes

2.4. Canadian legislation to be followed

Ships sailing in the Canadian Arctic are to comply with a rather extensive set of regulations. It can be found directly on the Marine Safety section of the *Transport Canada website* [11]. Most of the regulations are grouped under the “Acts and Regulations” appellation and some others under the “Transport Publications” one.

As mentioned previously, the two following regulation systems may be chosen for ships sailing in the Canadian Arctic area:

- the *Arctic Waters Pollution Prevention Act* [7], including the *Arctic Shipping Pollution Prevention Regulations* (with the zone/date system) and other regulations such as *Arctic Waters Pollution Prevention Regulations* and *Navigation Safety Regulations*. This Act is available on the Transport Canada website.

- the *Arctic Ice Regime Shipping System Standards* [9], published by the Transport Canada under the publication #12259, supplemented by the *Equivalent Standards for the Construction of Arctic Class Ships*, publication #12260 [10] giving the definition of the four Canadian Arctic Categories CAC 1 to CAC 4 on which the regulation is based.

Concerning other Acts and Regulations that might be of interest, another set of regulations is gathered under the *Canada Shipping Act, 2001* [12] and contains namely the following:

- *Ballast Water Control and Management Regulations*, dealing with the appropriate uses of ballast waters in Canadian waters,
- *Hull Construction Regulations*, basis regulations for the construction of ships sailing under Canadian flag,
- *Eastern Canada Vessel Traffic Services Zone Regulations*, consisting in additional requirements for ships sailing in sensible areas.

Among the publications issued by Transport Canada, the following are interesting to be quoted:

- TP3617 - *A Guide to Canada's Ballast Water Control and Management Regulations* [13] , complement to the *Ballast Water Control and Management Regulations,*
- TP13670 - *Guidelines for the Operation of Passenger Vessels in Canadian Arctic Waters* [14], additional guidelines for passenger vessels.

Although they do not represent additional regulations, the two publications *Ice Navigation in Canadian Waters* and *Winter Navigation on the River and Gulf of St Lawrence* are of great interest as they contain some useful advice for the navigation in Canadian Arctic and in ice-covered waters in general.

It is to be pointed out that oil tankers and chemical tankers are also to comply with the additional regulation *Joint Industry Coast-Guard Guidelines for the Control of Oil Tankers and Bulk Chemical Carriers* [15].

This list is not exhaustive but presents the main texts and regulations to be applied for ships sailing in the Canadian Arctic.

2.5. Additional interesting meteorological parameters

In addition to the ice conditions already quoted, Table 9 describes more precisely the prevailing meteorological conditions of the Canadian Arctic. The data, reflecting the extreme conditions that can be encountered during the winter, are given for information only and not for design purpose, calculations being based on averaged values in the whole sea regions and not on local extreme values. Moreover they were built from public data available on the Internet and consequently are not consistent enough for calculations.

Location	Air T°	Wind force	Waves (height – period)	Surface current
Beaufort Sea	– 30℃	20 m/s	2 m – 7 sec	0.4 m/s
Baffin Bay	– 39℃	18 m/s	4 m – 10 sec	0.1 m/s
Davis Strait	– 39℃	24 m/s	4 m – 10 sec	0.1 m/s
Canadian Arctic Archipelago	– 39℃	–	–	0.1 m/s
Greenland	– 35℃	25 m/s	7 m – 12 sec	1.0 m/s

Location	Ice season	Ice thickness *	Ridges	Icebergs
Beaufort Sea	October - July	180 cm (FY) 320 cm (MY)	5-15 ridges/km 10-15 m high	rare
Baffin Bay	October - August	160 cm (FY) 280 cm (MY)	–	> 2000/year 12 months present
Davis Strait	October - August	160 cm (FY) 280 cm (MY)	–	> 2000/year 12 months present
Canadian Arctic Archipelago	October - August	220 cm (FY) 350 cm (MY)	15-20 m high	few/year 12 months present
Greenland	January - May	50 cm (FY) 200 cm (MY)	–	12 months present

* FY : first-year ice; MY : multi-year ice

Table 9: Meteorological conditions in the Canadian Arctic

3. NAVIGATION IN GREENLAND WATERS

3.1. Typical ice conditions

East and West Greenland waters are subdivided into navigation areas (see Figure 3) based on general ice conditions.

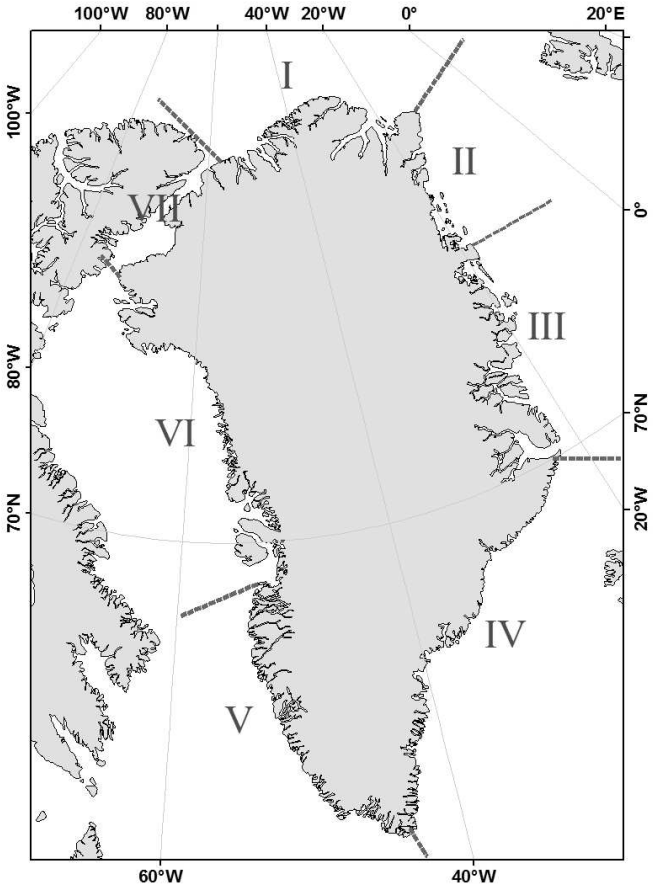

Figure 3: Navigation areas of East and West Greenland waters

North Greenland Waters (I): The thickest and most heavily deformed sea ice in the Arctic Ocean is found along the northern coast of the Canadian Arctic Archipelago and Greenland (zone I). This is an active area for ridge building; the region is ice covered year-round and the ice is predominantly multi-year sea ice. Multi-year sea ice from the Arctic Ocean is known as "Storis".

East Greenland Waters (II, III, IV): Storis flows through the Greenland Sea (zone II) year-round. A wide belt of Storis covers the east coast of Greenland most of the year (zones II, III and IV) and traces of Storis can be found as far south as Cape Farewell (zone IV). Seasonal first-year ice is present in East Greenland waters, forming in the fjords and extending out several hundreds of kilometers in some locations.

West Greenland Waters (V, VI, VII): Storis flows through Nares Strait (zone VII) during the summer months when the ice is mobile. The Storis that exists through Nares Strait flows west with the ocean currents and is rarely found along the west coast of Greenland (zone VI). The sea ice in Baffin Bay (zone VI) is seasonal first-year ice known as the "West Ice". To the south in Davis Strait (zone V), the extent of the West Ice in winter is highly variable but navigation is possible along the coast as far north as Sisimiut (~66.9N).

Two navigation seasons are defined: winter and summer. The definition of winter and summer seasons differs between the northern and the southern navigation areas:

- for zones I, II, III and VII, summer lasts from August to October and winter from November to July,
- for zones IV, V and VI, summer lasts from July to November and winter from December to June.

These definitions of the winter period are conservative, since the ice conditions are milder at the beginning and at the end of the season. They have been accordingly set in order not to encourage too early or too late entry into a zone by a class or a type ship.

For each navigation area, typical ice concentration and ice thickness values are given in Table 10 for the winter and summer seasons. These data represent the average ice conditions and are not intended for design purposes. There is a significant variability from year to year, particularly in zones III through VI.

The data in Table 10, as well as the definition of the navigation areas and of the summer and winter seasons in each region, are based on the ice charts from the Canadian Ice Service [16], the Danish Ice Service [17] and the U.S. National Ice Center [18]. The regional ice charts are drawn up weekly and contain information on ice concentration and ice type. Ice charts covering these last 20 years in both the winter and the summer seasons were reviewed.

Zone	Winter ice concentration		Summer ice concentration	
	Total	MY	Total	MY
I Arctic Ocean	9+/10	> 6/10	9/10	> 6/10
II North Greenland Sea	9+/10	6-9/10	7-9+/10	6-9/10
III South Greenland Sea	9+/10	6-9/10	< 4/10	< 3/10
IV Irminger Sea	9+/10	> 5/10	ice free	
V Davis Strai	0-3/10	-	ice free	
VI Baffin Bay	9+/10	< 1/10	ice free	
VII Nares Strait	10/10	4-6/10	4-6/10	4-6/10

Zone	Winter ice thickness		Summer ice thickness	
	FY (m)	MY (m)	FY (m)	MY (m)
I Arctic Ocean	2.0	15	1.2	15
II North Greenland Sea	2.0	6	1.2	6
III South Greenland Sea	1.8	6	1.0	6
IV Irminger Sea	0.7	3	ice free	
V Davis Strait	0.9	-	ice free	
VI Baffin Bay	1.2	3	ice free	
VII Nares Strait	2.0	15	1.2	15

Table 10: Typical ice concentrations for the total sea ice cover (Total), first-year ice (FY) and multi-year ice (MY) in each navigation area

Icebergs are present year-round in Greenland waters, the majority are found in eastern Baffin Bay (zone VI) where 20-25,000 icebergs are calved each year [19]. Source glaciers for icebergs are found in every other navigation area but they are less productive.

3.2. Selection of the appropriate ice class

Greenland/Denmark has not developed an ice class system unique to Greenland territorial waters, but supports the long-term goal of making mandatory the IMO Guidelines for ships operating in polar waters [20]. Based on a qualitative assessment of ice conditions in the navigation areas defined in Figure 3, appropriate ice class for winter (Win) navigation and summer (Sum) navigation of IACS Polar Class [5] and the four highest Canadian Type classes [9] are indicated in Table 11. It is to be noted that Type A through Type D ships are equivalent to BV ICE CLASS IA SUPER through ICE CLASS IC, respectively. The assessment has been based on ice multipliers [9] for Type ships and a correspondence between the Polar Classes [5] and Canadian Arctic Classes [9]. The minimum appropriate ice classes indicated are based on average ice conditions, but conditions can vary substantially from year to year, particularly in zones III through VI, so that in any one season a higher ice class might be needed for safe navigation or a lower ice class could be quite adequate.

Class	Zone I		Zone II		Zone III		Zone IV		Zone V		Zone VI		Zone VII	
	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum
PC 1	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PC 2	×	+	+	+	+	+	+	+	+	+	+	+	+	+
PC 3	×	×	×	×	×	+	×	+	+	+	+	+	+	+
PC 4	×	×	×	×	×	+	×	+	+	+	+	+	×	×
PC 5	×	×	×	×	×	+	×	+	+	+	+	+	×	×
PC 6	×	×	×	×	×	+	×	+	+	+	+	+	×	×
PC 7	×	×	×	×	×	+	×	+	+	+	+	+	×	×
Type A	×	×	×	×	×	+	×	+	+	+	+	+	×	×
Type B	×	×	×	×	×	+	×	+	+	+	×	+	×	×
Type C	×	×	×	×	×	×*	×	+	+	+	×	+	×	×
Type D	×	×	×	×	×	×*	×	+	+	+	×	+	×	×

+ : Navigation allowed

X : Navigation not allowed

* : 5 years out of 10, multi-year (MY) ice is absent and summer navigation possible.

Table 11: IACS Polar Class and Canadian Type for navigation in Greenland waters

3.3. Equivalences with Bureau Veritas ice class notations

The equivalences with the Bureau Veritas ice class notations are indicated in Table 12.

Ice type descriptions for POLAR CLASS 1 to POLAR CLASS 7 are those of the IACS *Unified Requirements concerning Polar Class* [5]. The typical ice thicknesses, not described in these Unified Requirements, are given here to an informative purpose only. Obtained from the *Sea ice nomenclature* [6] of the World Meteorological Organization, they reflect more or less the maximal ice thickness in which a ship is able to sail.

It is of importance to note that equivalences between ice classes are approximate and given to an informative purpose but are not officially recognized. Differences might appear in those equivalences, depending on the criteria of comparison.

The only officially recognized equivalences by the Canadian authorities are signalled in bold characters and concern the equivalences between the Bureau Veritas ice classes and the Type A to Type E Canadian ice classes. Ships without an explicit Canadian Arctic Category or Arctic Class will be assigned one of them by the authorities, on a case by case basis.

Ice Type	Typical ice thickness	Polar Class notation (BV) [2]	Ice Class notation (BV) [1]	Canada 1995 (ASPPR) [10]
Year-round operation in all polar waters	> 3.0 m	POLAR CLASS 1	–	
Year-round operation in moderate multi-year ice conditions	3.0 m	POLAR CLASS 2	–	
Year-round operation in second-year ice with old ice inclusions	2.5 m	POLAR CLASS 3	–	
Year-round operation in thick first-year ice which may contain old ice inclusions	> 1.2 m	POLAR CLASS 4	–	
Year-round operation in medium first-year ice with old ice inclusions	1.2 m - 0.7 m	POLAR CLASS 5, POLAR CLASS 6	ICE CLASS IA SUPER	Type A
Summer / autumn operation in thin first-year ice with old ice inclusions	0.7 m	POLAR CLASS 7	ICE CLASS IA	Type B
First-year ice	0.5 m	–	ICE CLASS IB	Type C
First-year ice	0.4 m	–	ICE CLASS IC	Type D

Table 12: Equivalences with Bureau Veritas ice classes

3.4. Legislation to be followed

The Danish Parliament has passed the Act on Greenland Self Government, Act No. 473 of 21 June 2009 (the 'Self Government Act'), whereby certain powers and authorities are being transferred from Denmark to Greenland. The legislation of the Danish Parliament makes provision for safety of navigation in Greenland waters.

Information on legislation, regulations and guidance on safety of navigation in Greenland waters is provided by the Danish Maritime Authority [21]. This website provides a comprehensive introduction to additional sources of information on navigation in Greenland waters. It refers to the Act on Safety at Sea, cf. Consolidated Act no. 903 of 12 July 2007, as put into force by Decree no. 882 of 25 August 2008, which contains provisions for safety of navigation in Greenland waters [22]. It sets requirements for mandatory reporting of position, course, etc. according to GREENPOS [23], navigator's qualifications, prohibits use of open lifeboats, safety measures and regulation for the use of ice searchlights [24].

3.5. Additional interesting meteorological parameters

In addition to the general ice conditions described in 3.1, Table 13 summarizes relevant meteorological parameters. For air temperature the data represent the average minimum winter conditions. For ridges the data represent the predominant sail height (elevation above mean sea level). For wind force and ocean currents the data represent the annual maxima values. For visibility and waves (significant height and period) in winter (Win) and summer (Sum) the data represent the predominant conditions. These data are for information only and are not intended for design purposes; the values represent averages over the whole navigation area and were derived from a review of publicly available literature and data sets.

The length of the ice season was defined based on the most recent 20-year record of regional ice charts from the CIS, NIC and DMI.

The mean minimum winter air temperature is based on the most recent 20-year record of temperature data from Greenland station data and modeled reanalysis data, NCEP/NCAR Reanalysis. Values represent averages over whole sea regions and are not intended for design purposes.

Ridge height data for zones I, II and III is from a database of ridge statistics that was compiled from the public literature by the National Research Council of Canada. No data is available for zones III through VII.

The density and occurrence of icebergs is highly variable. Data on the average density of icebergs, expressed as the number of icebergs found in a 2-degree latitude by 1-degree longitude area in Baffin Bay (Zone VI), is from [19]. Observations of icebergs are noted on the regional Canadian and Danish ice charts as a symbol, the data is qualitative and exact locations or numbers are not given. A qualitative estimate of the number of icebergs in zones IV, V and VII is derived from the ice charts. Iceberg symbols were not present in zones I, II or III although it is known that icebergs are present in these regions. The ice charts are a guide for navigation and the lack of observations in these zones likely reflects limited shipping activity.

Wind force and current data are based on a review of the available literature. Key references are [19], [25] and [26].

Significant wave height and period are from modeled reanalysis data, Wavewatch III. Values represent averages over whole sea regions and are not intended for design purposes. Data is not available when sea ice is present.

Zone	Ice season	Air T°	Ridges	Icebergs
I Arctic Ocean	all year	–40℃	6.5m high	present year-round
II N. Greenland Sea	all year	–35℃	3.0m high	present year-round
III S. Greenland Sea	all year	–25℃	1.0m high	present year-round
IV Irminger Sea	north: Jan – June south: Nov – June	–12℃	ND	many / year present year-round
V Davis Strait	north: Dec – May south: ice free	–25℃	ND	many / year present year-round
VI Baffin Bay	Oct – July	–30℃	ND	1 to 5 icebergs within 175 km^2 present year-round
VII Nares Strait	all year	–35℃	ND	few / year present year-round

Zone	Wind force	Current	Visibility Win / Sum	Waves (height – period) Win / Sum
I Arctic Ocean	ND	ND	ND	ND
II N. Greenland Sea	25 m/s	30 cm/s	clear / ND	ND
III S. Greenland Sea	15 m/s	30 cm/s	clear / ND	ND
IV Irminger Sea	25 m/s	30 cm/s	clear / 20%-30%	4.0m – 9sec / 1.5m – 8sec
V Davis Strait	30 m/s	35 cm/s	clear / 20%-30%	4.0m – 8sec / 1.8m – 7sec
VI Baffin Bay	20 m/s	10 cm/s	clear / 20%-30%	ND / 1.0m – 6sec
VII Nares Strait	30 m/s	20 cm/s	clear / ND	ND / ND

ND = no data

Visibility % corresponds to the percent of the total time in July

Table 13: Meteorological conditions in Greenland waters

4. NAVIGATION IN THE RUSSIAN ARCTIC

4.1. Typical ice conditions

Ice conditions vary a lot all along the Northern Sea Route and a good subdivision of areas with equivalent ice conditions is made by natural borders such as islands and peninsulas (see Figure 4).

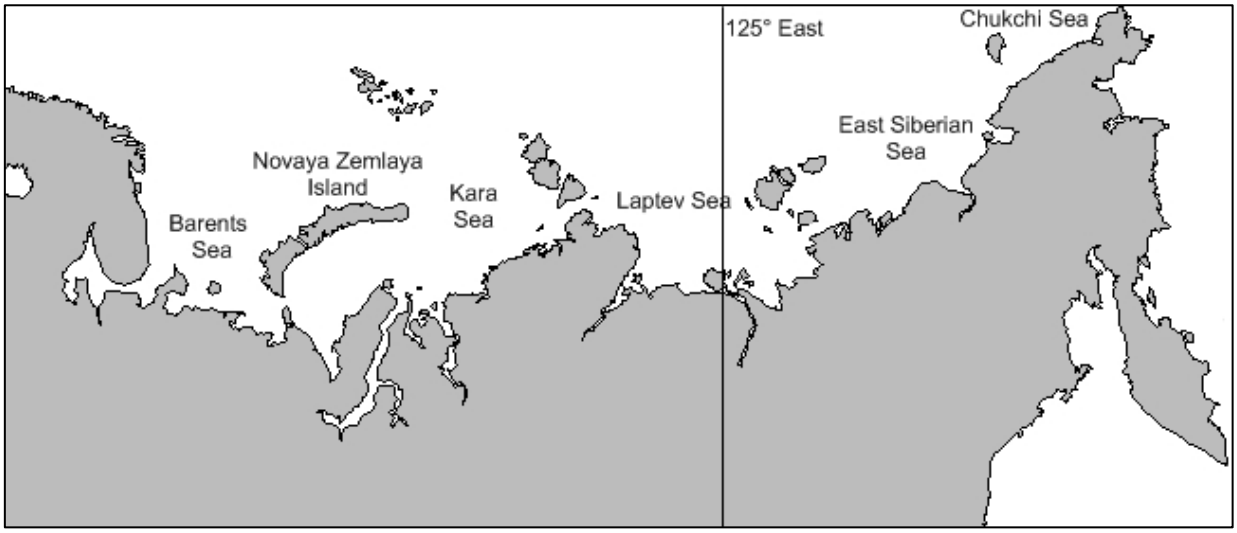

Figure 4: Russian Arctic Seas

For each area defined in Figure 4, the average expected ice thickness is given in Table 14. These data are extracts from Ref. [27].

Sea	Area	Season							
		Winter-spring navigation				Summer-autumn navigation			
		Soft	Medium	Hard	Extreme	Soft	Medium	Hard	Extreme
Kara	North	0.75	1.25	1.75	2.35	0.38	0.63	0.88	1.18
	South	0.45	1.00	1.70	2.20	0.23	0.50	0.85	1.10
Laptev	North	1.00	1.90	2.80	4.00	0.50	0.95	1.40	2.00
	South	0.65	1.50	2.25	3.70	0.33	0.75	1.15	1.85
East Siberian	North	1.00	1.70	2.40	3.20	0.50	0.35	1.20	1.60
	South	0.60	1.34	1.90	2.95	0.30	0.67	0.95	1.50
Chukchi	North	0.85	1.50	2.50	3.75	0.43	0.75	1.25	1.88
	South	0.50	1.18	2.00	3.45	0.25	0.60	1.00	1.73

Table 14: Mean ice thickness (in m) in the Russian Arctic Seas

4.2. Selection of the appropriate ice class

Tables 15, 16 and 17 present the advised Russian ice classes, linked with the expected ice conditions given in Table 14, and come from Arctic Logistics Information Office “Rules for Navigation in Northern Sea Route water area [28].

Table 15 presents ships without ice reinforcement and Russian classes Ice 1 - Ice 3, during navigation in the period July to 15th November.

Table 16 presents Russian classes Arc 4 - Arc 9, during navigation in the period January to June, July to November and December.

Table 17 presents Russian classes Icebreaker 6 - Icebreaker 8, during navigation in the period January to June and December.

They indicate, for each Russian ice class, and depending on various parameters such as the area of navigation (seas), the period in the year (December to June or July to November), the existing ice conditions (from easy to severe) and the operational conditions (independent navigation or navigation with icebreaker support), whether the ships are able to sail (+) or not (–).

The following symbols are used in Table 15, Table 16 and Table 17:

IN : Independent navigation
IS : Navigation with icebreaker support
S : Severe ice conditions
M : Moderate ice conditions
L : Easy ice conditions
+ : Navigation is allowed
– : Impermissible service.

Ships without ice reinforcement and ships with class Ice 1 - Ice 3 are not allowed to navigate in the Northern Sea Route water area in the periods from January to June and from 16th November to 31st December.

Ship ice reinforcement class	Ice navigation mode	**Navigation in the period July to 15th November in the:**						
		Kara Sea		**Laptev Sea**		**East Siberian Sea**		**Chukchi Sea**
		South-west part	North-East part	Western part	Eastern part	South-West part	North-East part	
		S M L	S M L	S M L	S M L	S M L	S M L	S M L
No reinforcement	IN	– – –	– – –	– – –	– – –	– – –	– – –	– – –
	IS	– – +	– – +	– – +	– – +	– – +	– – +	– – +
Ice 1	IN	– – +	– – +	– – +	– – +	– – +	– – +	– – +
	IS	– – +	– – +	– – +	– – +	– – +	– – +	– – +
Ice 2	IN	– – +	– – +	– – +	– – +	– – +	– – +	– – +
	IS	– + +	– + +	– – +	– – +	– – +	– – +	– – +
Ice 3	IN	– – +	– – +	– – +	– – +	– – +	– – +	– – +
	IS	+ + +	+ + +	– – +	– – +	– – +	– – +	– + +

Table 15: Russian classes Ice 1 - Ice 3 for navigation on Russian Arctic

Oil tankers, gas carriers and chemical tankers without ice reinforcement and with gross tonnage 10000 gt and more are allowed to navigate in the Northern Sea Route water area on open water in the period from July to 15th November only if they have icebreaker support.

Ships without ice reinforcement are only allowed to independently navigate in the Northern Sea Route water area on open water.

Ship ice reinforcement class	Ice navigation mode	**Navigation in the period January to June and in December in the:**						
		Kara Sea		**Laptev Sea**		**East Siberian Sea**		**Chukchi Sea**
		South-west part	North-East part	Western part	Eastern part	South-West part	North-East part	
		S M L	S M L	S M L	S M L	S M L	S M L	S M L
Arc 4	IN	– – +	– – +	– – +	– – +	– – +	– – +	– – +
	IS	– – +	– – +	– – +	– – +	– – +	– – +	– – +
Arc 5	IN	– – +	– – +	– – +	– – +	– – +	– – +	– – +
	IS	– – +	– – +	– – +	– – +	– – +	– – +	– – +
Arc 6	IN	– – +	– – +	– – +	– – +	– – +	– – +	– – +
	IS	– + +	– + +	– – +	– – +	– – +	– – +	– + +
Arc 7	IN	+ + +	– + +	– – +	– – +	– – +	– – +	– + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc 8	IN	+ + +	+ + +	– + +	– + +	– + +	– + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc 9	IN	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +

Ship ice reinforcement class	Ice navigation mode	**Navigation in the period July to November in the:**						
		Kara Sea		**Laptev Sea**		**East Siberian Sea**		**Chukchi Sea**
		South-west part	North-East part	Western part	Eastern part	South-West part	North-East part	
		S M L	S M L	S M L	S M L	S M L	S M L	S M L
Arc 4	IN	– + +	– + +	– – +	– – +	– – +	– – +	– + +
	IS	+ + +	+ + +	– + +	– + +	– + +	– + +	– + +
Arc 5	IN	+ + +	+ + +	– + +	– + +	– + +	– + +	– + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc 6	IN	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc 7	IN	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc 8	IN	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc 9	IN	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +

Table 16: Russian classes Arc 4 - Arc 9 for navigation on Russian Arctic

Ship ice reinforcement class	Ice navigation mode	Navigation in the period January to June and in December in the:						
		Kara Sea		Laptev Sea		East Siberian Sea		Chukchi Sea
		South-west part	North-East part	Western part	Eastern part	South-West part	North-East part	
		S M L	S M L	S M L	S M L	S M L	S M L	S M L
Icebreaker 6	IN	– + +	– + +	– – +	– – +	– – +	– – +	– + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Icebreaker 7	IN	+ + +	+ + +	– + +	– + +	– + +	– + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Icebreaker 8	IN	+ + +	+ + +	– + +	– + +	– + +	– + +	+ + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +

Table 17: Russian classes Icebreaker 6 - Icebreaker 8 for navigation on Russian Arctic

Icebreakers with ice reinforcement class Icebreaker 9 are not restricted in independent navigation in Northern Sea Route water area.
Icebreakers with ice reinforcement class Icebreaker 6 - Icebreaker 8 are not allowed to navigate independently during the navigation period July to November.

4.3. Equivalences with Bureau Veritas ice class notations

In Table 18, ice type descriptions for POLAR CLASS 1 to POLAR CLASS 7 are those of the *IACS Unified Requirements concerning Polar Class* [5]. The typical ice thicknesses, not described in these Unified Requirements, are given here to an informative purpose only. Obtained from the *Sea ice nomenclature* [6] of the World Meteorological Organization, they reflect more or less the maximal ice thickness in which a ship is able to sail.

It is of importance to note that equivalences between ice classes are approximate and given to an informative purpose but are not officially recognized. Differences might appear in those equivalences, depending on the criteria of comparison.

Table 18: Equivalences with Bureau Veritas ice classes

Ice Type	Typical ice thickness	Polar Class notation (BV) [2]	Ice Class notation (BV) [1]	Ice going ships (RMRS) [31]
Year-round operation in all polar waters	> 3.0 m	POLAR CLASS 1	–	Arc 9
Year-round operation in moderate multi-year ice conditions	3.0 m	POLAR CLASS 2	–	Arc 8
Year-round operation in second- year ice with old ice inclusions	2.5 m	POLAR CLASS 3	–	Arc 7
Year-round operation in thick first-year ice which may contain old ice inclusions	> 1.2 m	POLAR CLASS 4	–	Arc 6
Year-round operation in medium first-year ice with old ice inclusions	1.2 m - 0.7 m	POLAR CLASS 5, POLAR CLASS 6	ICE CLASS IA SUPER	Arc 5
Summer/autumn operation in thin first-year ice with old ice inclusions	0.7 m	POLAR CLASS 7	ICE CLASS IA	Arc 4
First-year ice	0.5 m	–	ICE CLASS IB	Ice 3
First-year ice	0.4 m	–	ICE CLASS IC	Ice 2
Open sea with ice floes	–	–	ICE CLASS ID	Ice 1

4.4. Other legislation to be followed

The legislation to be followed is very different depending on whether the ships are to enter the Northern Sea Route (NSR) or not. The NSR is delimited on the western side by the island of Novaya Zemlya and on the eastern side by the Bering Strait to the south of the Chukchi Sea. The actual management of shipping within the Northern Sea Route is split in two Marine Operational Headquarters (MOHQs), the division being the 125° east longitude. The western sector is under the responsibility of the Murmansk Shipping Company (MSCO), operating from Murmansk, while the eastern sector is under the responsibility of the Far East Shipping Company (FESCO), operating from Vladivostok.

To navigate through the Northern Sea Route, an authorization is to be requested to the Russian Ministry of Transports at least four months in advance. The full Regulations for icebreaker assistance and ice pilotage of the NSR are included in the publication *Guide to Navigating through the Northern Sea Route*. This Guide incorporates the following regulations, in force in the NSR **[29] [30] [31]**.

- *Regulations for Navigation on the Seaways of the Northern Sea Route*
  - » These regulations present the general requirements for navigation through the NSR, namely the fact that the Owner or the Master of a ship intending to navigate through the Northern Sea Route is to submit to the Administration (Marine Operational Headquarters) a notification and request for leading through the NSR.

- *Regulations for Icebreaker-Assisted Pilotage of Vessels on the NSR*
  - » These regulations define how to submit requests, the pilotage organization and the obligations and responsibilities of the Master of the ship, the Master of the icebreaker and the pilot on the waterways of the NSR.

- *Requirements for Design, Equipment and Supply of Vessels Navigating the NSR*
  - » These regulations give the particular requirements applying to the hull, machinery installations, systems and arrangements, stability and watertight integrity, navigational and communication facilities, supplies and emergency outfit, and manning.

All ships entering the NSR are to be inspected by the authorities prior to commencing the voyage. It is pointed out that ships not fully complying with the regulations may still be allowed to make the voyage on the condition of further implementation of requirements, such as the use of additional icebreakers, with additional costs for the shipowner.

Ships may be required to have on board an ice pilot, depending on the experience of the Master and officers in ice navigation. It is stressed that the pilot is to be on the bridge at all times when the situation demands his ice experience and knowledge of the locality. If the Master has no experience in ice navigation, two pilots may be required in order to maintain a full 24 hour bridge watch.

The Ice Passport, or Ice Certificate, issued by The Arctic and Antarctic Research Institute (AARI) or the Central Marine Research & Design Institute (CNIIMF), is compulsory for ships navigating the Northern Sea Route. It namely includes the following:

- concise information about the ship and its ice class,
- main working documents providing the ship’s safe speed in ice, i.e. ice performance curves, diagrams of safe speeds, distances and circular motion radiuses in the channel when following an icebreaker,
- assessment of the shipside compression strength.

4.5. Additional interesting meteorological parameters

In addition to the ice conditions already quoted, Table 19 describes more precisely the prevailing meteorological conditions of the Russian Arctic. The data, reflecting the extreme conditions that can be encountered during the winter, are given for information only and not for design purpose, calculations being based on averaged values in the whole sea regions and not on local extreme values. Moreover they were built from public data available on the Internet and consequently are not consistent enough for calculations.

Location	Air T°	Wind force	Waves (height – period)	Current
Barents Sea	– 20°C	22 m/s	2.7 m – 11 sec	0.5 m/s
Pechora Sea	– 20°C	22 m/s	2.5 m – 9 sec	1.2 m/s
Kara Sea	– 25°C	35 m/s	0.8 m – 5 sec	1.0 m/s
Laptev Sea	–- 30°C	40 m/s	0.4 m – 3 sec	0.9 m/s
East Siberian Sea	– 30°C	40 m/s	0.4 m – 3 sec	0.9 m/s
Chukchi Sea	– 45°C	40 m/s	7.0 m – 7 sec	0.2 m/s

Location	Ice season	Ice thickness*	Ridges	Icebergs
Barents Sea	all year	150 cm (FY) 250 cm (MY)	–	50/year January to June
Pechora Sea	November - July	100 cm (FY)	5-10 ridges/km 10 m high	rare
Kara Sea	November - September	160 cm	5-10 ridges/km 12 m high	–
Laptev Sea	October - July	200 cm	–	–
East Siberian Sea	October - August	140 cm	5-10 ridges/km 12 m high	–
Chukchi Sea	October - June	140 cm (FY) 230 cm (MY)	5-10 ridges/km 10-15 m high	–

* FY : first-year ice; MY : multi-year ice

Table 19: Meteorological conditions in the Russian Arctic

5. NAVIGATION IN THE BALTIC SEA

5.1. Typical ice conditions

The figures in Table 20 are averaged values computed from sets of data issued by the Finnish Institute of Marine Research [32] over the period between 1997 and 2007. The original material gives the values of the maximum ice thickness observed during the winter in the concerned areas shown in Figure 5. The input data consist in ground truth, visual air-borne data, and space-borne data of various satellites. A distinction is made between the fast ice (fastened to the shore and unable to be pushed away by the wind) and the sea ice found off the shore.

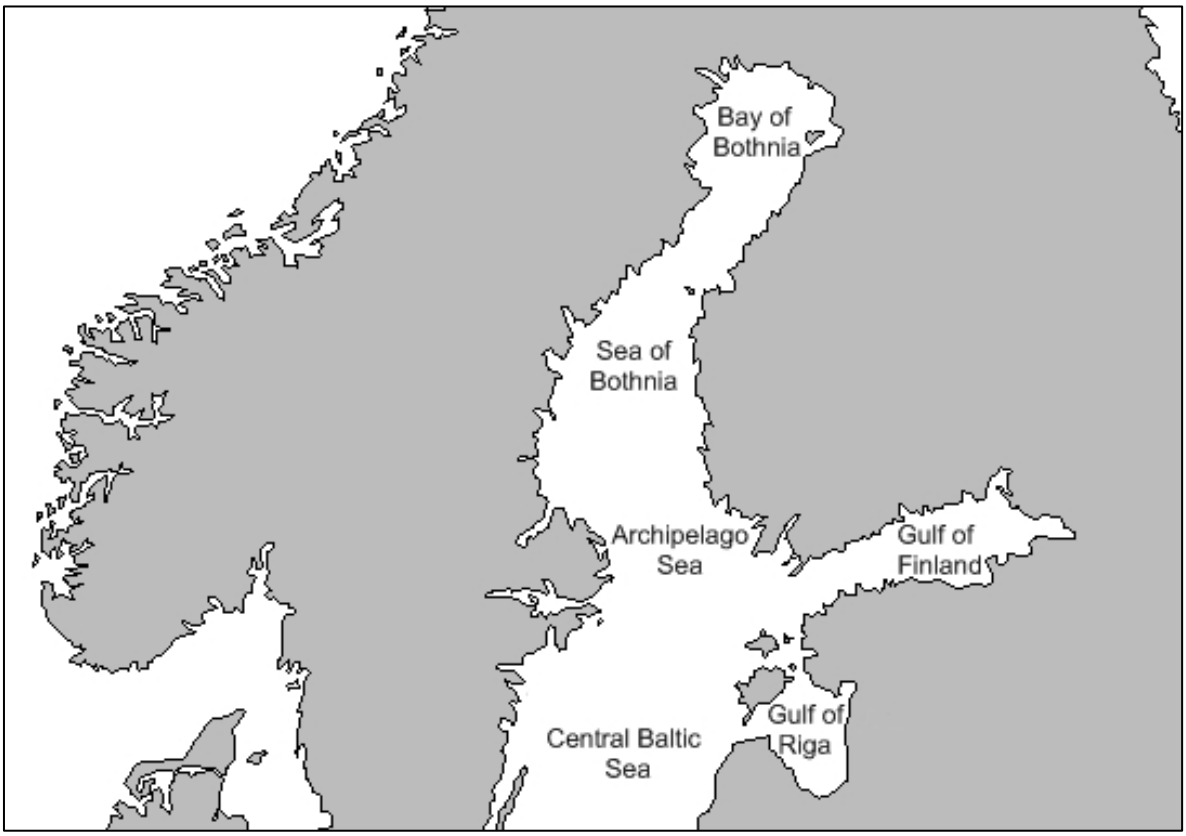

Figure 5: Areas of the Baltic Sea

Location	Fast ice thickness (cm)		Sea ice thickness (cm)	
	mean	extreme	mean	extreme
Northern Bothnian Bay	67	90	44	70
Southern Bothnian Bay	61	90	36	60
Bothnian Sea	45	75	18	40
Archipelago Sea	26	40	15	25
Western Gulf of Finland	37	65	26	75
Eastern Gulf of Finland	48	80	36	75

Table 20: Mean and extreme ice thicknesses (in cm) for the Baltic Sea

5.2. Selection of the appropriate ice class

The advised minimum ice classes for navigation in the Baltic Sea are described in Table 21. For each area, the minimum ice class for a year-round navigation is specified, as well as the probability to perform a year-round navigation with a lower ice class, if the winter is mild enough.

Area of navigation	Minimum advised ice class
Bothnian Bay	IA or IAS or PC 7 - PC 6: year round navigation
Northern Bothnia Sea	IA or PC 7: year round navigation IB: 50% possibility for year round navigation
Southern Bothnia Sea	IA or PC 7: year round navigation IB: 80% possibility for year round navigation
Eastern Gulf of Finland	IA or PC 7: year round navigation IB: 50% possibility for year round navigation
Western Gulf of Finland	IA or PC 7: year round navigation IB: 80% possibility for year round navigation
Central Baltic Sea	IC: year round navigation II: 80% possibility for year round navigation

Table 21: Minimum advised ice class in the Baltic Sea

Table 22 presents the typical restrictions that might occur during an average winter in the Baltic Sea. The total restriction period represents the period of the year where restrictions occur and the highest ice class restriction is the minimum ice class required to sail in the area all along the winter. When restrictions occur, they are usually raised and lowered gradually, especially in the Bothnian Bay and Gulf of Finland. The restrictions consist typically in a minimum ice class plus a requirement concerning the power propulsion or the ship's deadweight.

It is to be noticed that the navigation restrictions in the Baltic Sea occur in real time, i.e. they depend on the ice forecast and can vary a lot from one year to another. So, it is not possible to predict which ice class will be relevant for navigation at a given period, but Table 21 gives a good prediction of the advisable ice class selection in the Baltic Sea. Traffic restrictions are accessible through the web on the Baltic Icebreaking Management website [33].

Location	Total restriction period	Highest ice class restriction
Bay of Bothnia	January - May	IA, 4000 dwt
Sea of Bothnia	January - April	IA
Gulf of Finland	January - March	IA or IB, 2000 dwt
Gulf of Riga	January - March	IC, 1600 kW

Table 22: Typical ice restrictions in the Baltic Sea

5.3. Equivalences with Bureau Veritas ice class notations

As the Bureau Veritas Ice Class Rules are based on the Finnish-Swedish Ice Class Rules and are almost identical to them, the equivalences are immediate. Table 23 gives the officially recognized equivalences, as specified by the Finnish Maritime Administration [34].

In that specific case, the ice description is the one existing in the Rules [1], [4].

Ice description	Bureau Veritas Ice Class [1]	FMA Ice Class [4]
First-year ice thickness 1.0 m	ICE CLASS IA SUPER	IA Super
First-year ice thickness 0.8 m	ICE CLASS IA	IA
First-year ice thickness 0.6 m	ICE CLASS IB	IB
First-year ice thickness 0.4 m	ICE CLASS IC	IC

Table 23: Equivalences with Bureau Veritas ice classes

5.4. Other legislation to be followed

Except the restrictions concerning the access to some ports of the Baltic and the request for icebreaker assistance, there is no specific legislation on the ice capability of ships in the Baltic Sea.

Any ship is to report to the authorities well in advance when it is passing the Svenska Björn lighthouse for a transit in the Gulf of Bothnia. The ship is then entered into the icebreaker's management computer system and can be followed on a graphic plotting screen. When the ship reports to the icebreakers, it is given instructions on the suitable routes to be followed, around and in the ice, depending on its ice class. The aim is that ships transit the ice independently as much as possible and that the icebreakers provide assistance mainly to ships stuck in ice or in difficulty.

The different national administrations are responsible, in their regions, for the transit and the icebreaking assistance of ships through ice. The ports are responsible for ice management within the ports and it is why some small ports may be closed during the winter when the ice conditions are too severe. The icebreakers are positioned at strategic points in the Baltic Sea and their positions are included in the daily ice charts. The icebreaking authorities of each country manage icebreaking operations in their own regions: they allocate icebreakers to work areas, issue restrictions, monitor operating conditions and inform shipping stakeholders about ice and traffic conditions. The Masters of icebreakers work relatively independently in their operational areas.

It is expected that the masters of ships transiting the ice are familiar and experienced with the navigation in ice with icebreaker assistance and pilotage not to be compulsory. But, with the increasing volume of traffic and size of tonnage in the Baltic Sea, it has become apparent that all ships may not have ice experienced staff, it is why an ice advisory service has recently been provided by Finn pilots [35].

5.5. Additional interesting meteorological parameters

In addition to the ice conditions already quoted, Table 24 describes more precisely the prevailing meteorological conditions of the Baltic Sea. The data, reflecting the extreme conditions that can be encountered during the winter, are given for information only and not for design purpose, calculations being based on averaged values in the whole sea regions and not on local extreme values. Moreover they were built from public data available on the Internet and consequently are not consistent enough for calculations.

Location	Air T°	Wind force	Waves (height – period)	Current
Bothnian Sea	– 25°C	6 m/s	4.5 m – 8 sec	–
Bothnian Bay	– 25°C	6 m/s	4.5 m – 8 sec	–
Gulf of Finland	– 18°C	6 m/s	3.5 m – 8 sec	–

Location	Ice season	Ice thickness*	Ridges	Icebergs
Bothnian Sea	January - April	30 cm (FY)	4 ridges/km 4 m high	–
Bothnian Bay	December - May	70 cm (FY)	4 ridges/km 6 m high	–
Gulf of Finland	December - May	70 cm (FY)	4 ridges/km 5 m high	–

* FY : first-year ice

Table 24: Meteorological conditions in the Baltic Sea

6. NAVIGATION IN OTHER ICE-COVERED AREAS IN NORTH AMERICA

6.1. Other North-American ice-covered areas

During the winter, the Canadian Arctic is not the only area where sea and river ice occur. Some areas farther in the south may also present tough navigation conditions, such as the following areas, dealt with in this chapter:

- Cook Inlet and Bering Sea
- Labrador and Newfoundland coasts
- Saint Lawrence River and Seaway.

These areas are located on Figure 6.

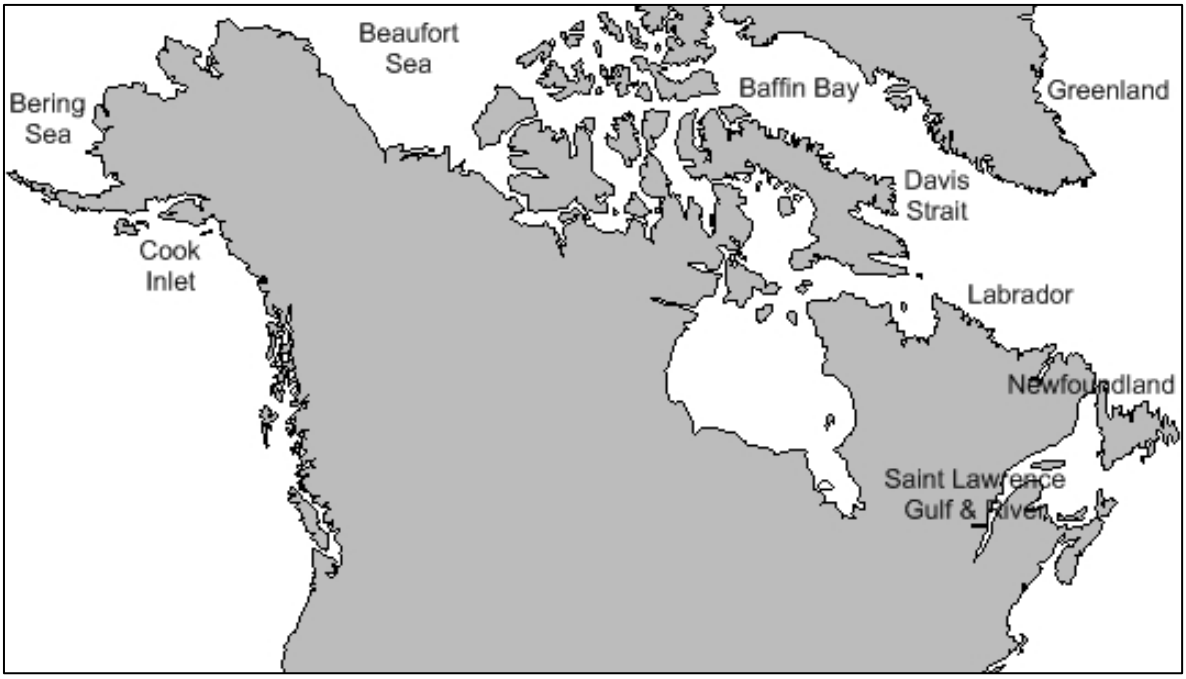

Figure 6: Canadian possibly ice-covered areas

6.2. Navigation in Cook Inlet and Bering Sea

Although the conditions in this part of Alaska are milder than in the Beaufort Sea, sea ice can occur in winter. Data of Table 25 reflect the extreme conditions that can be encountered during the winter, but are given for information only and not for design purpose, calculations being based on averaged values in the whole sea regions and not on local extreme values. Moreover they were built from public data available on the Internet and consequently are not consistent enough for calculations.

Nevertheless, it is possible to conclude from Table 25 that to perform year-round ice navigation in Bering Sea, a minimum POLAR CLASS 5 or POLAR CLASS 6 / ICE CLASS IA SUPER can be advised, while POLAR CLASS 7 or ICE CLASS IA is enough for Cook Inlet.

Location	Air T°	Wind force	Waves (height – period)	Surface current
Bering Sea	– 30℃	25 m/s	5 m	–
Cook Inlet	– 20℃	20 m/s	4 m – 7 sec	4 m/s

Location	Ice season	Ice thickness*	Ridges	Icebergs
Bering Sea	December - June	80 cm (FY)	5-10 ridges/km 5 m high	–
Cook Inlet	December - April	50 cm (FY)	7 m high	–

* FY : first-year ice

Table 25: Meteorological conditions in the Bering Sea and Cook Inlet

6.3. Navigation in Labrador Coast and Newfoundland

Although these areas have the same latitude as Great Britain, sea ice comes rather far on the south coast of Canada and sea ice can occur during the winter. Data of Table 26 reflect the extreme conditions that can be encountered during the winter, but are given for information only and not for design purpose, calculations being based on averaged values in the whole sea regions, and not on local extreme values. Moreover they were built from public data available on the Internet and consequently are not consistent enough for calculations.

To perform year-round ice navigation in Labrador Coast, a minimum POLAR CLASS 4 can be advised, while POLAR CLASS 5 is enough for Newfoundland.

Location	Air T°	Wind force	Waves (height – period)	Surface current
Labrador Coast	– 26℃	30 m/s	11 m – 14 sec	0.2 m/s
Newfoundland	– 17℃	28 m/s	11 m – 14 sec	0.9 m/s

Location	Ice season	Ice thickness*	Ridges	Icebergs
Labrador Coast	December - July	100 cm (FY) 150 cm (MY)	10 m high	1000/year 12 months present
Newfoundland	January - May	80 cm (FY)	6 m high	450/year April to July

* FY : first-year ice; MY : multi-year ice

Table 26: Meteorological conditions on Labrador Coast and Newfoundland

6.4. Navigation in Saint Lawrence Seaway and Saint Lawrence River

The following ice thickness data in Table 27 are extracts from the Canadian Ice Service website [8] and consist in weekly ice thickness measurements for different sites on Saint Lawrence Seaway and Saint Lawrence River which are shown in Figure 7. They range approximately from 1971 to 2000 for Saint Lawrence Seaway and from 1983 to 2001 for Saint Lawrence River. The mean ice thickness is computed from the available values and the extreme ice thickness is the greatest ice thickness recorded during the observation period.

To perform year-round ice navigation in Saint Lawrence Seaway and Saint Lawrence River, a minimum POLAR CLASS 4 can be advised, although, in mild winter, POLAR CLASS 5 might be enough.

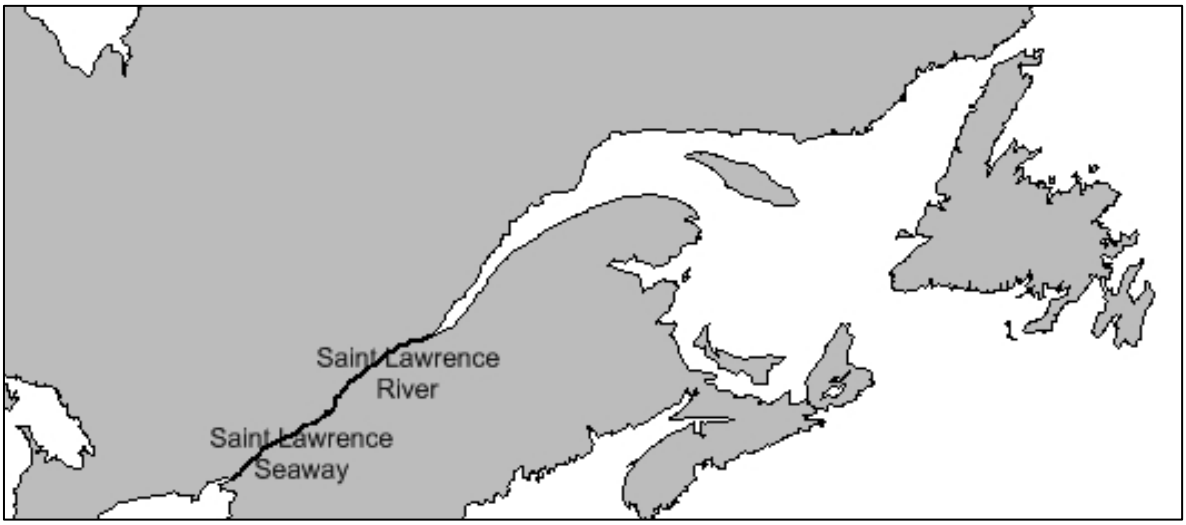

Figure 7: Saint Lawrence Seaway and Saint Lawrence River

Saint Lawrence Seaway	January	February	March	April	December
Mean ice thickness (cm)	34.8	43.3	45.9	48.0	26.8
Extreme ice thickness (cm)	69.0	91.0	114.0	109.0	33.0
Occurrence of the ice	every year	every year	every year	rare	rare

Saint Lawrence River	January	February	March	April	December
Mean ice thickness (cm)	41.8	52.3	64.2	41.0	35.9
Extreme ice thickness (cm)	105.0	105.0	126.0	41.0	70.0
Occurrence of the ice	every year	every year	every year	rare	rare

Table 27: Ice thickness data for Saint Lawrence Seaway and Saint Lawrence River

7. NAVIGATION IN OTHER ICE-COVERED AREAS IN THE EURASIAN CONTINENT

7.1. Other Eurasian ice-covered areas

During the winter, the Russian Arctic is not the only area where sea and river ice occur. Some areas farther in the south may also present tough navigation conditions, such as the following areas, dealt with in this chapter:

- Sakhalin area with Okhotsk Sea and Tatar Strait
- Bohai Bay
- Black Sea and Sea of Azov
- Caspian Sea.

These areas are located on Figure 8.

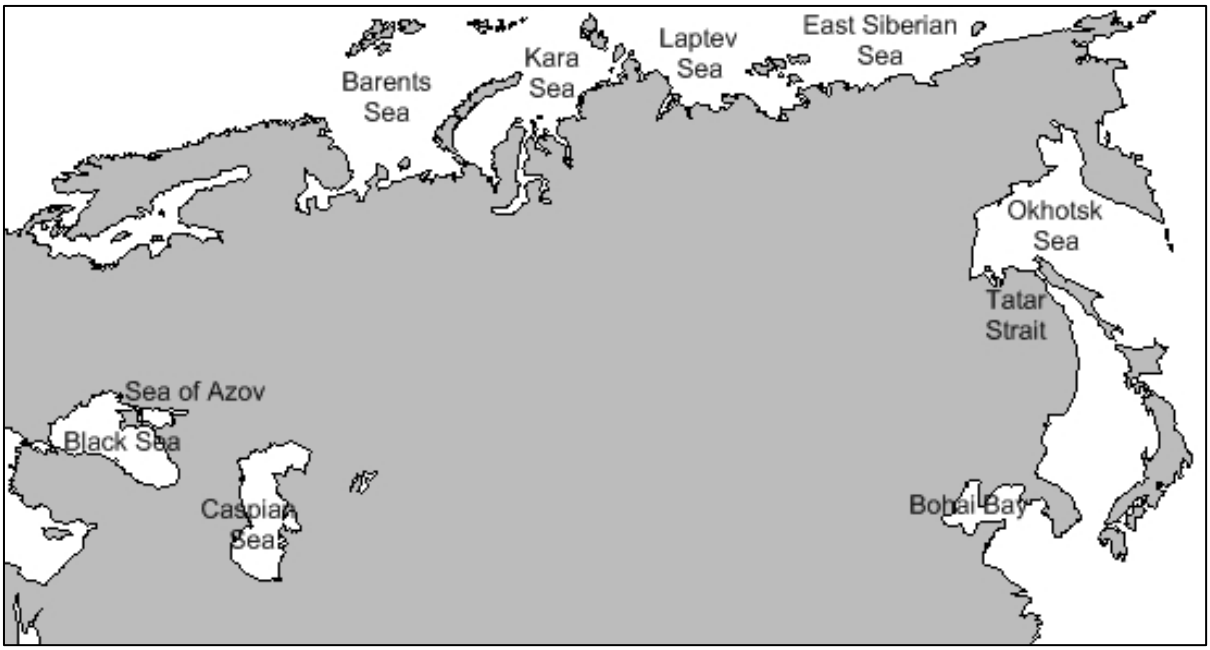

Figure 8: Russian possibly ice-covered areas

7.2. Navigation in Okhotsk Sea and Tatar Strait

Navigation in the north part of Sakhalin Island can be tough in winter: thick first-year ice and even ridges can occur in this area. Data of Table 28 reflect the extreme conditions that can be encountered during the winter, but they are given for information only and not for design purpose, calculations being based on averaged values in the whole sea regions and not on local extreme values. Moreover they were built from public data available on the Internet and consequently are not consistent enough for calculations.

To perform year-round ice navigation in northern Sakhalin area, a minimum POLAR CLASS 4 can be advised, while POLAR CLASS 6 or ICE CLASS IA SUPER can fit for the southern part of Okhotsk Sea.

Location	Air T°	Wind force	Waves (height – period)	Current
Tatar Strait	– 37℃	30 m/s	6 m – 10 sec	1.0 m/s
Okhotsk Sea	– 40℃	30 m/s	12 m – 10 sec	1.4 m/s

Location	Ice season	Ice thickness	Ridges	Icebergs
Tatar Strait	November - May	120 cm	20 ridges/km 12 m high	–
Okhotsk Sea	November - May	40 cm (south) 120 cm (north)	20 ridges/km 5-12 m high	–

Table 28: Meteorological conditions in Sakhalin area

7.3. Navigation in Bohai Bay

Although climate conditions are relatively mild in this bay, ice often occurs in winter, but the rather warm temperatures make the ice very thin and weak. Data of Table 29 reflect the extreme conditions that can be encountered during the winter, but they are given for information only and not for design purpose, calculations being based on averaged values in the whole sea regions and not on local extreme values. Moreover they were built from public data available on the Internet and consequently are not consistent enough for calculations.

To perform year-round ice navigation in Bohai Bay, a minimum ICE CLASS IB can be advised.

Location	Air T°	Wind force	Waves (height – period)	Current
Bohai Bay	– 10℃	–	3 m	2 m/s

Location	Ice season	Ice thickness	Ridges	Icebergs
Bohai Bay	December - March	50 cm	–	–

Table 29: Meteorological conditions in Bohai Bay

7.4. Navigation in Black Sea and Sea of Azov

Ice in the Black Sea occurs almost every year but only on a small portion of the area situated in its north-western part, while, in the Sea of Azov, ice can extend over the whole area, when winters are severe but a great variability occurs. Data of Table 30 reflect the extreme conditions that can be encountered during the winter, but they are given for information only and not for design purpose, calculations being based on averaged values in the whole sea regions and not on local extreme values. Moreover they were built from public data available on the Internet and consequently are not consistent enough for calculations.

To perform year-round ice navigation in Black Sea and Sea of Azov, a minimum ICE CLASS IB or ICE CLASS IC can be advised.

Location	Air T°	Wind force	Waves (height – period)	Current
Black Sea	– 25℃	30 m/s	0.4 m – 3 sec	0.4 m/s
Sea of Azov	– 5℃	20 m/s	0.3m – 5 sec	0.7 m/s

Location	Ice season	Ice thickness	Ridges	Icebergs
Black Sea	January - March	20 cm	–	–
Sea of Azov	December - March	30 cm	–	–

Table 30: Meteorological conditions in Black Sea and Sea of Azov

7.5. Navigation in Caspian Sea

Ice usually forms on the northern part of the Caspian Sea, but with a great variability from one year to another, and it is rather a strong ice due to the low salinity of the sea. Data of Table 31 reflect the extreme conditions that can be encountered during the winter, but they are given for information only and not for design purpose, calculations being based on averaged values in the whole sea regions and not on local extreme values. Moreover they were built from public data available on the Internet and consequently are not consistent enough for calculations.

To perform year-round ice navigation in every part of the Caspian Sea, a minimum ICE CLASS IA SUPER or POLAR CLASS 6 can be advised.

Location	Air T°	Wind force	Waves (height – period)	Current
North Caspian	– 20℃	25 m/s	1.3 m – 4 sec	0.5 m/s

Location	Ice season	Ice thickness	Ridges	Icebergs
North Caspian	November - March	80 cm	7 m high	–

Table 31: Meteorological conditions in Caspian Sea

8. NAVIGATION IN THE ANTARCTIC

8.1. Typical ice conditions

The Antarctic area is divided into six regions according to Figure 9:

- Ross Sea
- Bellingshausen Sea / Amundsen Sea
- Weddell Sea (west)
- Weddell Sea (east)
- Indian Ocean
- West Pacific Ocean.

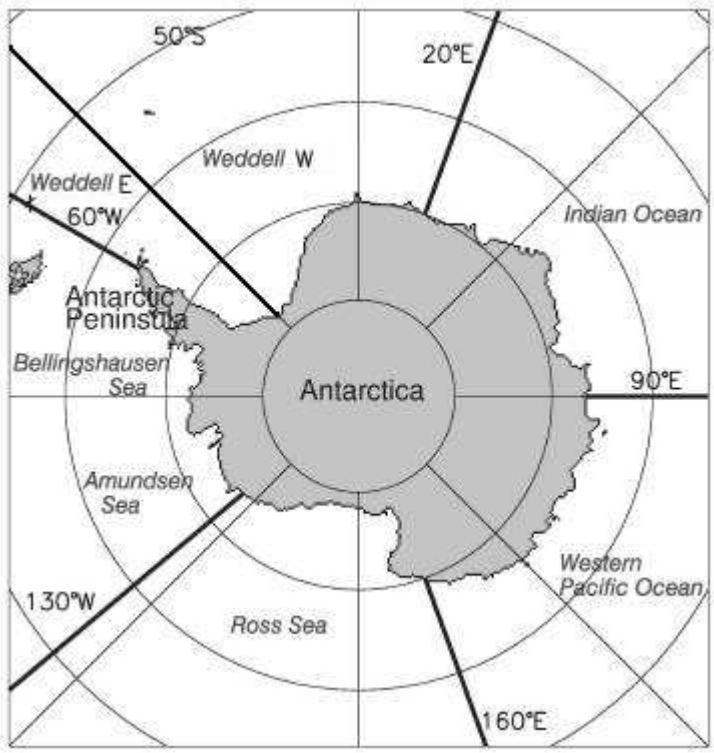

Figure 9: Navigation areas of Antarctic

8.2. Ice concentration

The data regarding ice concentration and expand in Antarctic Sea have been collected through satellite passive-microwave observations over the period 1978-2010 **[36], [37]**. Data of Table 32 reflect the extreme and average conditions that can be encountered during the winter, but they are given for information only and not for design purpose, calculations being based on averaged values in the whole sea regions and not on local extreme values. Moreover they were built from public data available on the Internet and consequently are not consistent enough for calculations.

To perform year-round ice navigation in every part of the Antarctic, POLAR CLASS 1 may be advised.

Location	Average annual ice thickness (m)	Maximum annual ice thickness (m)	Ice concentration
Ross Sea	1.07	3.0	6.7/10
Bellingshausen Sea Amundsen Sea	0.90	3.4	8.1/10
Weddell Sea (west)	1.33	3.0	6.5/10
Weddell Sea (east)	0.73	3.2	6.5/10
Indian Ocean	0.68	3.2	7.2/10
West Pacific Ocean	0.79	3.6	7.2/10

Table 32: Summary statistics of sea ice concentration and average ice thickness for each region around Antarctic

8.3. Iceberg concentration

The data regarding iceberg concentration and expand in Antarctic Sea have been collected over the period 2002-2010 [38]. There are three well-defined maxima, one in each ocean.

Figure 10 shows the average probability of icebergs from 2002 to 2010.

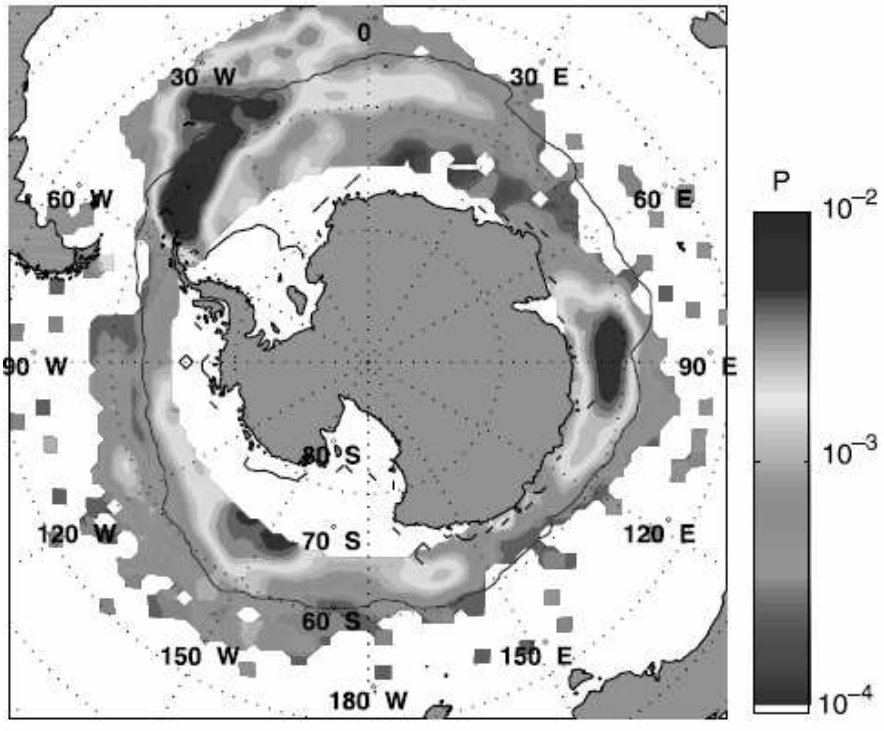

Figure 10: Average probability of icebergs from 2002 to 2010

References

[1] Chapter 8: Ice Class (ICE), *in:* Rules for the Classification of Steel Ships, Part E: Additional Class Notations, (NR 467) – Bureau Veritas.

[2] Rules for the Classification of POLAR CLASS and ICEBREAKER Ships (NR 527) – Bureau Veritas.

[3] Chapter 10, Section 11: Cold Weather Conditions *in:* Rules for the Classification of Steel Ships, Part E: Additional Class Notations (NR 467) – Bureau Veritas.

[4] Ice Class Regulations 2010: "Finnish-Swedish Ice Class Rules 2010" *in*: Trafi Maritime Safety Regulation – Finnish Transport Safety Agency
< http://www.trafi.fi/en/maritime/ice_classes_of_ships >

[5] Unified requirements I: Polar Class – International Association of Classifications Societies.
< www.iacs.org.uk/publications/publications.aspx?pageid=4&sectionid=3 >

[6] Sea-ice nomenclature – A.V. Bushuyev,
< www.aari.nw.ru/gdsidb/docs/wmo/nomenclature/WMO_Nomenclature_draft_version1-0.pdf >

[7] Arctic Waters Pollution Prevention Act (R.S., 1985, c. A-12) – Transport Canada: Government of Canada
< www.tc.gc.ca/eng/acts-regulations/acts-1985ca-12.htm >

[8] Canadian Ice Service – Transport Canada: Government of Canada
< www.ec.gc.ca/glaces-ice >

[9] Arctic Ice Regime Shipping System (AIRSS) Standards - TP 12259 – Transport Canada: Government of Canada
< http://www.tc.gc.ca/eng/marinesafety/tp-tp12259-menu-605.htm >

[10] Equivalent Standards for the Construction of Arctic Class Ships (1995) - TP 12260 – Transport Canada: Government of Canada
< www.tc.gc.ca/eng/marinesafety/tp-tp12260-menu-924.htm >

[11] Marine Safety – Transport Canada: Government of Canada
< www.tc.gc.ca/MarineSafety/menu.htm >

[12] Canada Shipping Act, 2001 (2001, c. 26) – Transport Canada: Government of Canada
< www.tc.gc.ca/eng/acts-regulations/acts-2001c26.htm >

[13] A Guide to Canada's Ballast Water Control and Management Regulations TP 13617 E – Transport Canada: Government of Canada
< http://www.tc.gc.ca/eng/marinesafety/tp-tp13617-menu-2138.htm >

[14] Guidelines for the Operation of Passenger Vessels in Canadian Arctic Waters - TP 13670 E – Transport Canada: Government of Canada
< www.tc.gc.ca/eng/marinesafety/tp-tp13670-menu-2315.htm >

[15] Joint Industry: Government Guidelines for the Control of Oil Tankers and Bulk Chemical Carriers in Ice Control Zones of Eastern Canada - TP 15163 B (2012) – Transport Canada: Government of Canada
< www.tc.gc.ca/eng/marinesafety/tp-tp15163-menu-4025.htm >

[16] 30-year Climatic Atlasses – Canadian Ice Service.
< http://www.ec.gc.ca/glaces-ice/default.asp?lang=En&n=08D7D137-1 >

[17] Greenland Regional Ice Charts – Danish Meteorological Institute
< http://www.dmi.dk/dmi/en/gronland/iskort.htm >

[18] National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format – U.S. National Ice Center (NIC)
< nsidc.org/data/g02172.html >

[19] Weather, Sea and Ice Conditions in Eastern Baffin Bay, Offshore Northwest Greenland: A Review – Danish Meteorological Institute
< www.geus.dk/ghexis/pdf/baffinb.pdf >

[20] IMO Resolution A.1024(26): Guidelines For Ships Operating In Polar Waters -– International Maritime Organistation

[21] Safety of navigation in Greenland waters -– Danish maritime authority
< www.dma.dk/ships/sider/greenlandwaters.aspx >

[22] Order on technical regulation on safety of navigation in Greenland territorial waters: Order no. 417 of 28 May 2009 – Danish Maritime Authority.
< www.dma.dk/SiteCollectionDocuments/Legislation/Orders/2009/BEK-417-28052009-sejlads%20i%20groenlandsk%20soeterritorium.pdf >

[23] Information about the GREENPOS System – Grønlands Kommando
< forsvaret.dk/GLK/GREENPOS/GREENPOS%20IN%20ENGLISH/Pages/default.aspx >

[24] Technical regulation on the use of ice searchlights during navigation in Greenland waters: Technical Regulation no. 169 of 4 March 2009 – Danish Maritime Authority.
< www.dma.dk/SiteCollectionDocuments/Legislation/Technical%20regulations/2009/TF%20169-04032009-isprojektoerer%20ved%20groenland.pdf >

[25] Weather, sea and ice conditions offshore West Greenland: Focusing on new license areas, 2004 -– Greenland Bureau of Minerals and Petroleum. Danish Meteorological Institute
< www.geus.dk/ghexis/pdf/weather_ice_2004.pdf >

[26] The circulation, water masses and sea-ice of Baffin Bay (2004) -– C. Tang, C. Ross, T. Yao, B. Petrie, B. DeTracey and E. Dunlap
< asofw.apl.washington.edu/assets/pdfs/progocean_tang_baffin.pdf >

[27] Improving efficiency of ships operating in severe ice conditions *in*: 3rd Arctic Shipping Conference (2007) – V; Evenkov, and S. Kaganov

[28] Rules of navigation in the Northern Sea Route water area -– Russian Federation Transport Ministry

[29] Guide to Navigating through the Northern Sea Route – Northern Sea Route Information Office

[30] Report on current regulations and practices and impact of IMO Guidelines – Central Marine Research and Design Institute CNIIM, GROWTH project GRD2-2000-30112 "ARCOP".

[31] Northern Sea Route and Icebreaking Technology (June 1994) – US Army Corps of Engineers, Cold Regions Research & Engineering Laboratory
< www.crrel.usace.army.mil/library/crrelreports/NSR.pdf >

[32] Ice conditions in the Baltic Sea – The Baltic Sea Portal
< http://www.itameriportaali.fi/en/tietoa/jaa/jaatalvi/en_GB/jaatalvi/ >

[33] Baltic Icebreaking Management.
< http://portal.liikennevirasto.fi/sivu/www/baltice >

[34] TraFi List of equivalences 2010 – Finnish Transport Safety agency.
< www.trafi.fi/en/maritime/ice_classes_of_ships >

[35] Finnish State Pilotage Enterprise
< http://www.finnpilot.fi/www/en_UK/ >

[36] Thickness distribution of Antarctic sea ice *in* Journal of Geophysical Research: Oceans, Vol. 113, Issue C5 (May 2008) – A. Worby, C. Geiger, M. Paget, M. Van Woert, S. Ackley, and T. DeLiberty

[37] Antarctic sea ice variability and trends, 1979–2010 *in*: The Cryosphere, Vol. 6, Number 4 (2012) – D. Cavalieri, and C. Parkinson

[38] Antarctic icebergs distributions, 2002-2010 *in*: Journal of Geophysical Research: Oceans, Vol. 117, Issue C5 (May 2012) – J. Tournadre, F. Girard-Ardhuin, and B. Legrésy