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AGREE − DISAGREE: COMPARING TRAFFIC LIMITATIONS IN THE KARA SEA

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ABSTRACT

Abstract: This study investigates variability of ships' operational limitations for ice conditions in view of national rules and international recommendations (the Rules for Navigation in the Water Area of the Northern Sea Route and the International Maritime Organization Recommendations). As an example, the Kara Sea region is considered for the period of 2017-2019. The ship data from two datasets were considered: (1) the Northern Sea Route Administration data and (2) the Automatic Identification System data. For each ship's ice class, the ice information (concentration and type) was used to derive operational limitations based on the Polar Operational Limit Assessment Risk Indexing System (POLARIS), and the results were compared with the newly updated Northern Sea Route access criteria. Preliminary results indicate that national rules are generally stricter than international recommendations, however on some occasions, the national rules impose lesser restrictions on operations as ships with ice class PC7/Arc4 are allowed to operate when international recommendations suggest an elevated probability of an accidental event.

Keywords: Kare Sea, rules, navigation, ice

1. INTRODUCTION

The safety and environmental provisions of the Polar Code [1] are mandatory under the International Convention for the Safety of Life at Sea (SOLAS) [2] with the addition of new chapter XIV [3] as well as under the International Convention for the Prevention of Pollution from Ships (MARPOL) [4] with amendments to Annexes I, II, IV, and V [5]. In addition, under the international agreement, the United Nations Convention on the Law of the Sea (UNCLOS), Article 234 [6], the Arctic Coastal States can adopt and enforce non-discriminatory laws and regulations in ice-covered areas in their exclusive economic zone. These laws and regulations "shall have due regard to navigation and the protection and preservation of the marine environment…" ([6], Sec. 8, Article 234). The latter statement is open to interpretations and therefore, and according to [7], from a legal viewpoint, there is no clear way to determine whether a national law is consistent with the international legal framework and recommendations (e.g., recommendations of the International Maritime Organization). This study is a first attempt at a nuanced quantification of consistency (or inconsistency) between national rules and international recommendations in ice infested Arctic waters while focusing on operational limitations. For a broader discussion on inconsistencies between national and international regulations refer to [7].

As a case study, water area of the Kara Sea region is chosen. The following sections briefly introduce the international- and national procedures for assessment of operational limitations and access criteria.

1.1 International guidelines: Operational limitations

International Maritime Organization [8] recommends a Polar Operational Limit Assessment Risk Indexing System (POLARIS) as an acceptable methodology to determine a set of operational limitations in ice. Despite limitations, POLARIS is "a pillar in the overall decision process of various stakeholders such as classification societies, underwriters, and shipowners" [9]. The basis of POLARIS is an evaluation of the risks (a probability of an accidental event or so-called the Risk Index Outcome (RIO) posed to a ship by ice conditions in relation to a ship's assigned ice class. The risk index outcome sets out the limitation of operations. The formula for the calculation of risk index outcome (r) from POLARIS is given as:

$$r = (C_1 \times R_1) + (C_2 \times R_2) + (C_3 \times R_3) + \ldots + (C_n \times R_n) \quad (1)$$

where C_1, C_2, …, C_n are the concentrations (in tenths) of ice types within the ice regime, including ice free area, and R_1, R_2, …, Rn are the corresponding Risk Index Values (RIV) for each ice type

and ice-free area. Tabulated RIVs, corresponding to a particular ice type/thickness and the ship's polar ice class, can be found in [8] (Tables 1.3 and 1.4).

The decision to operate or the limitation of operations is determined depending on RIO: normal operation ($r \geq 0$), elevated operational risk ($-10 \leq r < 0$), and operation subjected to special considerations ($r < -10$). Adaptive measures may be taken in consideration of the RIO, such as limiting the speed in ice, additional watchkeeping, or icebreaker support. Equation (1) is valid for independent navigation, whereas under the icebreaker escort, an average value of +10 should be added to the RIO value. The latter is only valid during planning of operations when ice conditions in front of the escorted ship are unknown. In addition, RIV depends on the ice thermal state/ice strength. For decayed ice in warmer ambient temperatures, higher RIVs are increased for certain ice types and the RIO value is increased.

For voyage planning, areas, in which the potential to encounter $r < 0$ has been identified, should generally be avoided (pt. 1.4.5 of [8]). In general, escorted operations should be reconsidered if the escorted ship is in an ice regime for which operation is subject to special consideration.

1.2 National law: Access criteria to the Kara Sea in the Rules for Navigation in the Water Area of the Northern Sea Route

All civil ships transiting northern Sea Route (including the Kara Sea region) should follow national regulations [10]. The updated rules were adopted in September 2020 and define criteria to access the water area of the Northern Sea Route.

In view of the access to the Kara Sea by Arc4-Arc9 ice class ships, below we highlight the important updates (for other geographical regions, refer to Table 2 in [10]).

1.2.1 New updates

Navigational area: The navigational area is now divided into several distinctive non-overlapping zones (for the Kara sea region, these are zones 1-10 and a part of 11 in Fig. 1). In earlier rules (the rules from 2013), the Kara Sea was divided into two parts, the Southwest Part (now zones 1-7) and the Northeast Part (zones 8-10 and partly 11). In each zone, depending on the severity of ice conditions and ship's ice class, the rules specify whether the ship can operate independently or under icebreaker escort.

Seasonal navigation: Seasonal criteria for navigation, i.e. (1) the winter-spring navigational season: January – June and December and (2) the summer-autumn navigational season: July – November), have been merged into one table instead of two. 'Ice free water' conditions (termed 'clear water' in the unofficial English translation of the document [10]) were added to the ice conditions. This is an addition the to the existing earlier distinction between severe ('heavy') ice conditions, moderate ('medium') ice conditions, and light ice conditions.

Access criteria: There is no change in access criteria for Arc7, Arc8, and Arc9 ships as well as there is no change in access criteria for independently navigating Arc4 and Arc5 ships during December and January-June in the Southwest part of the Kara Sea. A somewhat stricter access criteria have been imposed for the lower-class ships (Arc4, Arc5, and Arc6) in the northeast part of the Kara Sea.

Arc4 ships are now not allowed to independently operate in the northeast part when moderate ice conditions are present during July – November.

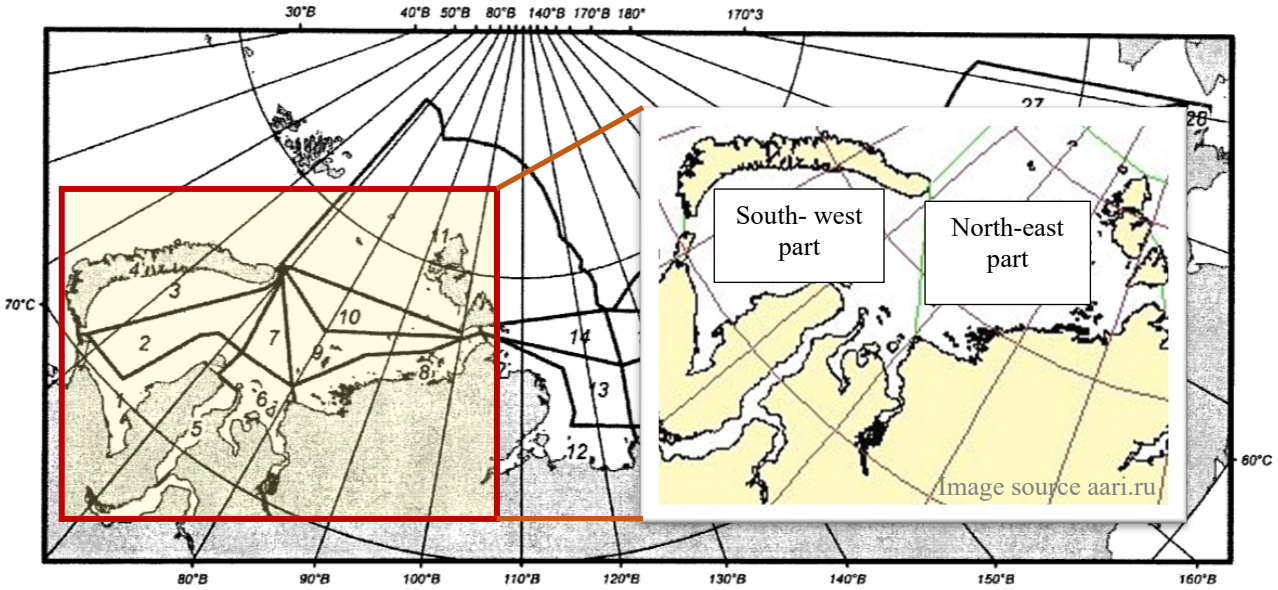

FIGURE 1: ZONES IN THE NEW RULES (ADOPTED FROM [10] WITH CLARIFICAIONS).

Arc5 ships are now not allowed to independently operate in the Kara Sea when ice conditions are severe during July-November and in the northeast part of the Kara Sea when ice conditions are moderate in July-November. Arc 6 ships are now not allowed to operate independently in the Northeast part during July-November, when ice conditions are severe. Less stricter access criteria for ships under icebreaker assistance: Ships with classes Arc4 – Arc9 are now allowed to operate year around in the Kara Sea region provided the icebreaker assistance. Arc6 ships are permitted to independently operate year around in the southwest part of the Kara sea in moderate ice conditions.

1.2.2 Remarks

From a practical viewpoint, due regard to ice navigation, an important question is how to distinguish between severe-, moderate-, and light ice conditions. It is assumed that it will be possible to uniquely place the severity of ice conditions into one of three groups (light-, moderate-, or severe ice conditions). At present, the severity of ice conditions is related to the ice thickness (or the ice age) and ice concentration, ref. Table 1. Note, that the rules itself do not define the severity of the ice conditions but rather require "The Authorized body or its subordinate organization" to post on their website about the "ice forecasts 72 hours in advance related to the water area of the Northern Sea Route including the forecast of assessing of the types of ice conditions "heavy", "medium", "light", "clear water" for the areas of the water area of the Northern Sea Route" (ref. pt. 42 in [10]). Furthermore, there is no, as noted by [11], identification of light, moderate or severe ice conditions in the normative documents of the Federal Agency for Sea and Inland Water Transport of the Russian Federation (Rosmorrechflot) and of the Federal Service for Hydrometeorology and Environmental Monitoring of the Russian Federation (Roshydromet).

In this view, ice conditions that are important to navigation must be considered. For example, in the Southwest part of the Kara Sea, according to [11], the land fast ice in the shallow part of the region do not have significant meaning for ice navigation, and thus should not be considered when determining severity of ice conditions. In contrast to this, the land fast ice should be considered in the northeast part because the shipping routes lie in it. Furthermore, when determining ice concentration, the measurement error should also be considered (e.g., this error could be 10% [11] or more depending on the ice information product and area under consideration).

Dumanskaya [11] argues for a possibility of using a freezing-degree-days parameter to characterize light, moderate, and severe ice conditions, and also that the difficult conditions for navigation is not only determined by the ice thickness but also could depend on the traffic density and the size of the ships in the area. "A loss of the ship's speed in ice (due to any reason) will make almost all ice conditions severe" – writes Dumanskaya [11]. She further argues to account for uncertainties in interpretation of satellite images and suggests establishing a 30% concentration limit rather than 25% (as set in Table 1a). Table 1 below lists practical gradation criteria of ice conditions.

TABLE 1a: GRADATION OF ICE CONDITIONS IN THE ARCTIC SEAS AND THE BERING SEA (ADOPTED FROM [11]).

Ice	Criteria
Light	New, Young ice, and First Year Ice (up to 0.7 m thick), possibly presence Medium First Year Ice (<1.2 m) concentrations < 25%
Moderate	Medium First Year Ice (up to 1.2 m) concentrations of 25% and more, possible presence of Thick First Year Ice (>1.2 m) concentrations <25%
Severe	Thick first year ice (>1.2 m) and old ice (2 m and more) with concentrations of 25% and more.

TABLE 1b: GRADATION CRITERIA OF ICE CONDITIONS BY THE NORTHERN SEA ROUTE ADMINITRATION [12].

Ice	Criteria
Light	The area of the first-year medium sea ice < 30%
Moderate	The area of the first-year medium ice ≥ 30%
Severe	The area of the thick sea ice ≥ 30%

To summarize, there are clear differences and similarities between national and international procedures for assessment of operational limitations and access to the icy waters. Both procedures reduce operational limitations for ships under icebreaker escort and do not account for reliability/uncertainty of the ice information; however, [8] does not distinguish between geographical areas nor explicitly the operational season whereas [10] does. It is also different how ice conditions are treated. A conceptual difference between the methodologies in national rules and international recommendations is that POLARIS is a decision support tool, whereas the national procedures are the 'allowed/not allowed' rules.

In this context, it is of interest to gain a deeper understanding of implications when using one or another assessment in the same geographical area for the same ice conditions.

1.3 Scope

This work is a follow up of the investigation by [13] in which operational limitations in the Kara Sea were studied from January through April for 2017–2019. In this study we extend the analysis to three full years 2017-2019. The aim is to investigate variability of ships' operational limitations for ice conditions in view of the national rules and international recommendations. In particular, the updated Rules for Navigation in the Water Area of the Northern Sea Route [10] and the Polar Operational Limit Assessment Risk Indexing System of IMO [8].

For each ship's ice class, the ice information (ice concentration and type) was used to derive operational limitations based on POLARIS, and the results were compared with the newly updated Northern Sea Route access criteria.

The following sections briefly describe the data and analysis methodology, present results of the analysis followed by a discussion.

2. MATERIALS AND METHODS

For this assessment, several data sources were considered and are listed in Table 2 with the corresponding characteristics. The considered datasets are the Northern Sea Route Administration (NSRA) data [12, 14], the Automatic Identification System (AIS) data, the Arctic and Antarctic Research Institute (AARI) data [15] as well as the national and international documents.

TABLE 2: DATA SUMMARY.

Dataset	Characteristics			Ref.
Regulations (public documents)				
IMO	International	Polar reg.	2017	[8]
NSRA	National	NSR	2020	[10]
Ship information				
NSRA	Irregular, daily	NSR (only)	2017-2019 (Jan-April)	[14]
AIS (Norway)	Irregular, sec., min.	NSR +	2017-2018 (Jan-April)	–
Sea ice information (observations)				
AARI	weekly	resolution	2017-2019	[15]

NSRA data, low temporal resolution, i.e., days: The records of ships in the Kara Sea region were taken from the Northern Sea Route Administration (NSRA) website [14], which daily updates the records. These records consist of ship's name, IMO number, position, heading, speed, and ship's ice class (as assigned by NSRA). The collected data (latitude and longitude information, the speed, and the headings) was pre-processed and cleaned to remove missing or erroneous entries. Also, the type of ship, the year built, deadweight, and the gross tonnage of the ship was also added to the dataset.

AIS data, high temporal resolution, i.e., seconds, minutes depending on the ship speed: The AIS data was retrieved from the Norwegian Coastal Administration (NCA) for the years 2017-2018 and January 2019 The AIS data was cleaned and enhanced with additional ship information before analysis (i., e., type of ship, year built, deadweight, ice class, and gross tonnage). Details can be found in [16]. Some ships can have two or more ice classes (e.g. Arc 5, Arc 4, and Ice 3) that depends on the operational draft. To simplify the problem, we kept only the lowest ice class.

Ice charts from Arctic and Antarctic Research Institute (AARI): The weekly ice data were downloaded from the website of AARI [15] in SIGRID-3 format [17] for the three years 2017 – 2019. The data description and processing were described in [13] and thus omitted herein.

First, we have investigated how the temporal resolution of ship data influences distributions of the RIO values in the Kara Sea. For this purpose, we have calculated RIO values following the procedure in [13] with only difference being the temporal resolution of the ship data.

Next, we have searched for consistencies and inconsistencies between international recommendations and national rules by using two methods:

(1) Derivation of access-to-Kara-Sea tables (ref. Section 3.2) for different modes of operation, ice class of the ship, and ice state. This was achieved by mapping the severity of ice conditions to the RIO value using the limiting concentrations for each of cases of severity (Light/Moderate/Severe in Table 1a). It was assumed that the severity of ice conditions can uniquely be placed into one of three groups following the definitions in Table 1a. The derived tables were analyzed and compared to the access rules [10].

(2) Derivation of the restricted operation areas in the Kara Sea by using POLARIS as well as by using definitions of ice severity from Table 1a and classifying the gridded ice data (AARI, 2017-2019) based upon the reported concentration and stage of development. The obtained access maps were analyzed and related to access rules [10].

Preliminary results are reported in the following section.

3. RESULTS AND DISCUSSION

3.1 Effect of temporal resolution of ship data on operational limitations

Figure 2 shows two frequency plots. One − is for the RIO values in the period 2017-2018 (January- April) calculated using AIS data, another – is for the RIO values in the same period but using the NSRA data. There are variations in the distribution of the RIO values, however, all calculated values lie between 20 and 30. *There is no effect of the ships' data temporal resolution on the range of the RIO values in the Kara Sea region*.

The temporal and spatial resolution of ice information (ice type and concentration) is crucial for assessment of operation limitations. The AIS data have essentially higher temporal resolution (minutes, seconds) than the available ice information (daily at most). This resolution discrepancy lowers the benefit of using the AIS data in similar assessments until more frequent ice information products become available.

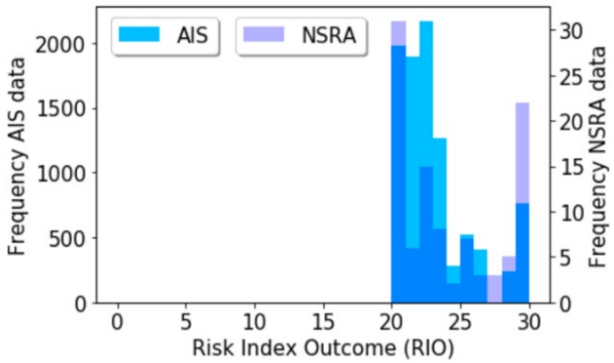

FIGURE 2: RIO FREQUENCY DISTRIBUTION FOR ARC7 (PC3) SHIPS FOR THE PERIOD 2017-2018 (JANUARY-APRIL) IN THE KARA SEA REGION. CALCULATED BASED ON AIS DATA, NSRA DATA, AND AARI ICE DATA.

3.2 Operational limitation based on [10] and [8]

Figure 3 presents results of a comparison between the national rules [10] and international recommendations [8]. To

calculate RIO under icebreaker escort we have added +10 to its calculated value. Note that this was a simplification (+10 is an average value which can vary significantly during actual operations).

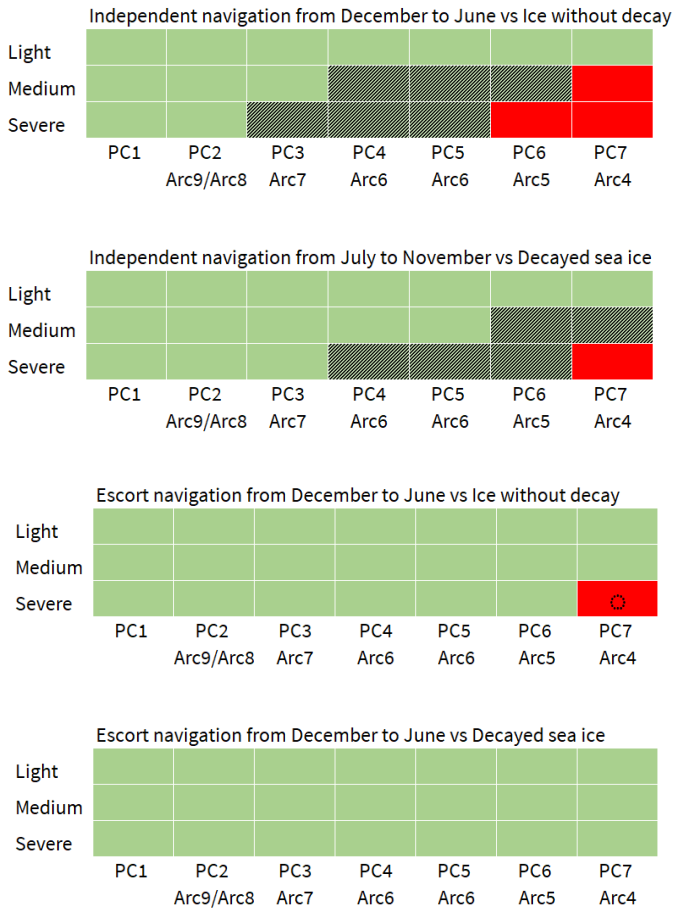

FIGURE 3: POALARIS RECOMMENDATIONS VS. NATIONAL ACCESS CRITERIA IN THE NORTHEAST KARA SEA. *GREEN* DENOTES NORMAL OPERATION (RIO ≥ 0) AND *RED* DENOTES RESTRICTED OPERATION (RIO < 0); HATCHED AREAS DENOTE 'NOT ALLOWED' OPERATION BASED ON [10] AND THE SYMBOL 'O' MEANS THE OPERATION IS ALLOWED BY [10].

Results reported in Figure 3 indicate the following: If the gradation on light-, moderate-, and severe ice conditions is only and uniquely based on the ice thickness (age) and concentration, then, according to POLARIS (IMO), the access of Arc4 (PC7) to the area with severe ice conditions should be subjected to special consideration even with the icebreaker escort (RIO < 0). However, new national rules imposed in the Kara sea region allow access of ships with ice class Arc4 under the icebreaker escort without additional considerations. This seems like an inconsistency between the national rules and international recommendations. However, this inconsistency could be justified by the specifics of operations on the Northern Sea route. The ice passport available on the ship regulates its speed even under the icebreaker escort. Furthermore, the escort operations can include towing which is not the same as the escort operation when a ship independently sails behind the icebreaker. POLARIS does not take the latter into account.

For higher ice classes (Arc7-Arc9) the international recommendations [8] and the national rules [10] are consistent in the southwest part of the Kara Sea. In the northeast part, the requirements of the new rules are stricter than that of POLARIS during months January-June and December. Ships with ice class Arc7 are not allowed to independently access the region when ice conditions are severe.

For independently navigating ships with lower ice classes (Arc4–Arc6), the national rules also impose stricter requirements than that of POLARIS in areas with moderate and severe ice conditions. According to the rules, none of these ships can independently access the region under severe ice conditions during January-June and December, whereas POLARIS allows it for Arc6.

In summary our results show that the new national rules [10] impose stricter requirements for independently navigating ships with Arc7 class but somewhat lesser restrictions for Arc4 ships with icebreaker escort in the Kara Sea. According to the results in Fig. 3, the Arc4 ships are allowed to operate under the elevated operational risk (probability of an accidental event).

The results presented in Fig. 3 assume that the gradation on light- moderate-, and severe ice conditions is unique. In practice, this is not true, and extra assumptions are necessary. When actual ice charts were used to determine severity of ice conditions (Fig. 4), on several occasions, it was not possible to uniquely determine the severity of ice conditions (ref. to gray-colored areas in Fig. 4). There is an uncertainty on how to treat multiyear ice inclusions with concentrations < 25%. The multiyear ice can be detected and avoided if their concentration is low, however, as pointed out by [18], "distinguishing first-year, second-year and multi-year from each other (and sometimes from glacial ice) can be extremely challenging, even for the most experienced personnel". Therefore, we argue that the current distinction between light-, moderate-, severe conditions is not straightforward (not all ice conditions are covered) and it could depend on the experience of the personnel.

Figure 4 presents access maps (12 in total) for Arc4/PC7 ships for three severity levels of ice-conditions (light-, medium, -severe), for two operational seasons (summer-autumn navigation and winter-spring navigation), and for two modes of operation (independent navigation and navigation under escort) Looking at Fig. 4, the following observations can be made:

1. During summer-autumn navigation (from 1st July to 30th November), for most of the cases, it was impossible to uniquely place ice conditions into one of the three groups. Thus, a comparison between the Russian rules [10] and POLARIS [8] cannot be made without introducing further assumptions.

2. During winter-spring navigation (1st January to 30th June and 1st Dec to 31st December), the restricted areas for navigation [10] are mostly consistent with RIO by POLARIS being negative. However, this is not the case for operations under the icebreaker escort when ice conditions are severe. POLARIS appeared to be stricter for Arc4/PC7 ice class ships with icebreaker escort. This is evident from looking at just the calculations without any actual ice data (i.e., Fig. 3) and is supported by actual ice data from AARI [15]. The escort operations are allowed (for Arc4/PC7 ice class ships having RIO<0) according to national rules, whereas according to international recommendations, the escorted operation should be reconsidered if RIO<0. This is one of the important inconsistencies between national rules and international recommendations.

To summarize, the *preliminary findings* are the following:

- The temporal resolution of the ship data does not affect RIO distribution in the considered area within the considered time (January – April, 2017-2018).

- National rules are generally stricter than international recommendations, however on some occasions, the national rules impose lesser restrictions on operations as ships with ice class PC7/Arc4 are allowed to operate when international recommendations suggest an elevated probability an accidental event.

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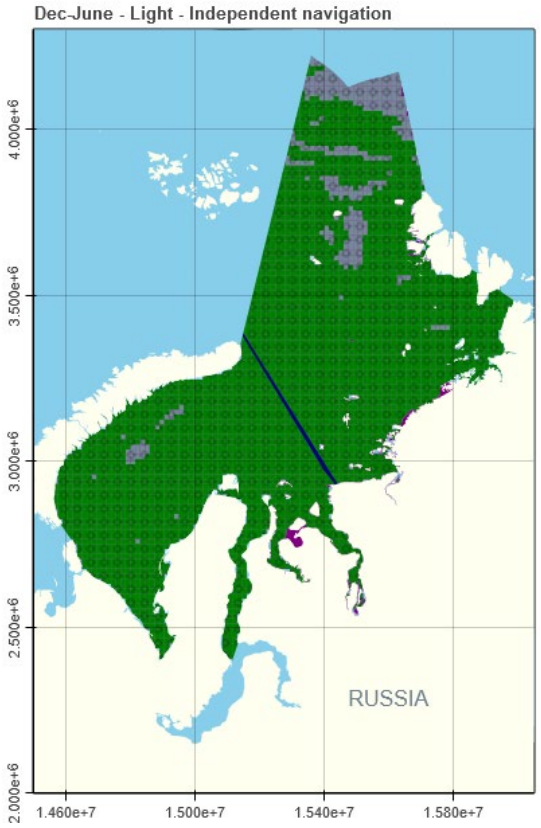
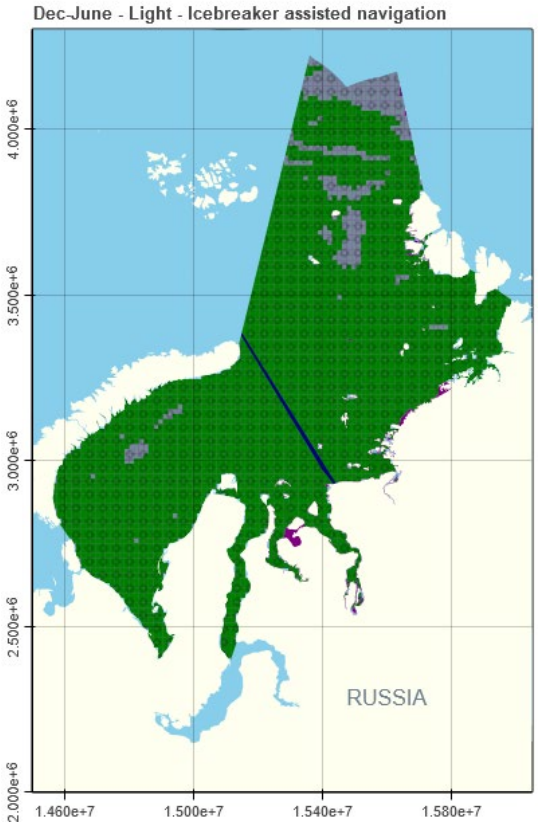
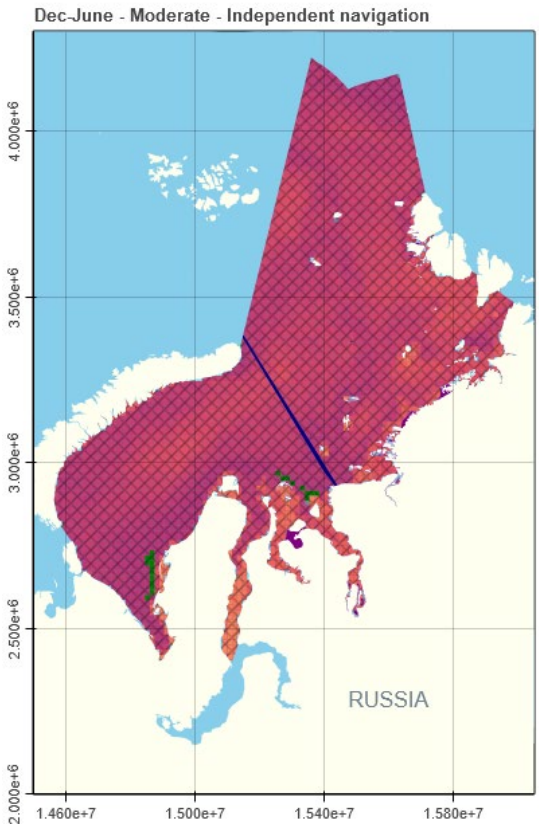
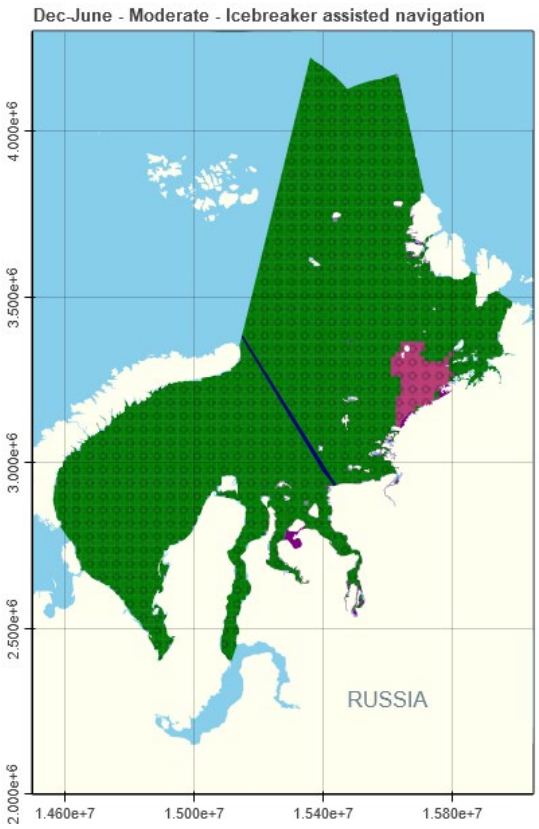
. 3.3 Lack of normative definitions

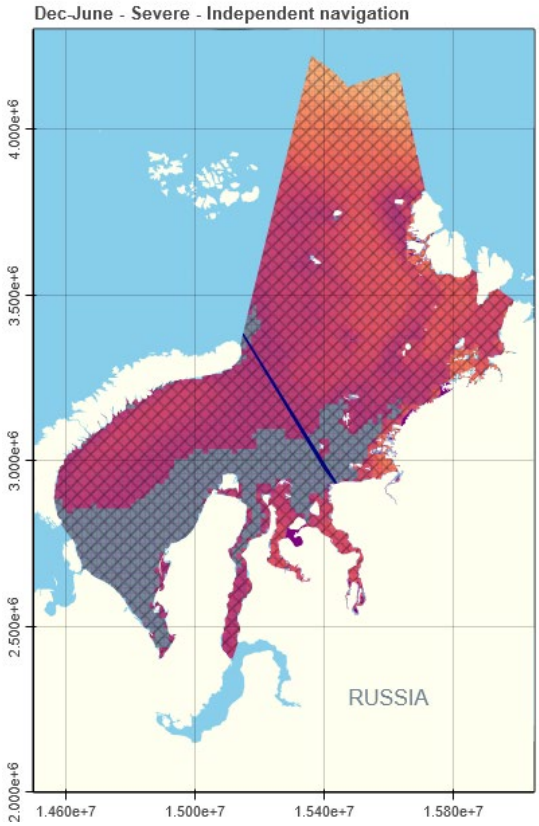
In the interest of clarity, to address the lack of normative definitions of ice conditions (i.e., light/moderate/severe), we have compared access maps based the definitions set in Table 1a and Table 1b (see Fig. 5). The NSRA definitions (from Table 1b) render even more uncertain areas (gray-colored regions in Fig. 5) since they do not contain fine-grained classification for old ice, or new and young ice.






Dec-June - Moderate - Independent navigation
4.000e+6
3.500e+6
3.000e+6
2.500e+6
2.000e+6
1.460e+7
1.500e+7
1.540e+7
1.580e+7
RUSSIA


Dec-June - Moderate - Icebreaker assisted navigation
4.000e+6
3.500e+6
3.000e+6
2.500e+6
2.000e+6
1.460e+7
1.500e+7
1.540e+7
1.580e+7
RUSSIA


Dec-June - Severe - Independent navigation
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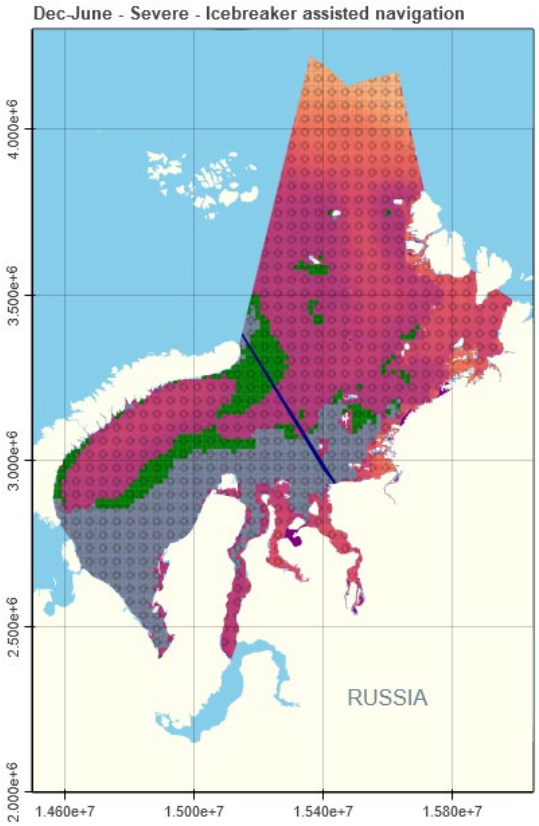
3.500e+6
3.000e+6
2.500e+6
2.000e+6
1.460e+7
1.500e+7
1.540e+7
1.580e+7
RUSSIA


Dec-June - Severe - Icebreaker assisted navigation
4.000e+6
3.500e+6
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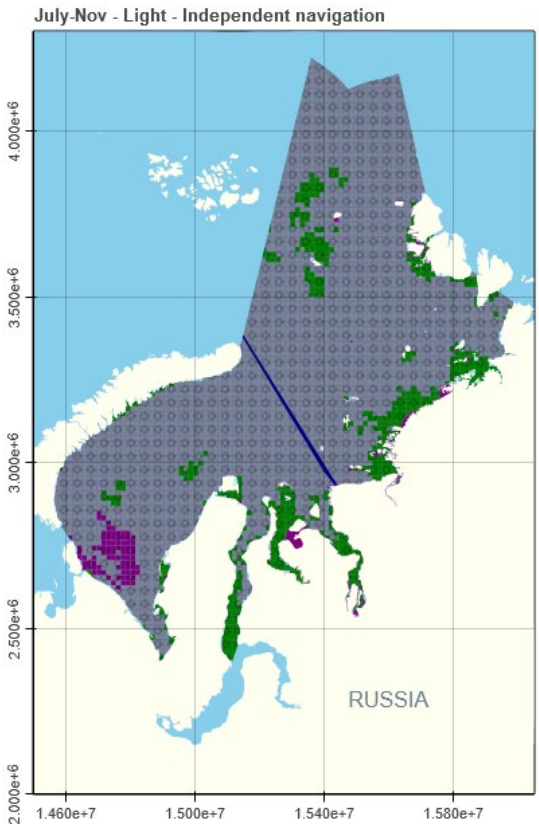
1.580e+7
RUSSIA


July-Nov - Light - Independent navigation
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3.000e+6
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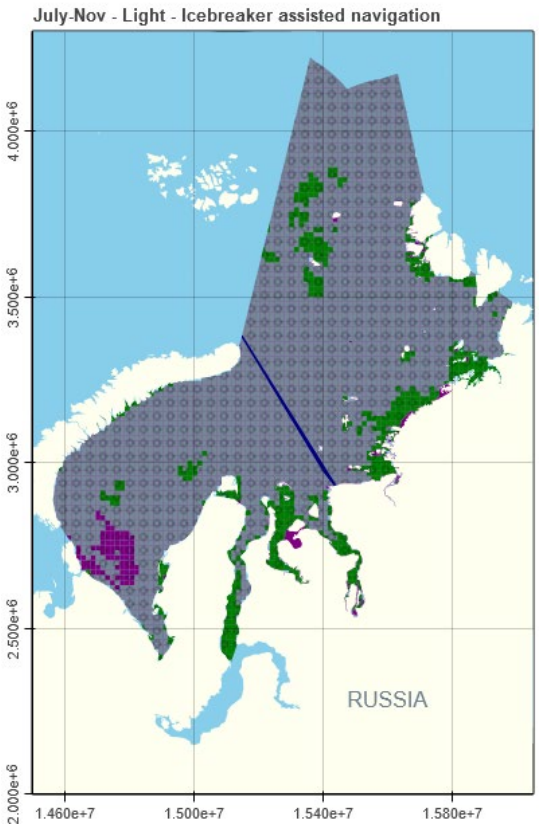
1.500e+7
1.540e+7
1.580e+7
RUSSIA


July-Nov - Light - Icebreaker assisted navigation
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3.500e+6
3.000e+6
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1.500e+7
1.540e+7
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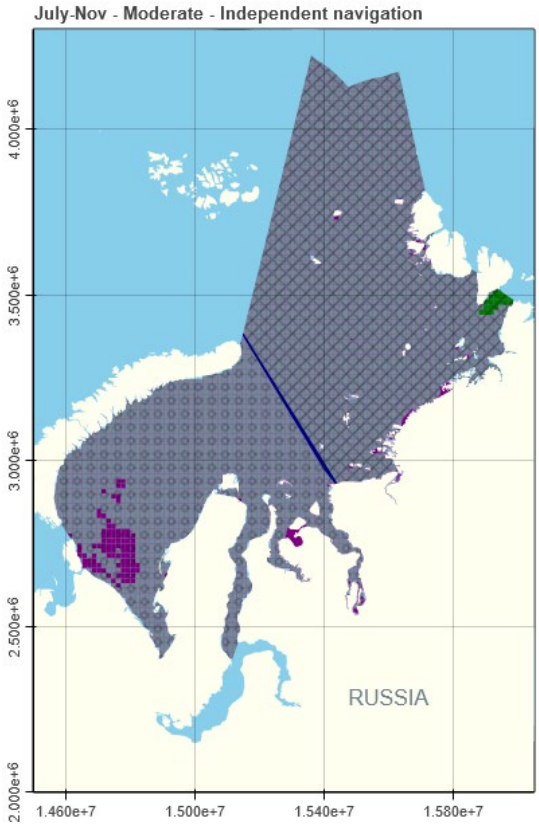
RUSSIA


July-Nov - Moderate - Independent navigation
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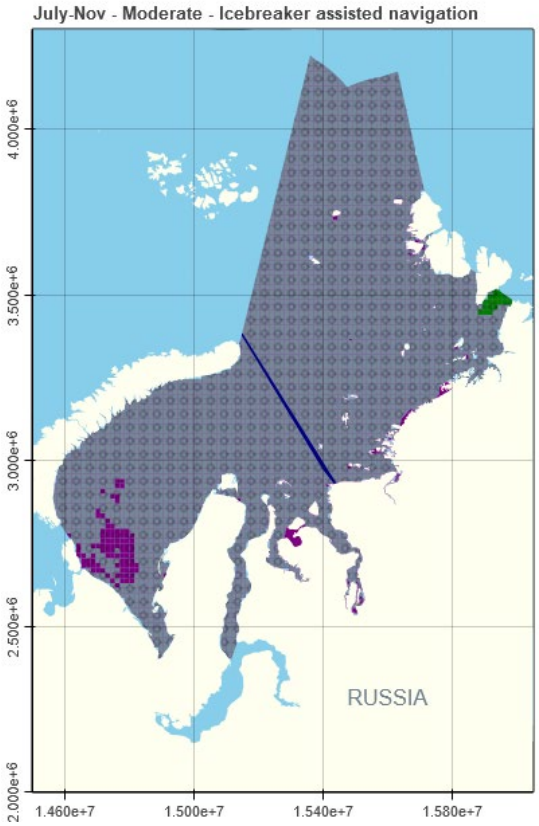
3.000e+6
2.500e+6
2.000e+6
1.460e+7
1.500e+7
1.540e+7
1.580e+7
RUSSIA


July-Nov - Moderate - Icebreaker assisted navigation
4.000e+6
3.500e+6
3.000e+6
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1.500e+7
1.540e+7
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RUSSIA

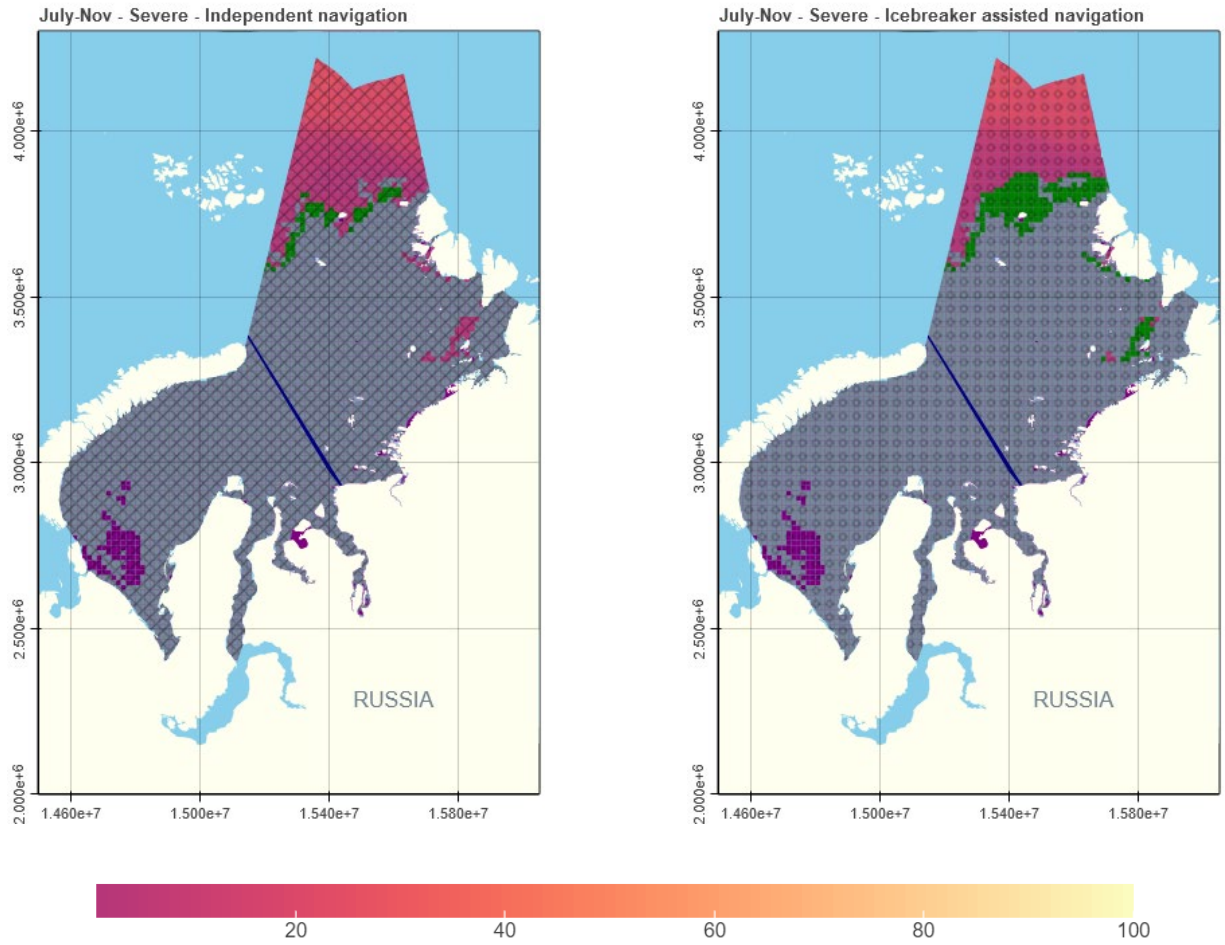
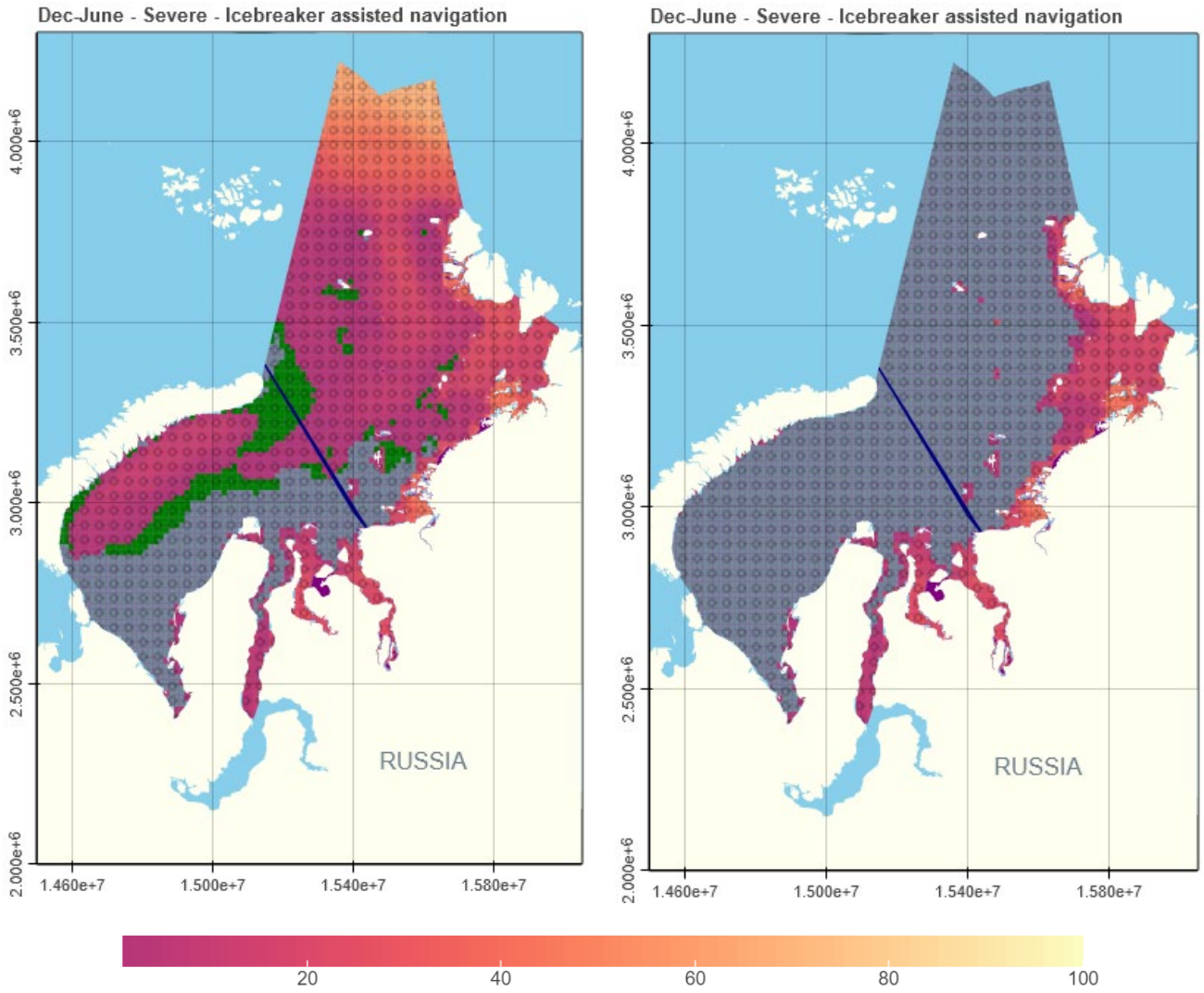


FIGURE 4: ACCESS MAPS TO THE KARA SEA REGION (FOR ARC4/PC7 SHIPS), CALCULATIONS ARE BASED ON POLARIS + AARI ICE DATA AND THE NATIONAL RULES; GRIDED DATA 15 KM BY 15 KM. NOTATIONS: *RED – YELLOW* (VALUES FROM 1 TO 100) DEOTE FREQUENCY OF RIO < 0 (ELEVATED OPERATIONAL RISK); *GREEN* DENOTES RIO ≥ 0 (NORMAL OPERATION); *GRAY* – ICE DATA AVALIABLE BUT UNABLE TO UNIQUELY CATEGORIZE IN LIGHT-, MODERATE-, AND SEVERE, *PURPLE*: RIO VALUES WERE CALCULATED USING ASSUMED STAGE OF DEVELOPENTS AS THEY WERE EITHER UNDETERMINED OR UNAVALIABLE. THE HATCH PATTERN 'x' DENOTES INACCESSIBLE REGIONS ACCORDING TO THE RUSSIAN RULES AND THE HARCH PATERN 'o' DENOTES ACCESSIBLE REGIONS (ARC4/PC7). THE *NAVY BLUE* STRAIGHT LINE DEMARCATES THE ZONE (1,2,3,4,5,6, AND 7 – SOUTHWEST KARA SEA AND ZONE (8,9,10, AND PART OF 11 – NORTHEAST KARA SEA). MAP CRS: WGS 84 / EPSG ARCTIC ZONE 3-15 (WGS 84 / EPSG ARCTIC ZONE 3-15 – EPSG:6078).

3.4 Ice class equivalence

This study assumed that there exists an equivalence between the ships ice classes. However, it should be noted that there is no commonly accepted equivalency between the various ice classes. Table 4 compiles ice class equivalencies found in literature. IMO [19] have published an equivalency table (refer to the third row of Table 4). It is noted that this equivalency should be used with caution and individual classification society rules should be referenced on a case-by-case basis. In the earlier study by [13], we have used a similar equivalency to that in [19], except PC1 was set equivalent to Arc9. In the context of this study, the latter assumption is acceptable as the difference between the results in Figure 3 for PC1 and PC2 is insignificant.



(a) BASED ON ICE CEVERITY CRITERIA IN TABLE 1a (b) BASED ON ICE CEVERITY CRITERIA IN TABLE 1b

FIGURE 5: EFFECT OF CRITERIA FOR ICE CONDITIONS SEVERITY

Table 4. Review of existing ice class equivalencies (Polar Class and Russian Register Ice Class)

PC1	PC2	PC3	PC4	PC5	PC6	PC7	Ref.
	Arc9	Arc8	Arc7	Arc6	Arc5	Arc4	[20]
	Arc9/Arc8	Arc7	Arc6	Arc6	Arc5	Arc4	[19]
Arc9	Arc8	Arc7	Arc6	Arc6	Arc5	Arc4	[13]
	Arc9/Arc8	Arc8/Arc7	Arc4	Arc6	Arc5	Arc4	[21]

3.5 Ice information

Spatial and temporal resolution of ice information (ice concentration and its type) is very important for the assessment of operational limitations and access to the regions on the Northern Sea Route; however, a timely and accurate information on ice conditions is difficult to find. Ice charts are typically published daily as well as the reports from ships. The presence and state of the brash ice is typically not given on the Arctic ice charts. However, their presence can be detected as old ship tracks are visible on the satellite images. An important indicator of ice conditions in a region could also be the density of ships in this region.

Note that the considered national rules and international recommendations use different levels of ice information. To use POLARIS, one needs to know a so-called ‘egg code’ (the thickness, extent, and concentration of the ice). To follow national regulations, the knowledge on the severity of the ice conditions is required. On the ice charts, produced by AARI, presence of grounded ridges/hummocks (stamukhas) is often

reported. However, it is uncertain how these features should be treated in POLARIS and placed within the context of the ice conditions described in Table 1. Same concerns are valid for icebergs, ice pressure events and ice jets.

In this study we have not considered the uncertainty or reliability/bias of the AARI ice data (for example, for an ice concentration in a range of 20-30 %, it was assumed 20% by arguing that the captains should be able to find areas with a less ice concertation for a passage). This assumption could be too simplistic, and in future studies, the uncertainty/reliability/bias of the ice data should be addressed in detail.

4. CONCLUSIVE REMARKS

In this study, we have investigated variability of ships' operational limitations for ice conditions in a view of national rules and international recommendations, i.e., the Rules for Navigation in the Water Area of the Northern Sea Route and the International Maritime Organization recommendations (Operational Limit Assessment Risk Indexing System). We have considered ship data (ice class, position, date) from two datasets (Northern Sea Route Administration Data and AIS Data form the Norwegian Coastal Administration) as well as the publicly available ice information from the Arctic and Antarctic Research Institute. For each ships's ice class, the ice information was used to derive operational limitations based on the Operational Limit Assessment Risk Indexing System, and the results were compared with the newly updated Northern Sea Route access criteria. The studied water area belongs to the Kara Sea region for the period of 2017-2019, but the approach is not limited to the geographical area.

The results show the following:

- The temporal resolution of the ship data does not significantly affect the distribution of risk index outcome in the considered area within the considered time frame (January-April)

- The Rules for Navigation in the Water Area of the Northern Sea Route generally impose stricter access criteria than international recommendations (i.e., Polar Operational Limit Assessment Risk Indexing System); however, under an icebreaker escort, the PC7/Arc4 ice class ships are allowed to operate when the international recommendations suggest an elevated operational risk.

The latter result is a new example on how international laws may be interpreted and applied inconsistently, thus imposing inconsistent and conflicting requirements and recommendations. *Should the Polar Operational Limit Assessment Risk Indexing System be further refined for escort operations (e.g., towing in ice)?* We recommend reporting uncertainty values (e.g., confidence bounds) together with the average value in pt. 1.6.4 of the IMO document [8]. *How to interpret seemingly 'agree-disagree' national rules and international recommendations in a view of the ice data uncertainty and reliability?* For example, the escort of Arc4/PC7 in severe ice conditions is allowed but one should not consider it due regard to international recommendations. *What does the latter mean for actual shipowners who have been planning their operations in the water area of the Northern Sea Route and came to different conclusions about the feasibility of their operations following national rules and international recommendations?* Not following the rules and regulations may lead to ship arrest, penalties, etc. However, following the rules and recommendations does not guarantee the accident-free passage; The observed inconsistencies could increase the costs and complexity of operations or change business practices. We recommend treating this inconsistency as a risk factor during risk mitigation planning and risk monitoring related to operations and businesses.

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