NRC·CNRC

Review of old ice extents in Atlantic Canada: A preliminary assessment

NRC-OCRE-2020-TR-003

April 20, 2020

Prepared for:
Transport Canada

Author:
Paul D. Barrette

Ocean, Coastal, and River Engineering (OCRE) Research Centre

National Research Council Canada | Conseil national de recherches Canada

Canada

Cat. No._ NR16-318/2020E-PDF
ISBN: 978-0-660-34552-9

NRC.CANADA.CA

Summary

Transport Canada (TC) is reviewing the Interim Standards for the Construction, Equipment and Operation of Passenger ships in the Sea Ice Areas of Eastern Canada, which contains information on old ice extents in Atlantic Canada. NRC-OCRE was asked to investigate if this information is still representative of today's old ice extents, or if changes are required. Using the Canadian Arctic Shipping Risk Assessment System (CASRAS), a tool developed by NRC-OCRE, data on old ice extents in Atlantic Canada were collected for every month, from 1990 to 2019. This analysis indicates that monthly coordinates for offshore Newfoundland and Labrador may need to be updated. New preliminary dates and areas/coordinates for old ice extents are provided. The coordinates for the Strait of Belle Isle still appear valid. More definitive recommendations could benefit from alignment with recent editions of relevant regulations and from a refinement in the analysis.

Table of Contents

Contents

Table of Figures

Table of Tables

1. Introduction

Transport Canada (TC) is reviewing the Interim Standards for the Construction, Equipment and Operation of Passenger ships in the Sea Ice Areas of Eastern Canada, referred to as TP 8941 (Transport Canada, 1987). NRC-OCRE was asked to update a map showing expected old ice extent in the standard (henceforth referred to as the 'Map') and associated coordinates, to determine if changes are required based on the recent extents of old ice in Atlantic Canada. If that is the case, NRC-OCRE was asked to recommend changes to the coordinates as appropriate, so as to be able to update the Map for future standard editions.

2. Objectives

The objectives of the work presented herein were as follows:

- To review available data using relevant sea ice data products and tools;
- Following the review and using the Map and coordinates in TP 8941 (Transport Canada, 1987) as a baseline, to assess whether there is a need to amend the Map and/or the coordinates, or confirm that they are still current;
- Following the review, using the Map and coordinates as a baseline, to identify which area(s) would need to be revised, if applicable;
- To provide preliminary dates and areas/coordinates for old ice extents, using the Map and coordinates as a baseline.

3. TP 8941

TP 8941, dated 02.09.1987 (Transport Canada, 1987), is a 12-page document. It applies to passenger ships "registered in Canada or engaged in the coasting trade of Canada, when operating within economic zones of Eastern Canada" (Clause 2). The sea ice areas covered in this document are south of 60° North. TP 8941 (Transport Canada, 1987) includes twelve clauses: 1) Document title, 2) 'Applications' (ships that should abide by these standards), 3) 'Interpretations' (definitions), 4) 'Sea ice areas of Eastern Canada' (the Map and the areas/coordinates), 5) 'Responsibility' (people's roles with regards to these standards), 6) 'Ice advisor' (the requirement for a qualified on-board ice observer), 7) 'Ice information' (seek and report ice information), 8) 'Conduct of ship' (reference to other rules), 9) 'Reporting' (how to report on ice conditions), 10) 'Equipment Failures and Casualties' (how to report damage, a casualty, a malfunction), 11) 'Ship arrangements' (requirements for hulls, doors, search lights, damage/survival assessments, lifesaving equipment), and 12) 'Subdivision' (comments related with ship resistance to ice).

3.1. A word on 'old ice'

According to the International Code for Ships Operating in Polar Waters, formerly the WMO Sea Ice Nomenclature (International Maritime Organization, 2014), "Old ice means sea ice which has survived at least one summer's melt; typical thickness up to 3 m or more. It is subdivided into residual first-year ice, second-year ice and multi-year ice." This definition is consistent with that used by the Canadian Ice Service[1]. The reason why old sea ice extent is important is that this ice is typically less saline, denser and therefore stronger than young sea ice. It can therefore exert higher loads on ships and offshore structures. For additional information on this ice type, the reader is referred to Johnston and G.W.Timco (2008a) and Johnston and G.W.Timco (2008b).

3.2. The Sea Ice Area Map (the 'Map')

A reproduction of the Map from TP 8941 (Transport Canada, 1987) is shown in Figure 1. Various areas are outlined within Eastern Canada's Economic Zone, each of which is associated with one or more month(s) of the year. The majority of the area boundaries follow a given latitude. As an example, according to the Map, a ship sailing north in Eastern Canada in August is informed that old ice "may be present" (Transport Canada, 1987, Clause 4.1) at a latitude of 56 degrees during that month. Additional information on the boundaries offshore Newfoundland and Labrador, as well as in the Strait of Belle Isle is provided in Figure

[1] https://www.canada.ca/en/environment-climate-change/services/ice-forecasts-observations/latest-conditions/glossary.html

2. TP 8941 (Transport Canada, 1987) does not provide any information as to what formed the basis for these boundaries, and what is meant by “historical frequency of occurrence of old ice” (Transport Canada, 1987, Clause 12.1). This text is shown in Figure 2 (outlined in yellow). Do they represent the southernmost observed ‘traces’ of old ice or higher concentrations of it? What % likelihood? Over what time span? Why do they follow latitude lines and have a resolution of one degree? Could it be for the sake of simplicity?

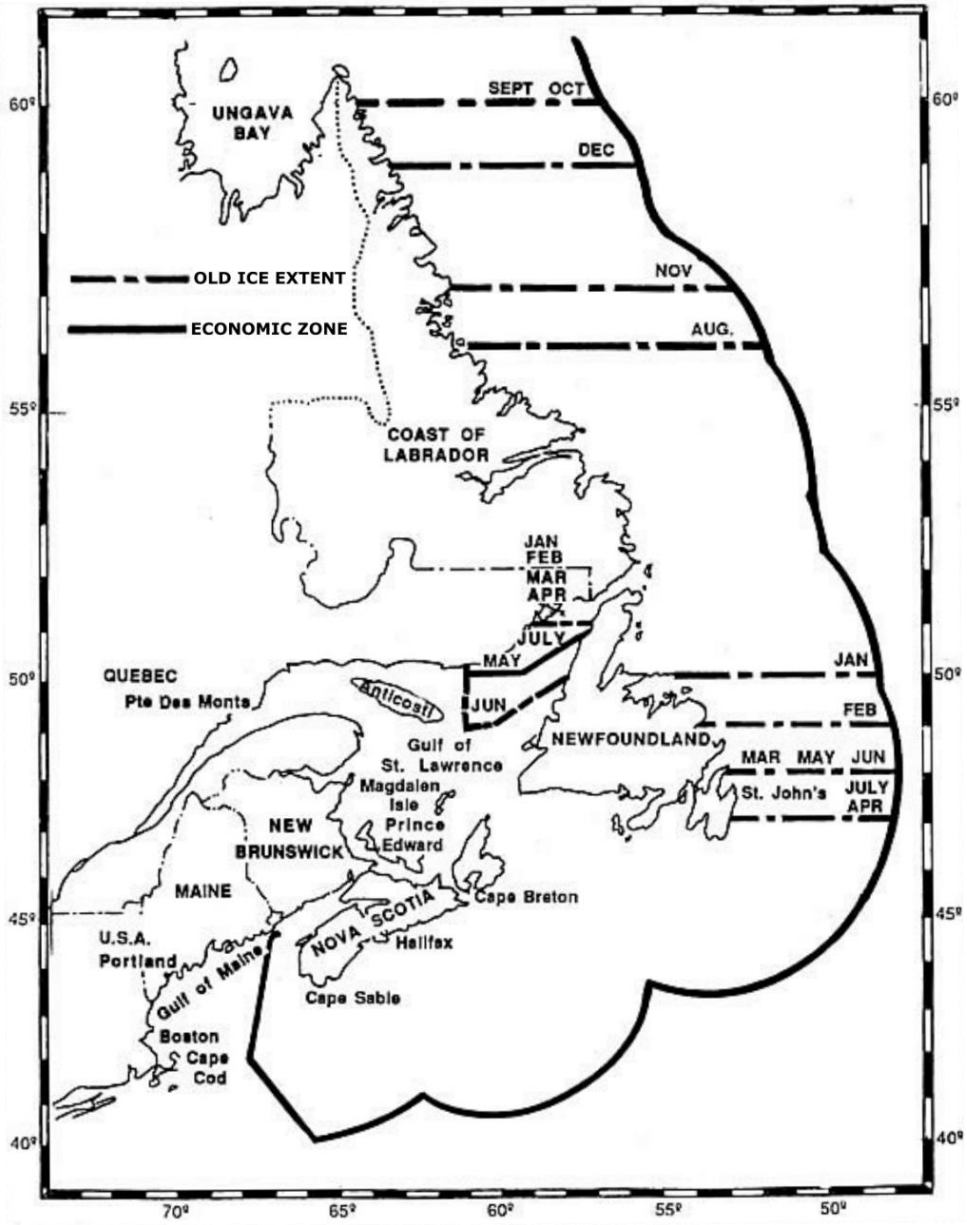

Figure 1: Map showing the extents of old ice, from TP 8941 (Transport Canada, 1987) for each of the twelve months of the year. For the purpose of this report, and at Transport Canada’s request, ‘Sea ice area’ in the legend was replaced with ‘Old ice extent’.

In the immediate term and without additional basis for how the monthly boundaries in the Map were derived, the questions that will now be addressed are as follows: Can we obtain preliminary information on what boundaries could be representative of old ice extents in 2020? If so, how do they compare with those in TP 8941 (Transport Canada, 1987)? The sources of information and the procedures that were used to address this question are discussed next.

Month	Southernmost Latitude
January	50
February	49
March	48
April	47
May	48
June	48
July	48
August	56
September	60
October	60
November	57
December	59

the area known as the Strait of Belle Isle to the following extent

(i) during the months of January, February, March and April, north of 51° North latitude

(ii) during the month of May, north of a line drawn between Port au choix, Pointe Riche, Newfoundland Island and 50° North latitude, 59° West longitude and 50° North latitude, 61° West longitude and the south shore of Quebec at 61° West longitude.

(iii) during the month of June, north of a line drawn between, Green Point 49°41 North latitude, 57°57 West longitude, Newfoundland Island and 49° North latitude, 60° West longitude and 49° North latitude, 61° West longitude and the South Shore of Quebec at 61° West longitude.

(iv) during the month of July North 51° North latitude.

12. SUBDIVISION

12.1 The sea ice areas as defined in section 4 of the standards have been developed on the basis of the historical frequency of occurrence of old ice (sea ice which has survived at least one summers melt). Since younger types of sea ice and/or ice-bergs, may also be present and outside these areas, the areas do not imply that conditions elsewhere are ice free or without ice hazard.

12.2 Recognizing that first year fresh water ice may be as hard as old ice and the possible presence of ice bergs and sea ice, all ships operating within the economic zones of eastern Canada shall comply with the standard of subdivision specified in Section 12.2.1.

12.2.1 All ships shall have a deepest subdivision load waterline assigned in accordance with the Hull Construction Regulations to a two compartment standard of subdivision for operation in ice.

Figure 2: Information provided in Transport Canada (1987, TP 8941). The table shows the latitudes North as the boundaries of the Atlantic areas north of which old ice may be present, as per TP 8941 (Transport Canada, 1987). The text below, labelled (i) to (iv), is what that document provides about the distribution of old ice in the Strait of Belle Isle (see also Figure 1). Clause 12 further below includes information of how sea ice areas have been developed (text outlined in yellow).

4. CIS and CASRAS

The Canadian Ice Services (CIS) is a division of the Meteorological Service of Canada, which is itself a branch of Environment and Climate Change Canada. CIS provides information on ice conditions in Canada's navigable waters, and maintains an archive of ice charts on sea ice conditions extending back to 1960 (Tivy et al., 2011). Amongst its products are 'Regional Ice Charts', which are generated on a weekly basis, and include detailed information on Canada's waters. This includes the concentration of old ice, if there is any, given in tenths (1/10). There are five overlapping charts (Figure 3). Two charts provide information on ice conditions in Eastern Canada and the Strait of Belle Isle: Hudson Bay and Eastern Coast.

Figure 3: Coverage of Canada's icy waters is done by CIS' five regional charts[2].

The Canadian Arctic Shipping Risk Assessment System (CASRAS) was developed by an NRC team of Arctic sea ice specialists and software developers with input from industry experts, government stakeholders, captains and community representatives (Charlebois et al., 2017, Kubat et al., 2017). The product of this collaboration is a software platform for storing, searching and analyzing data relevant to shipping activities in the Arctic, with integrated risk assessment tools. CASRAS incorporates a number of historical datasets, e.g. marine weather, marine hydrography, physical oceanography, marine protected areas and sea ice conditions. The latter comprises CIS' Regional Charts. Using CASRAS' convenient user interface, one is able to quickly retrieve the charts over a time frame of interest that provide information on old ice extent. An example is shown in Figure 4. The southernmost latitude, indicated with a red line in that figure, is the information that was extracted for that month.

[2] https://www.canada.ca/en/environment-climate-change/services/ice-forecasts-observations/latest-conditions/archive-overview/information-about-data.html

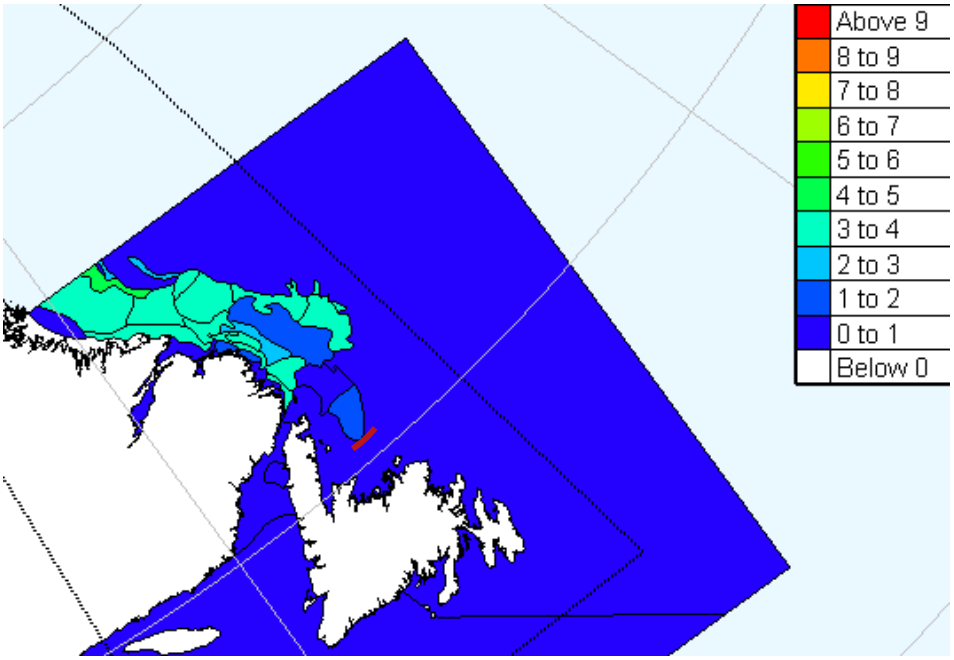

Figure 4: Example of a CIS Eastern Coast regional map, dated June 11 1990 – only information on 'old ice' was queried, such that other ice types were filtered out. The numbers in the legend are the old ice concentration (in tenths). The small red line indicates the southernmost latitude (about 50 deg. N. in this case) to which old ice extends in that particular chart.

According to the Sea Ice Climatic Atlas (Canadian Ice Service, 2010), the frequency of occurrence of old ice is the "likelihood of old ice greater than or equal to 1/10 on a weekly basis […] and can provide an idea of the likelihood that old ice will occur at a particular location for the appropriate date". This is also how the data presented in this report should be interpreted.

5. Procedures

The procedures used to collect information on the presence of old ice in Atlantic Canada were as follows:

- Regional ice charts for Hudson Bay and Eastern Coast charts (Figure 3) were retrieved from CASRAS. The querying was done so as to bring out old ice extents in the charts.
- This was done over the last 30 years (i.e. from January 1990 to the latest charts available) – this time frame is "the standard for representing statistical averages and extremes" (Canadian Ice Service, 2010, p.2).
- The southernmost latitude of the old ice extent (one tenth or more in concentration, i.e. old ice is either present or not) was collected manually, using the CASRAS user interface. In the example shown in Figure 4, that latitude was 50º28'N.
- For this preliminary assessment, only one regional chart for each month (instead of for each week) was examined, arbitrarily chosen as the first one of the month. This implies that the analysis in this report is not as refined as it could have been, had we had more time to allocate to this work.
- All latitudes were rounded to the lower-bound degree, e.g. for the location in Figure 4, the number that was retained was 50.
- For this study, although the area of interest is up to 60 degrees latitude, observations were made as far north as 67 degrees. That number should be seen as an upper bound in the analysis.
- For the Strait of Belle Isle, both latitude and longitude were collected. For the longitude, it was rounded to the upper-bound degree, e.g. for the location 62º45', the number that was retained was 63.

6. Outcome

6.1. Eastern Canada

The raw information on old ice extent in Eastern Canada, as extracted from the regional charts queried in CASRAS, is shown in Table 1. For each month of every year, the southernmost latitude at which old ice concentration of 1/10 or higher could be found is provided in that table. The two last columns to the right of the table are the average and the minimum extent, respectively, of the numbers for each of the twelve months. Figure 5 provides the same information in a series of plots, which also shows the boundaries provided by TP 8941 (Transport Canada, 1987).

A summary of the data listed in Table 1 and plotted in Figure 5 is provided in Figure 6. This summary plot compares the information provided in TP 8941 (Transport Canada, 1987) with the observations collected as part of the present study. For the latter, two traces are shown (corresponding the two columns at the right of Table 1, discussed previously). One trace indicates, for each month, the average southernmost extent over the full 30-year spectrum. The other trace is more conservative, as it indicates, for each month, the lowest value recorded during that time span. Based on the latter, there is less old ice southerly intrusions in the fall and winter months, and more southerly intrusions in the spring and summer, such that the Map could be less conservative for some months, but may need to be more conservative for others. Interestingly, none of the plots in Figure 5 shows clear evidence of a gradual change in the old ice extents over that spectrum, as might be expected in a changing climate.

6.2. Strait of Belle Isle

For the Strait of Belle Isle, TP 8941 (Transport Canada, 1987) specifies latitude and longitude, along with some geographical reference points on land. The raw information on old ice extent in the Strait of Belle Isle is shown in two tables: Table 2 for latitude, and Table 3 for longitude. Old ice was observed only in seven charts which is why most cells in these tables are empty. The seven charts are shown in Figure 7.

Table 4 is a summary of Table 2 and Table 3. It is meant to compare these data with the information provided in TP 8941 (Transport Canada, 1987). Overall, there is an agreement between the information collected during this study and the guidance provided in TP 8941 (Transport Canada, 1987)(to +/- one degree). However, that is only on the basis of these few charts. To increase the number of samples, every weekly chart should be looked at (as opposed to once a month, as done in this preliminary assessment).

Table 1: Southernmost latitude for the occurrence of old ice in Eastern Canada.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average	Minimum
January	64	67	62	64	67	67	67	67	67	66	67	67	67	67	67	67	67	67	65	67	67	67	67	67	66	65	67	67	67	67	66	62
February	64	55	64	63	64	67	63	66	64	60	65	67	64	67	67	67	62	67	65	67	66	67	64	66	62	63	66	66	67	67	65	55
March	58	53	65	52	62	61	66	66	62	64	64	65	59	65	65	67	64	67	63	63	64	66	67	62	59	64	61	61	67	64	63	52
April	57	67	65	62	45	62	63	58	53	63	62	64	62	62	63	67	62	51	58	62	62	60	60	65	57	61	61	59	67	63	61	45
May	45	67	62	58	45	60	65	61	62	63	63	60	52	62	61	64	63	47	60	55	60	60	59	67	59	58	58	61	64	64	60	45
June	50	48	61	55	49	49	49	49	49	64	67	50	54	53	63	63	65	49	49	54	61	59	61	67	58	57	67	49	62	60	56	48
July	49	50	61	62	55	62	54	54	62	65	67	54	59	62	62	66	59	55	61	57	61	61	62	67	58	57	54	62	62	61	59	49
August	62	53	61	62	67	65	60	67	65	64	67	63	61	66	64	67	64	64	64	62	67	67	61	67	67	64	67	62	62	62	64	53
September	67	63	61	65	67	67	64	67	67	67	67	64	67	67	67	67	67	64	67	67	67	67	67	67	67	64	67	67	67	67	66	61
October	67	67	67	67	67	67	67	67	67	65	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	65	67	67	67	67	67	65
November	67	67	67	67	67	67	67	67	67	67	67	67	67	66	67	67	67	67	67	67	67	67	67	67	67	65	67	67	67	67	67	65
December	67	67	67	67	67	67	66	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	66

Table 2: Southernmost latitude for the occurrence of old ice for the Strait of Belle Isle. The empty cells are those for which no ice >1/10 was observed in the regional charts.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average	Minimum
January																																
February																																
March																																
April						51																									51	51
May						49												50													50	49
June		49																50										51			50	49
July		49																													49	49
August																																
September																																
October																																
November																																
December																																

Table 3: Westernmost longitude for the occurrence of old ice for the Strait of Belle Isle. The empty cells are those for which no ice >1/10 was observed in the regional charts.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average	Maximum
January																																
February																																
March																																
April						57																									57	57
May						60												57													59	60
June		**63**																59										51			58	63
July		**60**																													60	60
August																																
September																																
October																																
November																																
December																																

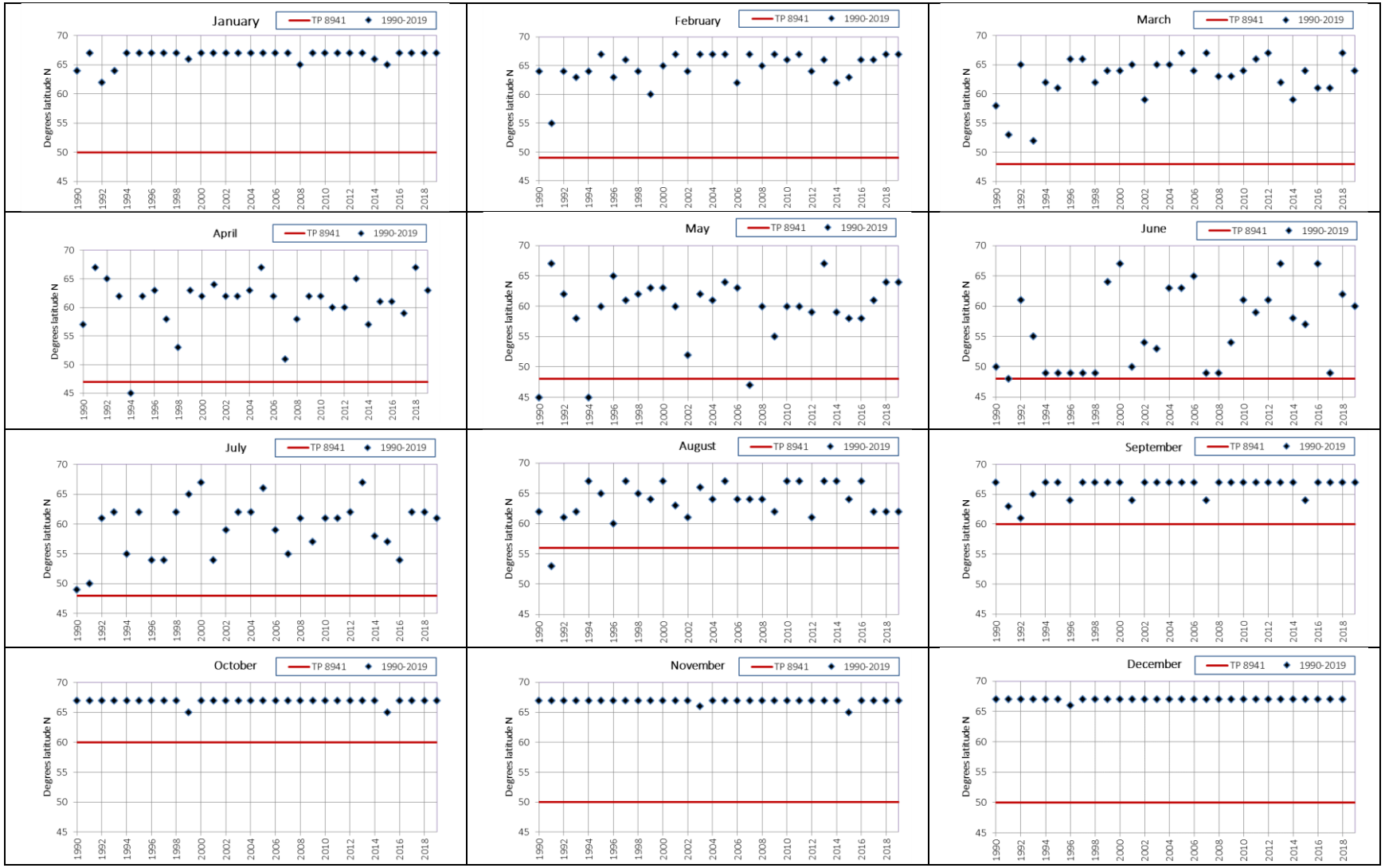

Figure 5: Plots of old ice extent for each month and for all years (blue diamonds) in Eastern Canada, up to 67 degrees latitude. The latitude for the boundaries of the areas as provided by TP 8941 (Transport Canada, 1987) (Figure 2) is also indicated, for comparison purposes (the red lines labelled TP 8941).

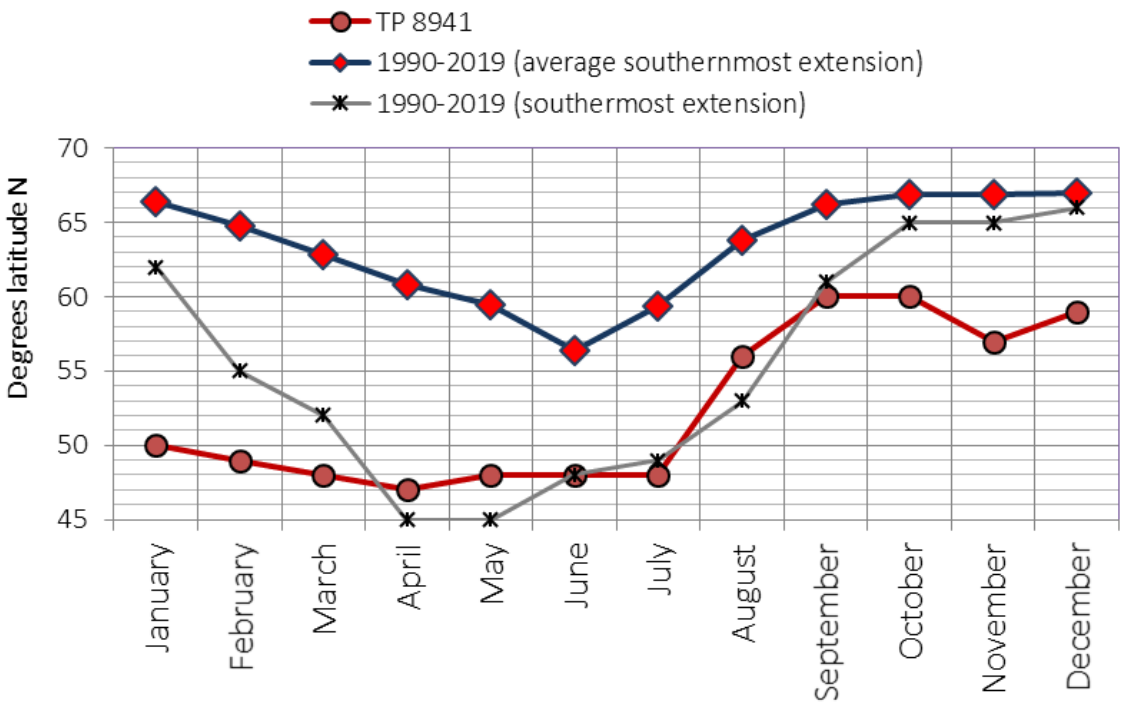

Figure 6: Old ice southernmost extents for the Atlantic region. Summary of the observations listed in Table 1 and plotted in Figure 5.

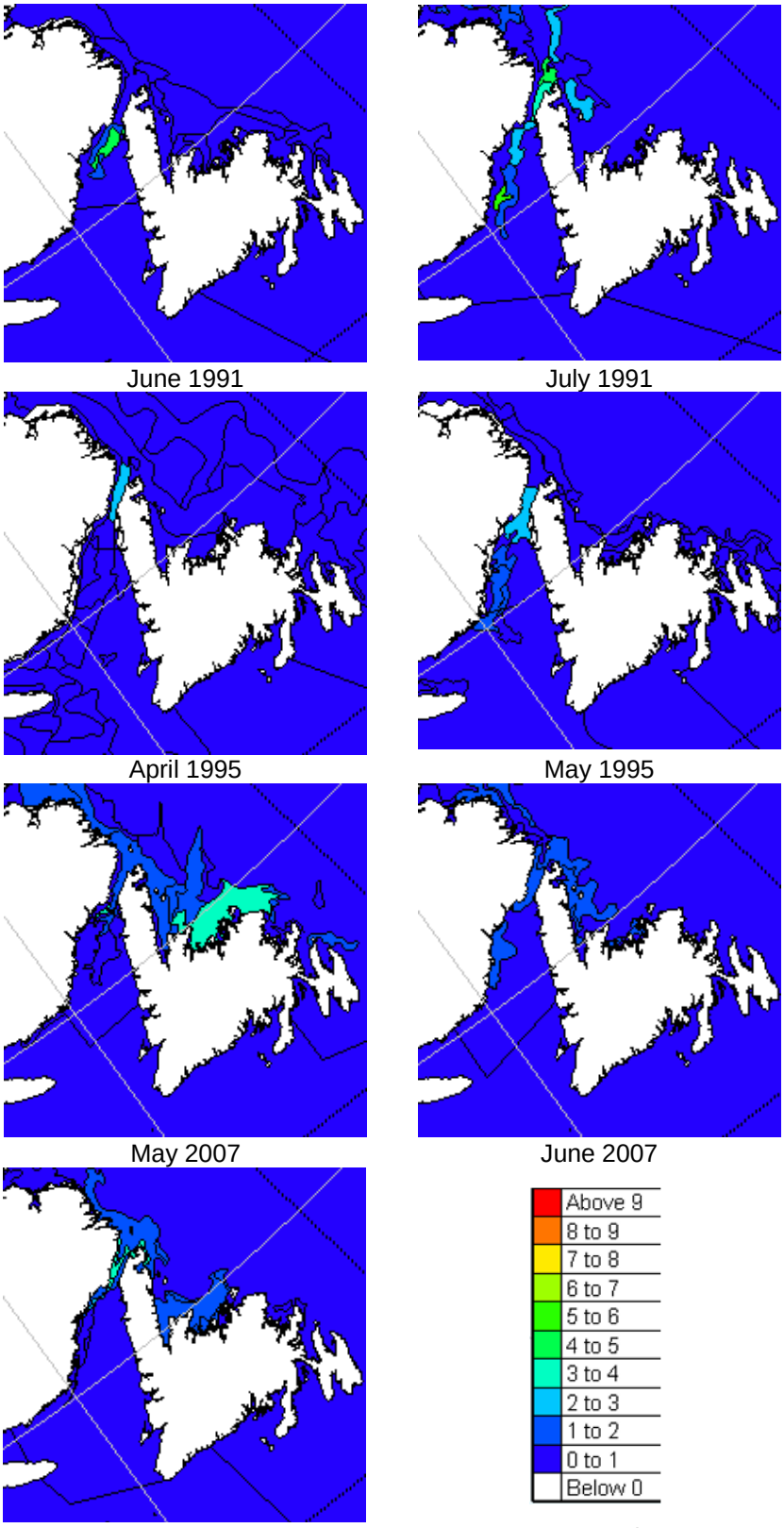

Figure 7: Old ice was observed in seven charts (in the lighter blue shade and turquoise), which are shown above. The numbers in the legend are the old ice concentration (in tenths).

Table 4: Southernmost latitude and westernmost longitude for old ice extent in the Strait of Belle Isle. This table is a comparison of observations collected as part of the current work (1990-2019) and the information provided by TP 8941 (Transport Canada, 1987).

	TP 8941		1990-2019			
	Southermost latitude	Westernmost longitude	Southernmost latitude (average)	Southermost latitude	Westernmost longitude (average)	Westernmost longitude
January	51	n/a	No ice	No ice	No ice	No ice
February	51	n/a	No ice	No ice	No ice	No ice
March	51	n/a	No ice	No ice	No ice	No ice
April	51	n/a	51	51	57	57
May	50	61	50	49	59	60
June	49	61	50	49	58	63
July	51	n/a	49	49	60	60
August	No guidance		No ice	No ice	No ice	No ice
September	No guidance		No ice	No ice	No ice	No ice
October	No guidance		No ice	No ice	No ice	No ice
November	No guidance		No ice	No ice	No ice	No ice
December	No guidance		No ice	No ice	No ice	No ice

7. Conclusion

According to the Sea Ice Climatic Atlas (Canadian Ice Service, 2010), the frequency of occurrence of old ice is the “likelihood of old ice greater than or equal to 1/10 on a weekly basis […] and can provide an idea of the likelihood that old ice will occur at a particular location for the appropriate date”. This is also how the data presented in this report should be interpreted. The data collected during this study were for the lowest concentration of old ice reported in the regional ice charts. In other words, what was recorded as an ‘occurrence’ is any amount of old ice above 1/10, but not including traces.

The ultimate purpose of the work reported herein was to provide a preliminary assessment of old ice extents in the sea ice areas of Eastern Canada, and to see whether or not the information in TP 8941 (Transport Canada, 1987) needed to be updated. The information obtained during the work reported herein suggest that the old ice extents in Atlantic Canada for every month of the year would need to be updated. Tentative dates are provided, on the basis of a preliminary assessment described in this report. The old ice extents in the Strait of Belle Isle, on the other hand, appear still valid.

The following is what could be considered as a prospective way forward:

- It could be of benefit to refine the analysis by looking at more, or all, weekly charts for any given months inside the 30-year period that was investigated (as opposed to one chart per month, as was done in the present study).
- If resources allow, it would be instructive to repeat the exercise conducted in this study for a series of time slices within that 30-year period, for instance, 1990-1994, 1995-1999, etc. up to 2020. This could identify trends indicating a gradual change in old ice extent across that time period. Such trends, if they exist, would provide further guidance, for instance, by allowing an extrapolation into future years.
- An update should be sought regarding what should be considered in establishing a new standard. Questions to address in furthering this work include: What sources of information should be consulted (beyond CIS’ ice charts)? How much old ice represents a hazard? What constitutes an

appropriate 'likelihood' of encounter? Do weekly observations provide sufficient resolution in establishing boundaries?

- Although the Arctic Safety Shipping and Pollution Prevention Regulations (Government of Canada, 2020) and the International Code for Ships Operating in Polar Waters (International Maritime Organization, 2014) apply for vessels sailing north of 60, they may provide insights for the update of the Standards studied in this report.

8. Acknowledgments

This project was funded by Transport Canada. Lawrence Charlebois initiated the project, and Dave Watson and Philippe Lamontagne supplied the author with the relevant information for data extraction from CASRAS. The report benefited from helpful reviews by R. Frederking, D. Sudom and A. Barker. Comments from Transport Canada are gratefully acknowledged.

9. References

Canadian Ice Service, 2010. *Sea Ice Climatic Atlas - East Coast 1981-2010*. Ottawa.

Charlebois, L., Kubat, I., Lamontagne, P., Burcher, R. and Watson, D., 2017. *Navigating in polar waters with CASRAS*. The Journal of Ocean Technology, 12(3), p. 43-52.

Government of Canada, 2020. *Arctic Shipping Safety and Pollution Prevention Regulations*. SOR/2017-286. Ottawa.

International Maritime Organization, 2014. *International Code for Ships Operating in Polar Waters - Resolution MSC.385(94)* London.

Johnston, M.E. and G.W.Timco, 2008a. *Guide for understanding and identifying old ice in summer*, Proceedings of the 8th International Conference on Ships and Marine Structures in Cold Regions (ICETECH), Banff.

Johnston, M.E. and G.W.Timco, 2008b. *Understanding and identifying old ice in summer*. National Research Council, Ottawa, 235 p.

Kubat, I., L., C., Burcher, R., P., L. and Watson, D., 2017. *Canadian Arctic Shipping Risk Assessment System*, Proceedings of the 24th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), Busan.

Tivy, A., Howell, S.E.L., Alt, B., McCourt, S., Chagnon, R., Crocker, G., Carrieres, T. and Yackel, J.J., 2011. *Trends and variability in summer sea ice cover in the Canadian Arctic based on the Canadian Ice Service Digital Archive, 1960–2008 and 1968–2008*. Journal of Geophysical Research, 116, p. C03007.

Transport Canada, 1987. *Interim standards for the construction, equipment and operation of passenger ships in sea ice areas of Eastern Canada*. Ottawa.