Scoping study: ice information requirements for marine transportation of natural gas from the High Arctic

Timco, G. W.; Gorman, B.; Falkingham, J.; O'Connell, B.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/12340988
Technical Report (National Research Council of Canada. Canadian Hydraulics Centre); no. CHC-TR-029, 2005-02

Scoping Study: Ice Information Requirements for Marine Transportation of Natural Gas from the High Arctic

G.W. Timco, B. Gorman, J. Falkingham and B. O'Connell

Technical Report CHC-TR-029

February 2005

Scoping Study: Ice Information Requirements for Marine Transportation of Natural Gas from the High Arctic

G.W. Timco[1], B. Gorman[2], J. Falkingham[3] and B. O'Connell[4]

[1]Canadian Hydraulics Centre
National Research Council of Canada
Ottawa, Ont. K1A 0R6

[2]Enfotec
25 Tapiola Cres. Suite 206
Ottawa, Ont. K1P 2J7

[3]John Falkingham
Environment Canada
Ice Forecasting Services
373 Sussex Drive LaSalle Academy
Ottawa, Ontario K1A 0H3

[4]Canadian Coast Guard
200 Kent St., 5th Floor
Ottawa, Ont. K1A 0E6

Prepared for:
Climate Change Technology and Innovation Initiative
Unconventional Gas Supply

Technical Report
CHC-TR-029

February 2005

ABSTRACT

This report describes a scoping study that was performed to investigate methods for improving transportation in the High Arctic. Fourteen Captains of ice-class vessels were interviewed. They unanimously said that the detection and avoidance of multi-year ice was the key issue. They also indicated that better knowledge of regions where ice pressure and leads develop is important. A one-day Workshop was held with several key Stakeholders and issues related to improved systems were discussed. This report summarizes these findings as well as reviews the existing ice information systems, the Canadian Ice Service operations, and the use of ice information by the Canadian Coast Guard. A three-year program is suggested that would significantly improve detection of multi-year ice.

TABLE OF CONTENTS

ABSTRACT ... 1
TABLE OF CONTENTS ... 3
LIST OF FIGURES ... 5
LIST OF TABLES ... 6
1.0 INTRODUCTION ... 7
2.0 TRANSPORT CANADA REGULATIONS ... 10
2.1 The Zone-Date System ... 10
2.2 The Ice Regime System ... 10
2.3 Application for Year-Round Arctic Shipping ... 14
3.0 PAST AND CURRENT ICE INFORMATION SYSTEMS ... 15
3.1 The Aircraft Era 1970's to 1995 ... 15
3.2 The RADARSAT Era 1995 to Present ... 19
3.3 Other Shipboard Sensors ... 20
3.3.1 SONAR ... 21
3.3.2 Low-light and IR Sensors ... 21
3.3.3 Advanced Marine Radar ... 21
3.4 Current Integrated Ice Navigation Systems ... 24
3.5 Future Direction ... 25
4.0 CANADIAN ICE SERVICE OPERATIONS AND PRODUCTS ... 26
4.1 Organization ... 26
4.2 Data Acquisition ... 27
4.3 Output products and forecasts ... 27
4.4 Publications ... 29
4.5 Mailing address ... 30
5.0 CANADIAN COAST GUARD Use of Ice Information ... 38
5.1 Introduction ... 38
5.2 Ice Information Services ... 41
5.3 Use of Ice Information in Ice Operations Centres ... 42
5.4 Use of Ice Information by Icebreakers ... 44
5.5 Use of Ice Information by the Icebreaking Program (National & Regional) ... 45
5.6 CCG Development of Ice Information Systems ... 46
5.6.1 The Integrated Ice System (IIS) ... 46
5.6.2 Ice Routing Model ... 47
5.6.3 ICEggs ... 47
5.6.4 Ice Thickness Sensor ... 48
5.6.5 Cross Polarized Radar ... 49
6.0 SURVEY OF ICEBREAKER CAPTAINS ... 50
6.1 Background Information ... 50
6.2 Analysis of the Interviews ... 51
6.2.1 Ice Parameters of Interest ... 51
6.2.2 Sources of Ice Information ... 52

6.2.3 Present Day Situation ... *53*
6.2.4 View to the future. ... *54*
7.0 ICE INFORMATION WORKSHOP ... 58
7.1 Background Information ... 58
7.2 Results of the Workshop ... 60
8.0 ICE INFORMATION ROADMAP ... 62
9.0 ACKNOWLEDGEMENTS ... 64
10.0 REFERENCES ... 64
Appendix A ... A1
Appendix B ... B1

LIST OF FIGURES

Figure 1: Map illustration two options for moving natural gas from the Arctic................ 8
Figure 2: Map showing the regions of the Zones in the Zone-Date System.................... 12
Figure 3: Canadian Ice Service Dash-7 Ice Reconnaissance Aircraft 15
Figure 4: SLAR imagery collected by the Canadian Ice Service DASH7 Aircraft.......... 16
Figure 5: SAR imagery of Resolute Passage (de Bastiani 1987).................................... 17
Figure 6: CIRS SAR-equipped ice reconnaissance aircraft.. 17
Figure 7: Hardcopy display of airborne radar data on the bridge of a ship 18
Figure 8: Ice Navigation system on MV Arctic with computerized STAR-VUE display – 1988 (Gorman 1988)... 18
Figure 9: Enfotec's IceNav display showing the range of functionality now available in PC-based ice navigation systems used in the RADARSAT era. 20
Figure 10: H/H polarized (left) and H/V polarized (right) showing glacial ice detection capability of X-Pol radar technology... 23
Figure 11: Standard radar display (left) and an image from the same radar scan converted and digitized to 256 grey levels (right) showing the great improvement in ice detection possible with advanced radar image processing. 23
Figure 12: IceNav integrated satellite and marine radar ice navigation system 25
Figure 13: Example of a Daily Ice Chart - Newfoundland... 31
Figure 14: Example of a Daily Ice Hazard Bulletin 32
Figure 15: Ice Reconnaissance Chart - Gulf of Boothia... 33
Figure 16: Daily Iceberg Analysis Chart – East Coast of Canada.................................. 34
Figure 17: RADARSAT image analysis chart - Labrador Coast.................................... 35
Figure 18: RADARSAT imagery - Lake Erie 36
Figure 19: Regional Weekly Ice Chart – Eastern Canadian Arctic 37
Figure 20: Chart: Excerpt from Climatic Ice Atlas – East Coast.................................... 38
Figure 21: CCG vessel in escort service... 41
Figure 22: Ice concentration chart for the Arctic.. 42
Figure 23: Recommended Ice Route Displayed on Ice Analysis Chart........................... 44
Figure 24: Photograph showing escort through pressured ice... 44
Figure 25: Illustration of the integrated ice system 46
Figure 26: Illustration of the ice routing model and ice severity index 47
Figure 27: Illustration of the ICEggs system.. 48
Figure 28: Illustration of the fixed mount ice thickness sensor....................................... 48
Figure 29: Ice parameters identified as the highest concern by the Captains during the survey... 52
Figure 30: Plot showing the sources of ice information mentioned by the Captains. 53
Figure 31: Schematic illustration of general planning for a voyage in ice conditions. 59
Figure 32: Basic table framework for discussion used during the Workshop. There was a separate table for Long Term, Today and 1-Hour planning. 60
Figure 33: Schematic illustration of a proposed test program to improve ice information systems for shipping in the High Arctic. 63

LIST OF TABLES

Table 1: Zone-Date Table 11
Table 2: Table of the Ice Multipliers (IM) for the Ice Regime System 13
Table 3: List of CCG Icebreakers 39
Table 4: List of Captains Interviewed 51
Table 5 : Workshop Results - Long Term Requeirments 61
Table 6: Workshop Results - Today's Requirements 61
Table 7: Workshop Results - 1-Hour requirements 61

Scoping Study: Ice Information Requirements for Marine Transportation of Natural Gas from the High Arctic

1.0 INTRODUCTION

The High Arctic contains significant reserves of natural gas (NG). The Canadian Gas Potential Committee estimated that there are 7.7 Tcf of discovered marketable natural gas in the Hecla field and Drake Point field on Melville Island in the Canadian Archipelago (CGPC, 2001). There are, however, major accessibility issues due to its remote location. Tankers are the most viable option for transporting this resource. There are two potential routes for bringing the gas to southern markets: (1) the "eastern" route proposed in the original Arctic Pilot Project of bringing LNG tankers along the east coast of Canada into Nova Scotia and Quebec, and (2) the "western" route of connecting to the (proposed) pipeline from the Beaufort Sea down the Mackenzie valley. Figure 1 illustrates these two routes. The extreme ice conditions of the Arctic Archipelago and North West Passage are seen as a major obstacle to year-round marine transportation. Innovation in characterizing and forecasting the unique ice conditions of the Arctic is proposed as a key avenue to achieve economically competitive and safe development of High Arctic natural gas.

In a recent study carried for Indian and Northern Affairs Canada (INAC), it was concluded that based on a preliminary analysis, production and ship-borne transportation of natural gas from Melville Island is economically feasible (CERI, 2004). The report states, however, that ship-borne transportation to southern markets represents the largest challenges to any development option, and that shipping times would represent a major uncertainty for the project. Furthermore, shipping costs represent a large component of the project expenditures. If ice conditions cause transit times to be slower than anticipated, additional ships would be required. Also, if a ship gets stuck, icebreaker support may be required. Damage to ships and corresponding downtime for repairs could reduce deliveries.

Clearly, confidence in shipping in the Arctic is critical. There must be certainty in transit times with low risk of structural damage to the tanker. Confidence in year-round shipping is based on two factors – the capability of the tanker in different ice conditions, and good ice information and routing to minimize the risk of damage and transit time. This report will address the ice issue.

The tankers will necessarily be quite large and must be able to operate on a year-round basis. Regardless of the ultimate choice for the route, collisions with ice hazards could lead to vessel and environmental damage or operational delays. The physical size of the tankers will significantly limit their maneuverability especially on a short time span. This makes it essential to have both detailed and accurate knowledge of local ice conditions (multi-year ice, large ridges, etc.) so that safe and operationally efficient routes can be planned. Currently, ice information and forecasts are oriented towards regions of temperate ice such as the Gulf of St. Lawrence, the East Coast of Labrador and Newfoundland. The conditions of the Arctic are more severe, and there is very limited experience with winter navigation. The High Arctic is dominated by numerous narrow channels involving a mix of first year, multi-year and ridged ice. Ice consolidation usually takes place and forms relatively large-thickness, high-strength fields. One of the most striking phenomena that results from those ice conditions is the formation of massive ice arches that can block a channel. Such arches are often observed in Lancaster Sound, and may present a serious impediment to shipping.

Figure 1: Map illustration two options for moving natural gas from the Arctic

This report provides a summary of a scoping study that was undertaken to provide information on the current state of ice information technology and to develop a road map for modifying it and improving it for the High Arctic. The work was done with direct input from the end users – industrial shipping companies in the Arctic, the Canadian Coast Guard, Transport Canada and the Canadian Ice Service. The work was carried out by the authors on behalf of the Climate Change Technology and Innovation Initiative through Natural Resources Canada.

The work was carried out with direct input from Captains of icebreaking vessels. Their experience was seen as a key element in understanding ice information systems and in identifying potential areas for improvement. This scoping study contains the following information:

Chapter 2.0 analyzes the current Transport Canada regulations for year-round shipping in the Arctic.

Chapter 3.0 discusses the past and current ice information systems that are used in the Arctic.

Chapter 4.0 details the information supplied by the Canadian Ice Service.

Chapter 5.0 discusses the Canadian Coast Guard approach for using ice information.

Chapter 6.0 presents a summary of the discussions held with a number of Captains of icebreaking vessels.

Chapter 7.0 provides an overview of a Workshop that was held in Montreal to discuss these results.

Chapter 8.0 provides a basic roadmap identifying issues that should be addressed for improved ice information systems, especially as they relate to year-round transportation in the High Arctic.

2.0 TRANSPORT CANADA REGULATIONS

Transport Canada is responsible for regulating shipping in the Arctic regions under the Arctic Shipping Pollution Prevention Regulations (ASPPR). These regulations apply to shipping north of 60º latitude. The regulations are comprised of two different parts – the Zone-Date System (ZDS) and the Ice Regime System (IRS). These systems are briefly described in this section and discussed in terms of their application to year-round shipping in the Arctic.

2.1 The Zone-Date System

In 1972, the Canadian Government drafted the Arctic Shipping Pollution Prevention Regulations (ASPPR) to regulate navigation in Canadian waters north of 60°N latitude. These regulations include the Shipping Safety Control **Zones** (Figure 2), and the **Date** Table (Table 1), made under the Arctic Waters Pollution Prevention Act. Both of these are combined to form the "Zone/Date System" matrix that gives entry and exit dates for various ship types and classes. In this system, the ship types and classes, in descending order of ice capability are:

Arctic Class:	10, 8, 7, 6, 4, 3, 2, 1A, 1
Type Ships:	A, B, C, D, E

The Arctic Class was normally but not accurately described as the thickness in feet of level ice that the vessel would have the power and strength to break. The Type ships represent the Classifications Societies' designation of ice-capable ships that are in turn equivalent to the Baltic Rules. The "Zone-Date System" is based on the premise that nature consistently follows a regular pattern year after year. It is a rigid system with little room for exceptions.

2.2 The Ice Regime System

Transport Canada, in consultation with Stakeholders, has made extensive revisions to the Regulations through the introduction of the Ice Regime System (ASPPR 1989; Canadian Gazette 1996; Equivalent Standards 1995; AIRSS 1996). The changes are designed to reduce the risk of structural damage in ships which could lead to the release of pollution into the environment, yet provide the necessary flexibility to Shipowners by making use of actual ice conditions, as seen by the Master to determine transit.

In this system, an "Ice Regime", which is a region of generally consistent ice conditions, is defined at the time the vessel enters that specific geographic region, or it is defined in advance for planning and design purposes. The Arctic Ice Regime Shipping System (AIRSS) is based on a simple arithmetic calculation that produces an "**Ice Numeral**" that combines the ice regime and the vessel's ability to navigate safely in that region. The Ice Numeral (IN) is based on the quantity of hazardous ice with respect to the ASPPR classification of the vessel (see Table 2). The Ice Numeral is calculated from

Table 1: Zone-Date Table

Item	Category	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13	Zone 14	Zone 15	Zone 16
1.	Arctic Class 10	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
2.	Arctic Class 8	July 1 to	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Oct. 15
3.	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	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
4.	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	All Year	All Year	July 1 to Mar. 31	All Year	All Year	All Year	All Year	All Year
5.	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	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
6.	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	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
7.	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	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
8.	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	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
9.	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	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
10.	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	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
11.	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	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
12.	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	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
13.	Type D	No Entry	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 10 to Oct. 5	Aug. 15 to Oct. 20	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
14.	Type E	No Entry	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 10 to Sept. 30	Aug. 20 to Oct. 20	Aug. 20 to Oct. 15	Aug. 10 to Oct. 20	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

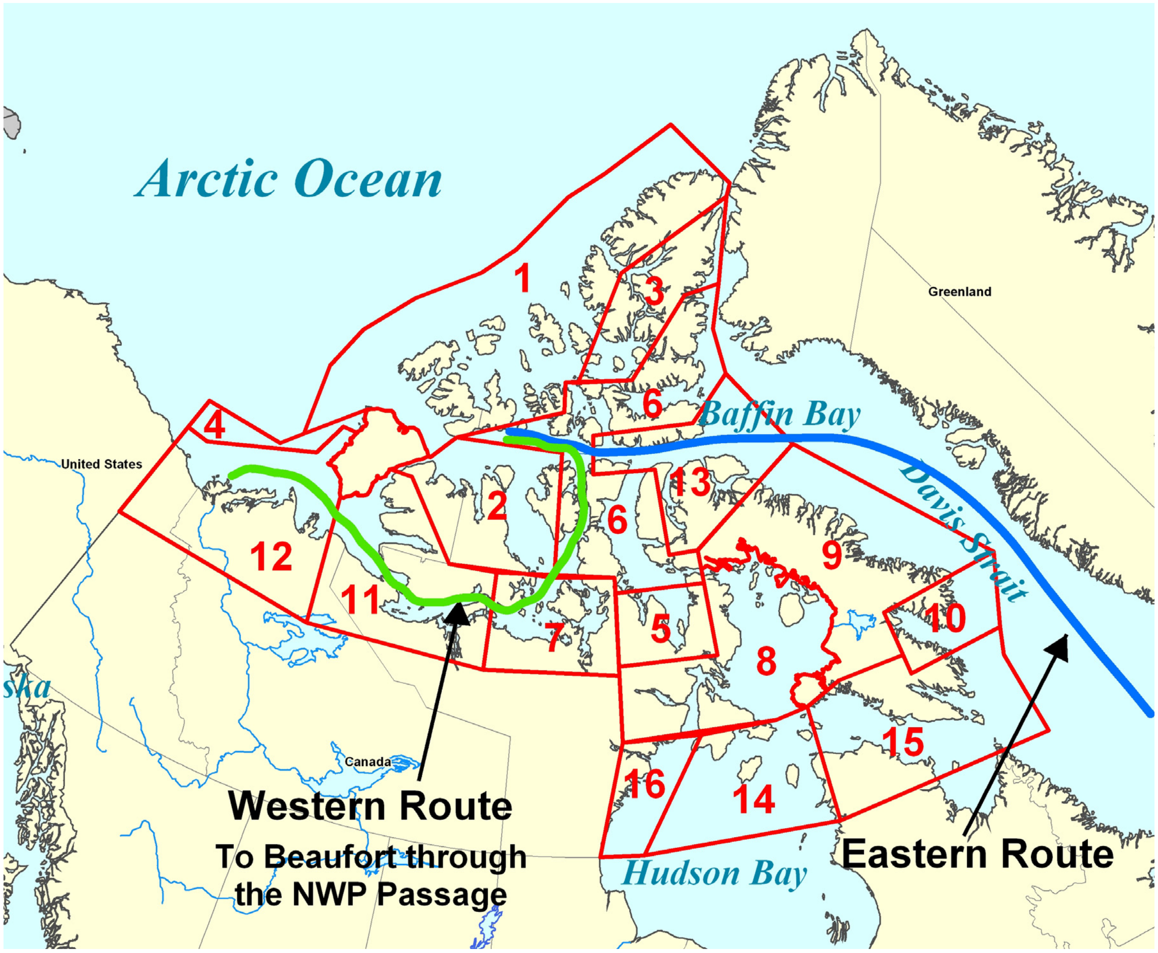


Figure 2: Map showing the regions of the Zones in the Zone-Date System.

$$IN = [C_a\,x\,IM_a] \quad + \quad [C_b\,x\,IM_b] \quad + ... \qquad [1]$$

where
IN = Ice Numeral
C_a = Concentration in tenths of ice type "*a*"
IM_a = **Ice Multiplier** for ice type "*a*" and Ship Category (from Table 2)

The term on the right hand side of the equation (*a, b, c,* etc.) is repeated for as many ice types as may be present, including open water. The values of the Ice Multipliers are adjusted to take into account the decay or ridging of the ice by adding or subtracting a correction of 1 to the multiplier, respectively (see Table 2). The Ice Numeral is therefore unique to the particular ice regime and ship operating within its boundaries.

The vessel class is defined in terms of vessels that are designed to operate in severe ice conditions for both transit and icebreaking (Canadian Arctic Class - **CAC**) as well as vessels designed to operate in more moderate first-year ice conditions (**Type** ships). The classes were developed based on a “nominal” ice type, which were correlated to the World Meteorological Organization (WMO) classification for sea ice.

Table 2: Table of the Ice Multipliers (IM) for the Ice Regime System

Ice Types			Ice Multipliers						
			Type **E**	Type **D**	Type **C**	Type **B**	Type **A**	CAC **4**	CAC **3**
Old / Multi-Year Ice................	(MY)		-4	-4	-4	-4	-4	-3	-1
Second Year Ice...................	(SY)		-4	-4	-4	-4	-3	-2	1
Thick First Year Ice...............	(TFY)	> 120 cm	-3	-3	-3	-2	-1	1	2
Medium First Year Ice............	(MFY)	70-120 cm	-2	-2	-2	-1	1	2	2
Thin First Year Ice............... Thin First Year Ice - 2nd Stage	(FY)	30-70 cm 50-70 cm	-1	-1	-1	1	2	2	2
Thin First Year Ice - 1st Stage		30-50 cm	-1	-1	1	1	2	2	2
Grey-White Ice.....................	(GW)	15-30 cm	-1	1	1	1	2	2	2
Grey Ice.............................	(G)	10-15 cm	1	2	2	2	2	2	2
Nilas, Ice Rind		< 10 cm	2	2	2	2	2	2	2
New Ice..............................	(N)	< 10 cm	"	"	"	"	"	"	"
Brash (ice fragments < 2 m across)			"	"	"	"	"	"	"
Bergy Water			"	"	"	"	"	"	"
Open Water			"	"	"	"	"	"	"

Ice Decay: If MY, SY, TFY or MFY ice has Thaw Holes or is Rotten, add 1 to the IM for that ice type.

Ice Roughness: If the total ice concentration is 6/10s or greater and more than one-third of an ice type is deformed, subtract 1 from the IM for the deformed ice type.

The Ice Regime System determines whether or not a given vessel should proceed through that particular ice regime. If the Ice Numeral is negative, the ship is *not* allowed to proceed. However, if the Ice Numeral is zero or positive, the ship is allowed to proceed into the ice regime. Responsibility to plan the route, identify the ice, and carry out this numeric calculation rests with the Ice Navigator who could be the Master or Officer of the Watch. Due care and attention of the mariner, including avoidance of hazards, is vital to the successful application of the Ice Regime System. Authority by the Regulator (Pollution Prevention Officer) to direct ships in danger, or during an emergency, remains unchanged.

At the present time, there is only partial application of the Ice Regime System, exclusively outside of the “Zone-Date” System. That is, vessel traffic is regulated by the Zone-Date System, but is allowed to proceed into a (normally) restricted zone if the ice conditions are such that the Ice Regime System gives a positive Ice Numeral. For this, the vessel must have an Ice Navigator onboard and initially send an *Ice Regime Routing Message* to the CCG-NORDREG office in Iqaluit indicating a positive ice regime.

Following the voyage, an *After Action Report* must be submitted to Transport Canada. Full details are found in the applicable regulatory standards guidelines.

2.3 Application for Year-Round Arctic Shipping

The ice zones that would be encountered by a tanker would be different for the two routes.

For the Western route as shown in Figure 1, the tanker would have to proceed initially in an easterly direction (through Zone 6) turning south through McClintock channel between Victoria Island and Prince of Wales Island. This would put in on the route through the Northwest Passage. It would travel south of Victoria Island through Amundsen Gulf to the Beaufort Sea. Examining this route on Figure 2 shows that the tanker would travel through Zones 6, 7, 11 and 12 to get to the Beaufort Sea. Thus, the most severe zone would Zone 6. Based on the Zone-Date table (Table 1), this would require an Arctic Class 7 vessel for year-round operation.

For the Eastern route (Figure 1), the tanker would travel east across Viscount Melville Sound, through Barrow Strait and through Lancaster Sound south of Devon Island. It would proceed into Baffin Bay and down through Davis Strait and along the eastern coast of Canada to arrive a terminal in southern Canada. Examining Figure 2 shows that the tanker would travel through Zones 6 and 13 (and possible 9) during this voyage. Thus, similar to the western route, the highest zone for travel is Zone 6. Thus, this would require an Arctic Class 7 vessel for year-round operation.

3.0 PAST AND CURRENT ICE INFORMATION SYSTEMS

The ice navigation systems in use today have been developed over many decades of research and development. The history of development that has led to the systems in use today is reviewed. This is then followed by a description of the existing systems in use today with a view to future developments.

3.1 The Aircraft Era 1970's to 1995

The use of aircraft for ice reconnaissance dates back many decades. The first successful systems were based on large four engine long range reconnaissance aircraft outfitted with Side-Looking Airborne Radar (SLAR) systems. In Canada, both the Lockheed Electra and Dash-7 aircraft were used for ice reconnaissance as illustrated in Figure 3.

Figure 3: Canadian Ice Service Dash-7 Ice Reconnaissance Aircraft

The SLAR systems were "real-aperture" radar systems, such as the Motorola APS-94 or the CAL-100. These systems were relatively inexpensive to purchase compared to Synthetic Aperture Radar (SAR) systems but provided lower resolution imagery. However, they were still adequate for ice reconnaissance providing image resolution in the range of 30 to 200 metres. Imagery at this resolution was adequate for the delineation of larger ice floe boundaries, as evident by the SLAR image of the channels around Bathurst Island presented in Figure 4, imaged by the CAL-100 SLAR outfitted on the Dash-7 aircraft. A ship's track through fast ice is evident in the centre-right portion of the image.

A significant improvement to the resolution of airborne radars came with the introduction of the Intera STAR (Sea Ice and Terrain Assessment Radar) SAR system in 1984. Using advanced radar processing technology, known as coherent signal processing, it was possible to greatly increase the resolution of radar images collected by ice reconnaissance aircraft. The system was used operationally for ice reconnaissance by offshore oil exploration companies in the Beaufort Sea and by Canarctic Shipping in the high Arctic islands in the 1980's and by the Canadian Ice Service and the Canadian Coast Guard with the Intera Comprehensive Ice Reconnaissance Service (CIRS) between 1990 and 1995. Figure 5 is an example of the high resolution SAR imagery collected by the Intera STAR -SAR system as installed on the CIRS SAR equipped aircraft (Figure 6).

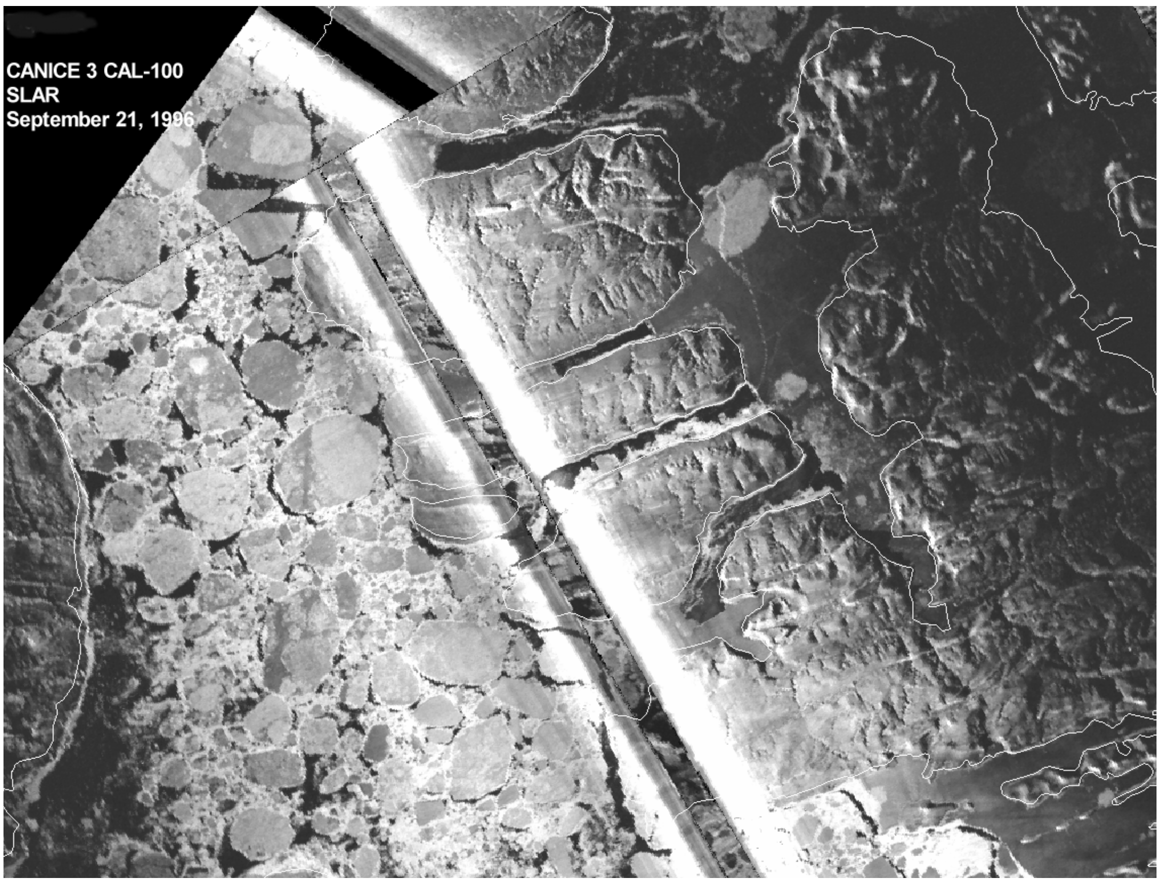


Figure 4: SLAR imagery collected by the Canadian Ice Service DASH7 Aircraft

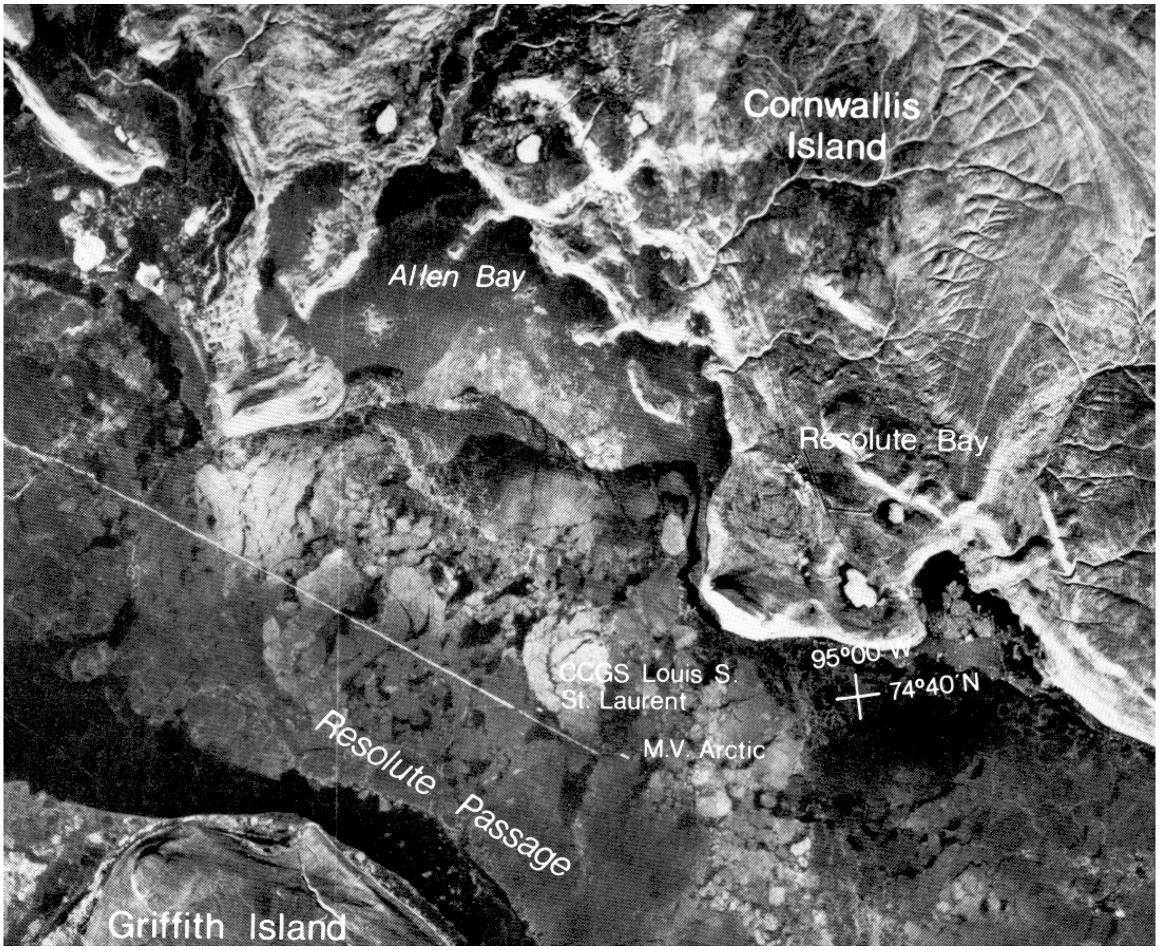


Figure 5: SAR imagery of Resolute Passage (de Bastiani 1987)

Figure 6: CIRS SAR-equipped ice reconnaissance aircraft

Shipboard equipment was developed to receive the direct downlink of imagery from the ice reconnaissance aircraft. The first downlink systems developed in the early 1980's were based on the printing of hardcopy prints on the vessel of the received imagery (Figure 7) and advanced to computer displays by the late 1980's (Figure 8).

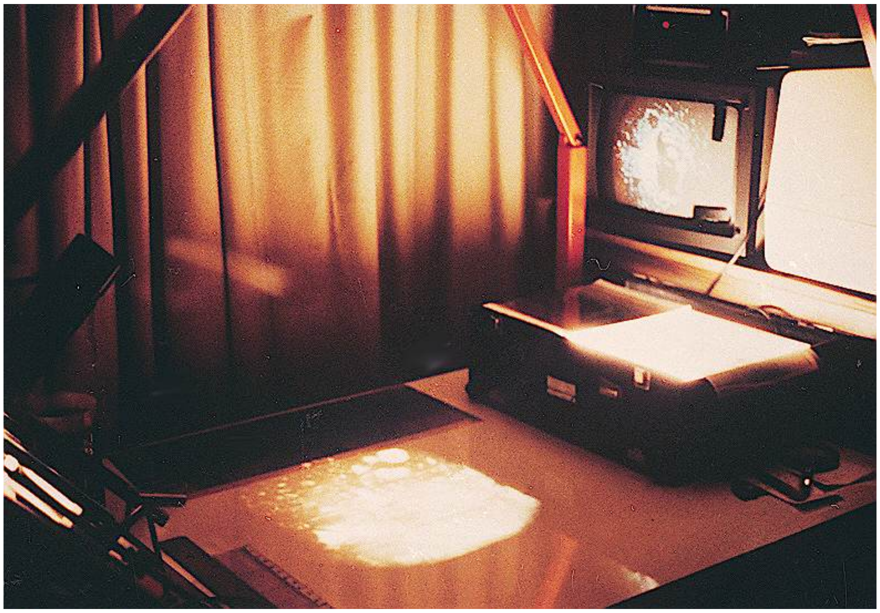


Figure 7: Hardcopy display of airborne radar data on the bridge of a ship

Figure 8: Ice Navigation system on MV Arctic with computerized STAR-VUE display – 1988 (Gorman 1988)

The shipboard use of direct downlinked airborne SAR imagery culminated with the use of the Intera STAR-VUE system, first tested on the MV Arctic between 1986 and 1989 and installed on the larger Canadian Coast Guard icebreakers between 1990 and 1995 as part of the CIRS program.

The shipboard equipment required to receive the direct downlink of airborne radar imagery from the ice reconnaissance aircraft was custom built and very expensive, averaging between $300K and $500K per unit. In addition, the equipment required a specially trained operator on board at all times.

Airborne ice reconnaissance systems were successful in satisfying the ice navigation needs of ships. They were responsive to the “near-real-time” needs for ice information and provided very high resolution imagery. The downfall of airborne systems was the very high cost of operations and the difficulty a plane has in covering a large area. Often, ice information was needed over a much larger area than one plane could cover in any given period. With the launch of the Canadian RADARSAT in November 1995, the aircraft systems were scrapped and overnight a new approach to the implementation of ice navigation systems for ships was required.

3.2 The RADARSAT Era 1995 to Present

The loss of the ice reconnaissance aircraft meant the loss of the “real-time” downlink of radar imagery of ice directly to the vessel. This is because the processing of the radar signal into an image that was done in “real-time” on the aircraft is now done at the ground receiving station for data collected by satellite. Data must be relayed by communications satellite to the vessel, often several hours after collection by the satellite. In addition, the planning of image acquisition for satellite data is limited by the availability of satellite passes over an area and not the dedicated flight plan available with an aircraft. These were considered to be serious limitations to the use of satellite SAR data as a replacement for aircraft ice reconnaissance. Experiments were run in the early 1990’s by the Canadian Ice Service, Canarctic and the Transportation Development Centre (TDC) Transport Canada that demonstrated imagery from the European experimental SAR radar satellite ERS-1 could be sent to a vessel and used for ice navigation (Gorman and Flett 1995). However, the expensive shipboard ice navigation equipment used for receiving aircraft data was not compatible with RADARSAT data and a completely new approach was required.

Ice navigation systems have been developed in response to this need to replace the airborne downlink systems for the receipt and display of satellite radar imagery. These include:

- IceNav (Enfotec)
- Icevu (Canadian Ice Service)
- IcePlot (VTT Finland)

These ice navigation systems are based on inexpensive PC systems that cost as little as 1% the cost of the airborne downlink systems they replaced. They also provide much more flexibility in terms of functionality and data they can handle and the ease to which they can be integrated into the navigational environment on a bridge of a vessel. Figure 9 below shows the screen of Enfotec's IceNav system showing the integration of the ship's GPS position on a RADARSAT image used for planning and executing a voyage in the Antarctic.

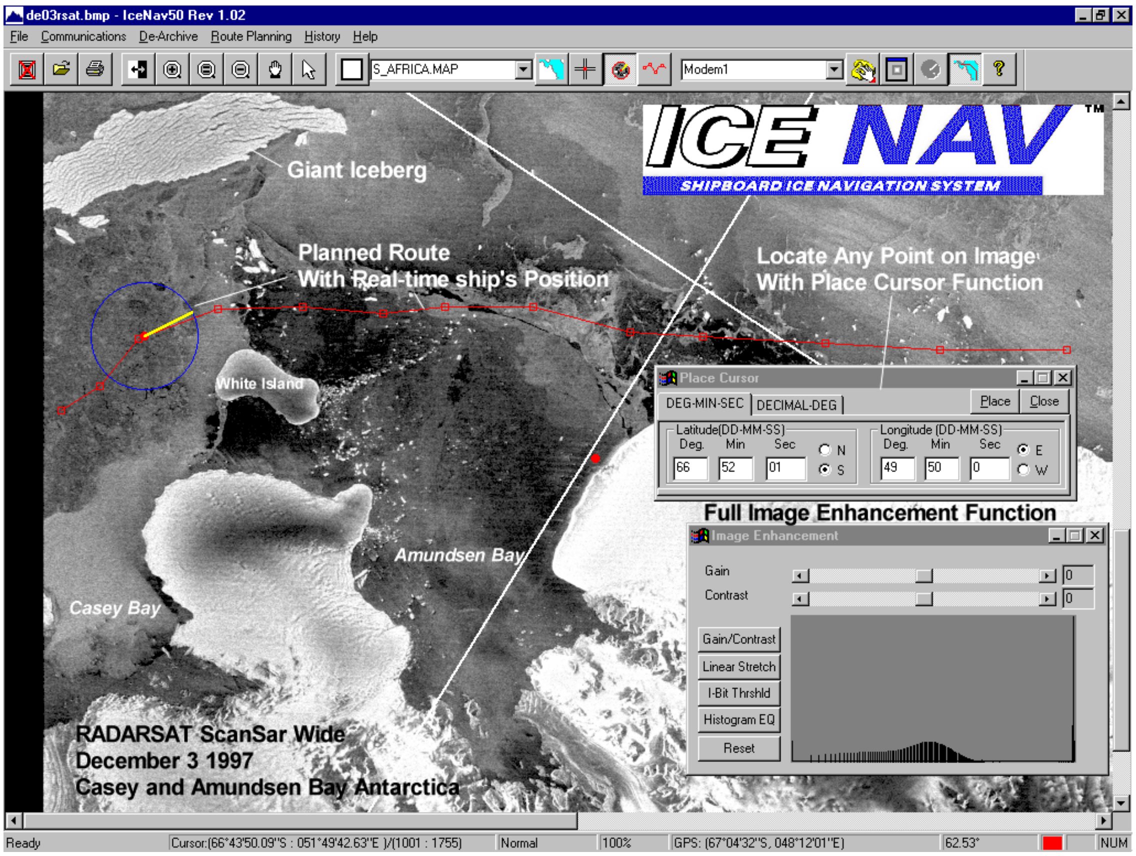


Figure 9: Enfotec's IceNav display showing the range of functionality now available in PC-based ice navigation systems used in the RADARSAT era.

3.3 Other Shipboard Sensors

In addition to systems that receive radar images from aircraft and satellites, a significant amount of effort has also been place on the development of other shipboard sensors to assist in ice navigation. These include:

- SONAR
- Thermal/low light devices
- Advanced marine radars

3.3.1 SONAR

A significant body of research has been completed on the utility of SONAR as an ice navigation device including work by Petro Canada (Remotec 1982) in the early 1980's and Canarctic in 1985/86 (de Heering et al 1985, de Heering and Sutcliffe 1987).

The conclusions from the SONAR trials were:

- Medium to large icebergs were easily detected.
- SONAR returns were complex, with significant scatter effect from the ship's hull, sea bottom as well as under sea ice limiting the detection of smaller objects.
- Changing temperature and salinity profiles in Arctic sea water made the modeling of the SONAR equation difficult.
- Sea ice impacts cause significant damage to a SONAR transducer requiring costly and extensive re-engineering.

The limitations of SONAR for ice navigation were found to be significant in the trials and further work in the use of SONAR was not pursued.

3.3.2 Low-light and IR Sensors

Investigations into the use of light-intensifying and infrared devices have been completed (Remotec 1982, Robson 1982). The findings of these studies were that the environmental conditions that limited vision (such as fog, snow etc.) also limited low light and infra red sensors. The conclusions were that high-powered search lights were far more effective in detecting ice hazards than low-light or IR devices.

3.3.3 Advanced Marine Radar

The most promising results on research into ship-based sensors have come with work on marine radars. Sea and glacial ice display unique properties when illuminated at radar frequencies making this technology the most attractive for ice detection and avoidance.

Standard marine radars were originally developed as target detectors (for other ships, navigation beacons and coastlines) and not imaging devices. A marine radar was not designed to provide a high definition image for ice navigation. The reason for this is that as a target detector, the standard marine radar is set to show all targets on the display that appear above a pre-set threshold value as equally bright, whether the target is a small fishing boat or a large cargo vessel. It is equally important to detect both and thus the radar is set-up to do just that. However, the technology used in standard marine radars is capable of producing high quality images for ice navigation by changing some of the operational parameters. The parameters of interest are:

- Frequency
- Polarization

- RPM and PRF (pulse repletion frequency)
- Coherency
- Display resolution

Frequency

X-Band (3 cm) has been selected as the optimum frequency for marine radars, as it combines both good resolution with good rain and sea clutter penetration as well as limited loss due to atmospheric vapour. However, within an ice cover (particularly under Arctic conditions) there is no sea or rain clutter to worry about and atmospheric vapour is very low so an "ice radar" does not need to be restricted to the X-Band frequency. Higher frequencies such as K_u (16.5 Ghz) and K_a (35.0 GHz) and others provide higher image resolution potential. There has been limited work in the investigation of these frequencies for ice detection (Haykin et al. 1994) and the results were encouraging but much remains to be done in this area.

Polarization

Standard marine radars transmit and receive in horizontal polarization as this has been found to limit rain and sea clutter on radar displays. However, like frequency, these are not limitations in ice covered waters. In addition, comparing cross transmit and receive polarizations has shown some interesting results in ice detection. First year ice, with a high surface salinity, acts as a high loss substance not allowing radar energy to penetrate into the ice. Old and glacial ice, being essentially fresh water ice is a low loss substance to radar energy, allowing the energy to penetrate into the ice where imperfections in the ice that causes a scatter of the energy and polarization of the radar pulse. Experiments have shown that by tuning a radar to an unlike polarization to the transmit pulse, it is possible to separate old ice and glacial ice from first year ice on a radar display (Haykin et al 1994, Gorman 1987).

Figure 10 illustrates the effect of cross polarization on being able to distinguish between old ice and glacial ice on a radar display. This example comes from experimentation undertaken on board the MV Arctic with an experimental cross polarized radar in 1986. This technology shows promise as a glacial and old ice hazard detector for a vessel but much work remains to produce an operational system.

Rotation and Display

Standard marine radars rotate at 30 RPM as 2 seconds was how long a target illuminated on a phosphorous display would remain visible until another pass was required. Marine radars no longer use phosphorous displays and have not done so for years yet the 30 RPM design persists. Altering the rotation speed of the radar could greatly enhance the ability of the radar to image ice hazards in front of the vessel by increasing the number of pulses illuminating a target over a given period.

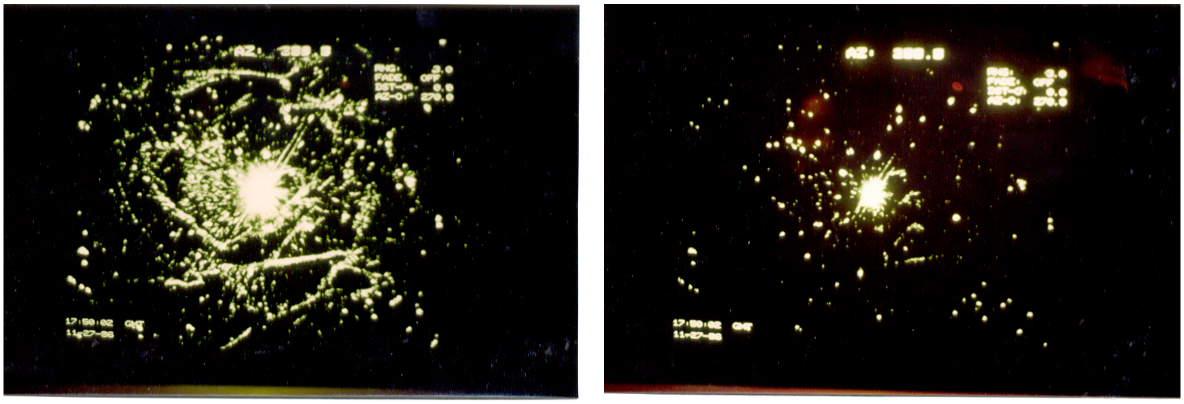


Figure 10: H/H polarized (left) and H/V polarized (right) showing glacial ice detection capability of X-Pol radar technology

In addition, increasing the digitization of the radar signal to 256 grey level from the existing 4 of standard radars greatly increases the imaging capabilities of the marine radar. This, along with averaging scans together to reduce noise and clutter on the image, allows for a much higher quality image of the ice cover than that available on standard marine radar displays. Figure 11 illustrates the improvement in ice detection that occurs due to radar image scan conversion.

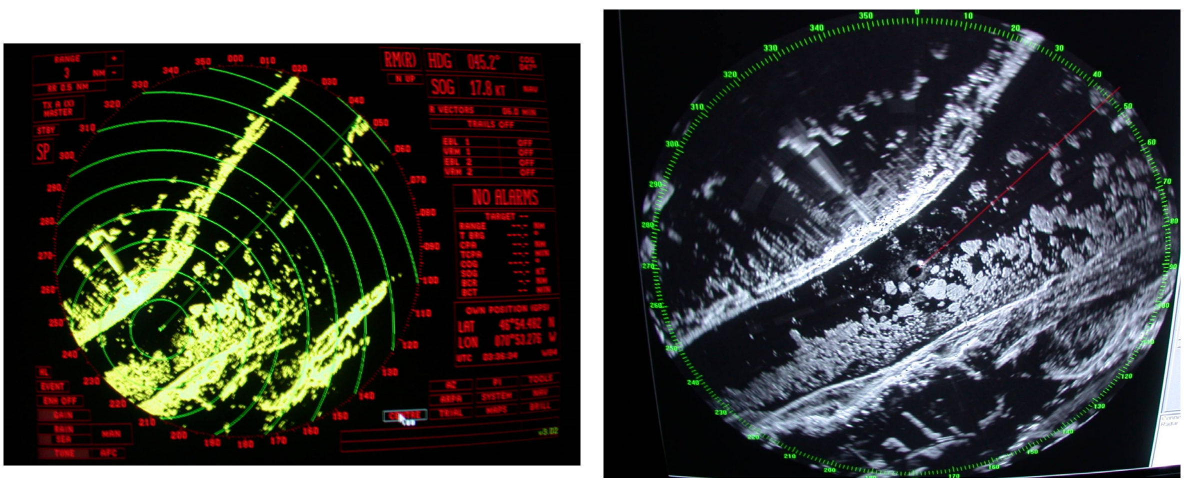


Figure 11: Standard radar display (left) and an image from the same radar scan converted and digitized to 256 grey levels (right) showing the great improvement in ice detection possible with advanced radar image processing.

Coherent Marine Radar

Standard marine radars are considered "noncoherent" since the image is only based on the amplitude of the returning signal. Since ice represents a relatively poor radar target, there is sometimes insufficient separation in the amplitude domain between a signal of an ice target and background noise and clutter, particularly for small objects like individual ice floes or growlers in high sea state. However, there is much more to a radar signal such as frequency, phase and polarization that conventional marine radars do not process. We have described above how frequency and polarization can be used to improve ice discrimination but there is one more important element that can be used that of the phase of the radar signal.

Conventional marine radars measure only the amplitude of each individual returning pulse in isolation. However, much like the changing sound of a car as it passes by, there is also a change in the phase as successive pulses move past an object, known as the Doppler principle. With a coherent marine radar, the phase of the received signal is measured against the transmitted signal as well as adjacent signals. The ability to measure the phase shift on each pulse significantly increases the information content and the ability to resolve features on the radar. This is the same principle used in Synthetic Aperture Radar and provides for much higher resolution images and target discrimination.

Experimentation with coherent surface radars has been undertaken by the Communications Research Laboratory (CRL) at McMaster University. CRL developed an experimental coherent radar called the IPIX (Intelligent Pixel-Processing Radar) that allowed for experimentation in phase, frequency and polarization dimensions of the radar signal. Results from the radar experiments were encouraging but demonstrated that gaining an understanding of the interactions of these parameters was a complex problem (Currie et al. 1991). Coherent marine radars use very advanced technology and represent a cost much higher than standard marine radars that limits the commercialization of the technology at the moment.

3.4 Current Integrated Ice Navigation Systems

In order to satisfy the ice information requirements of the navigation officer on a vessel transiting through ice covered waters, an ice navigation system must be able to integrate data sources both externally from the ship (such as satellite imagery) with those generated on board the vessel (such as the vessel's marine radar). In addition, the system must integrate into the navigational environment on the ship, such as with the GPS and INMARSAT (or similar) communication systems.

Significant strides have been achieved toward the development of an integrated ice navigation system, such that which exists with Enfotec's IceNav-VMR system illustrated in Figure 12. The IceNav-VMR integrates satellite radar imagery from RADARSAT with an enhanced scan converted marine radar image. Such an integrated system allows the navigation officer to see ice conditions in the immediate vicinity of the vessel as well as longer range out to 100 nautical miles and beyond (Gorman and Zagon 2005).

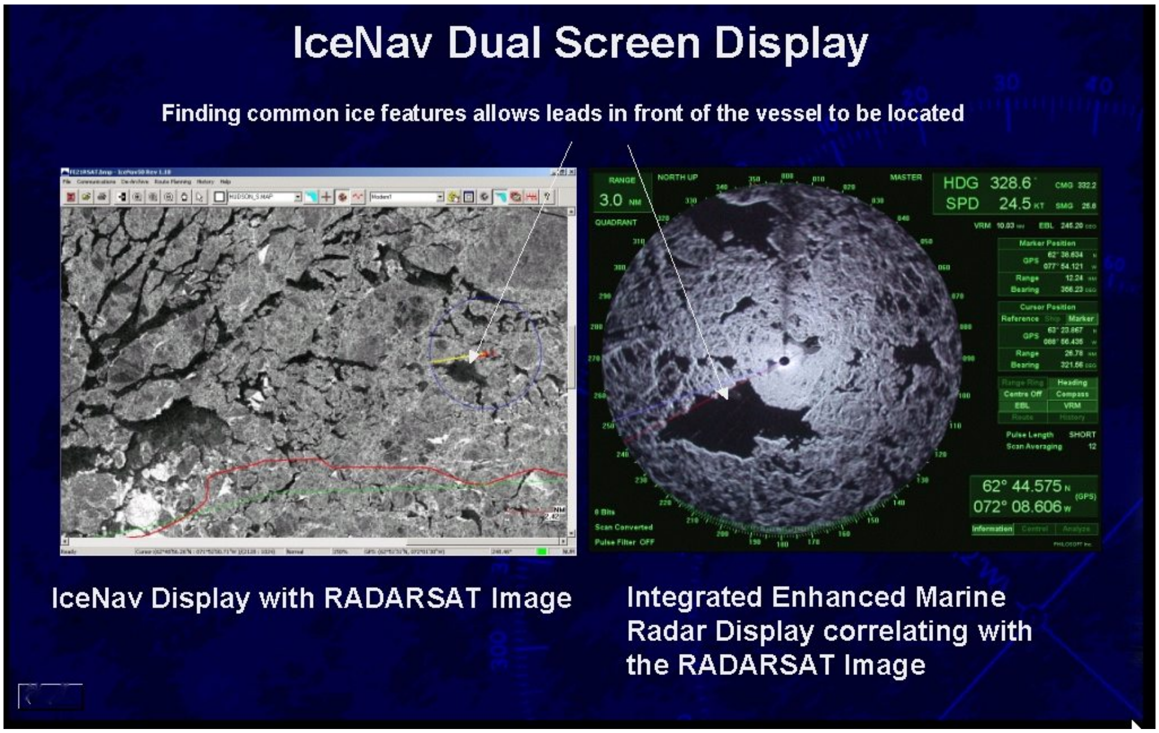


Figure 12: IceNav integrated satellite and marine radar ice navigation system

3.5 Future Direction

Although much has been accomplished in the creation of ice navigation systems, much remains to be achieved, particularly in the area of ice hazard detection in front of the vessel. Advances in marine radar technology hold the most promising opportunities to achieve this goal, particularly in the area of polarization and coherency. There is an opportunity to create the “Ice Navigation Radar” that will greatly improve the safety and efficiency of vessels plying ice covered waters.

4.0 CANADIAN ICE SERVICE OPERATIONS AND PRODUCTS

4.1 Organization

The Canadian Ice Service, a division of the Meteorological Service of Canada in the Department of Environment, is a centre of expertise for ice related information for all of Canada and its surrounding waters. The Ice Service co-operates closely with the Canadian Coast Guard which operates Canada's fleet of icebreakers to assist marine transportation in Canadian waters.

The Canadian Ice Service promotes safe and efficient maritime operations and protects Canada's environment by providing reliable and timely information about ice conditions in Canadian waters. For example, the Ice Service provides timely warnings of icebergs and ice conditions that pose immediate threats to ships, ports and other marine operations; advises on ice conditions in shipping routes for navigators; provides information to help shipping, fishing and offshore operators plan their seasonal operations in a safe and efficient manner.

To meet its mission, the Canadian Ice Service collects and analyses data on ice conditions in all regions of the country affected by the annual cycle of pack ice growth and disintegration. In summer, the focus is on conditions in the Arctic and the Hudson Bay region. In winter and spring, attention shifts to the Labrador Coast and East Newfoundland waters, the Gulf of St. Lawrence, the Great Lakes and St. Lawrence Seaway.

Major users of Ice Service products and services are:

- the Canadian Coast Guard uses weather and ice information for marine safety, icebreaking operations and efficient marine transportation
- port authorities obtain site-specific information on current and long-term ice conditions in ports and shipping routes
- the commercial shipping industry uses ice information for strategic and tactical vessel passage planning
- fishing fleets obtain enroute and on-site ice conditions for ice-encumbered areas
- the offshore oil and gas companies use iceberg and sea ice information for exploration and production, both on-site and in transit
- the marine construction industry uses site-specific current and historical data for offshore and onshore projects, such as bridges and port facilities
- the tourism industry gets technical and general information for the operation of cruise ships and the enjoyment of passengers
- the marine insurance industry uses ice information for risk assessment for offshore operations affected by ice
- environmental consultants use ice data, analyses and expert advice for environmental impact assessments

- research scientists use ice information relating to research on transportation, construction, climate change, meteorology, oceanography, biology and socio-economic impacts.

The Canadian Ice Service operates a comprehensive ice information service, encompassing reconnaissance, analysis and forecasting, ice climatology, data archiving, informatics support and research and development. It has a staff of approximately 80 people working at the Ice Centre in Ottawa, aboard Coast Guard icebreakers and in field offices.

4.2 Data Acquisition

Radar imagery from satellites is the principal data source, augmented by visual observations from fixed-wing aircraft and helicopters. Radarsat and Envisat synthetic aperture radar (SAR) data provides extensive and detailed (up to 30 metres) coverage of ice conditions. The Ice Service uses approximately 5,000 SAR images covering over a billion square kilometres annually. Data are received in real-time by two Canadian satellite receiving stations, processed and delivered to the Canadian Ice Service and disseminated to marine users within hours.

Visual and infrared imagery from U.S. polar orbiting satellites is also used extensively in the ice analysis program. Passive microwave imagery is received daily to provide background information on the general ice distribution at low resolution.

Experienced ice observers are stationed on the major Coast Guard icebreakers and in regional ice offices. They conduct local visual reconnaissance by helicopter and transmit the observations to the Ice Centre immediately after the flight. These observed ice charts are posted on the Ice Service web site marine users immediately upon receipt.

The Canadian Ice Service is integrated with the national meteorological network and has access to the necessary meteorological and oceanographic inputs. Co-operation with research institutes, universities and other federal departments also provide other valuable data.

4.3 Output products and forecasts

The Canadian Ice Service provides its clients and the Canadian public with a variety of accurate and timely analyses and forecasts of ice conditions ranging from daily bulletins on ice hazards to seasonal outlooks. Information on ice conditions posing immediate threats, such as ice hazard bulletins and special warnings for ships, are directly available from the Ice Service web site and through weather and marine radio broadcasts.

Specialized products and services to meet the short-term tactical and longer-range planning needs of clients are also available. These products include detailed ice analysis charts, radar and satellite imagery, image analysis charts, and special forecasts covering days to months (see Figure 13 to Figure 19). These products are distributed in a variety of formats, including mail, e-mail, fax, and Internet.

The Ice Service provides a variety of field services, normally through the Coast Guard, for clients who need specialized ice information. Ice Service Specialists provide field support to clients on shore and aboard ships, including briefings on ice conditions, direct analysis of satellite images and special visual observations.

The Canadian Ice Service has expertise in ice modelling, remote sensing and climatological ice conditions in and around Canada. It supports research and development by scientists working in government, universities and the private sector. Drawing on the Canadian Ice Service national ice data archive, ice analysts work directly with clients to identify and analyze appropriate climatological ice information and provide advice on historical ice and iceberg conditions.

Ice information products and services are provided in those areas of Canada's waters where there is marine activity in the vicinity of sea ice. Arctic areas are active from June to November while southern areas, including the Gulf of St. Lawrence and the Great Lakes are active from December to May.

Ice Charts

Ice charts graphically illustrate ice or iceberg conditions at a particular time, presenting data by means of a standard international code. Charts may be used for strategic and tactical planning. Charts available from the Canadian Ice Service include:

- Regional Weekly Ice Chart
- Daily Iceberg Analysis Charts
- Daily Ice Analysis Charts
- Ice Reconnaissance Charts
- Radarsat Image Analysis Charts

Bulletins

Bulletins provide advice on present and forecast ice or iceberg conditions in simple text format. The following bulletins are available from the Canadian Ice Service:

- Daily Ice Hazard Bulletins
- Daily Iceberg Bulletins
- Daily St. Lawrence River Ice Bulletins
- 30-day Ice Forecast Bulletins
- Seasonal Ice Summary
- Seasonal Ice Outlook

Images

In preparing the charts and bulletins, the Canadian Ice Service uses an extensive array of satellite data. Raw images are available to users depending on their ability to receive image data:

- Visual / Infrared Satellite Imagery
- SAR images from Radarsat and Envisat

Weather Maps

The Canadian Ice Service makes available the following weather maps produced by Environment Canada:

- Surface Analysis Weather Map
- 500 HPA Height Analysis Map
- Surface Prognostic Weather Map out to 120 hours
- 500 HPA Prognostic Weather Map out to 120 hours
- Public and Marine Weather Forecast Bulletins
- significant weather depiction charts
- ocean wave analysis
- 12-24-36 hour ocean wave prognosis

Special Services

The Canadian Ice Service responds to enquiries from users and provides a range of specialized forecasting, consultation and advisory services on a best-effort, cost-recovered basis. If needs are substantial, the user is referred to the private sector when possible.

4.4 Publications

The Canadian Ice Service has a collection of reference material related to sea ice and icebergs. The following representative publications are available in printed format and on-line as indicated:
Seasonal Summary for the Canadian Arctic: Summer 2004
(available on-line).
MANICE - Manual of Standard Procedures for Observing and Reporting Ice Conditions.
(available on-line).
Ice Thickness Climatology (1961-1990)
Melting and Freezing Degree Days (1961-1990)
Sea Ice Climatic Atlas - Northern Canadian Waters 1971-2000 (also in CD)
(available on-line).
Sea Ice Climatic Atlas - East Coast of Canada 1971-2000
(available on-line).
Lake Ice Climatic Atlas - Great Lakes 1973-2002
(available on-line).

Annual Arctic Ice Atlas (CD only from 2003)
(available on-line).

4.5 Mailing address

Canadian Ice Service – Environment Canada
373 Sussex Drive, Block E - 3rd floor
Ottawa, Ontario
Canada K1A 0H3

Telephone:	(613) 996-1550
	or toll-free in North America (800) 767-2885
fax:	(613) 947-9160
e-mail	cis-scg.client@ec.gc.ca
URL	http://ice-glaces.ec.gc.ca

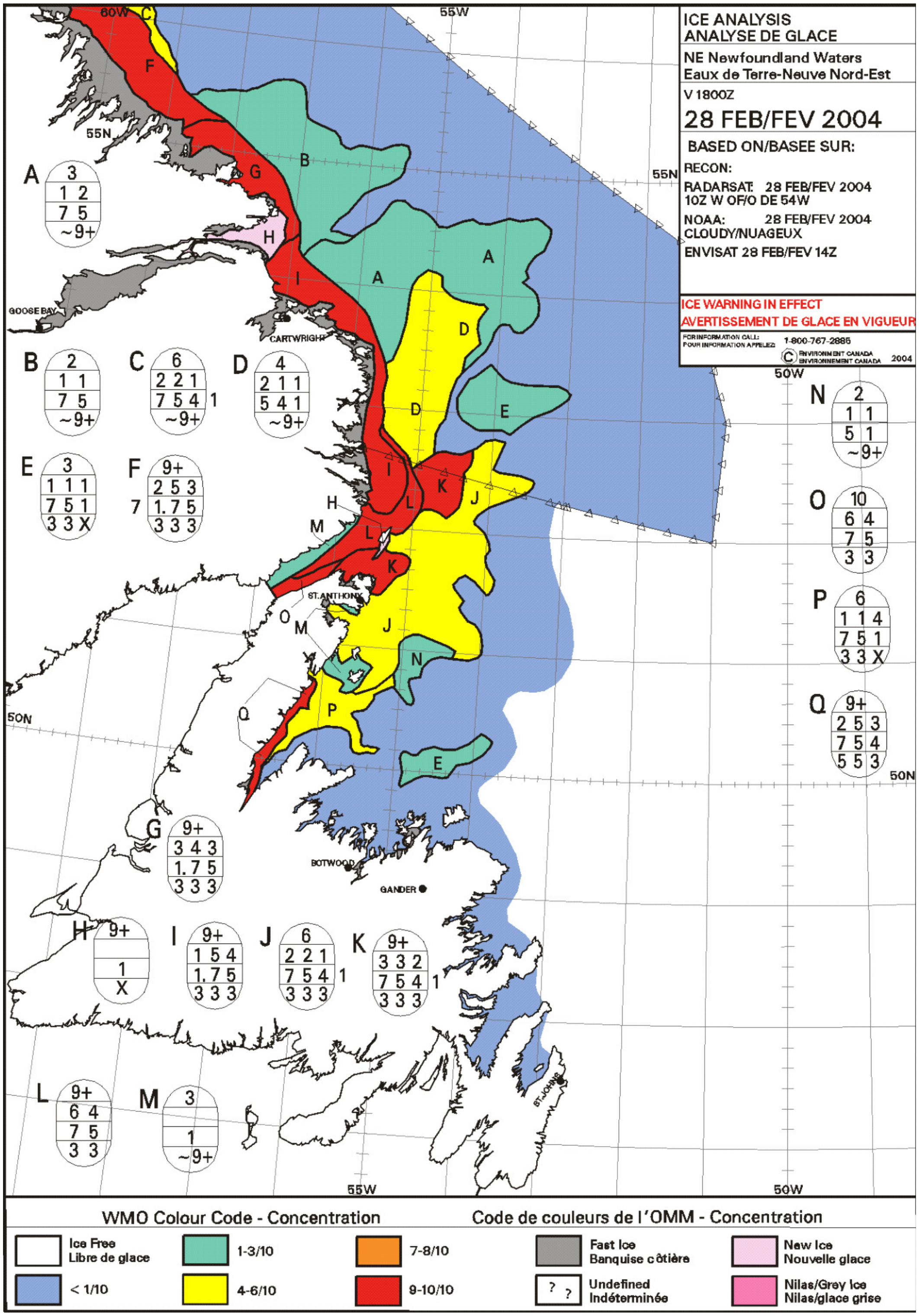


Figure 13: Example of a Daily Ice Chart - Newfoundland

Daily Ice Hazard Bulletin
Newfoundland

```
FICN18 CWIS 281449
ICE HAZARD BULLETIN FOR THE EAST COAST OF NEWFOUNDLAND AND LABRADOR
ISSUED BY ENVIRONMENT CANADA AT 1500 UTC SATURDAY 28 FEBRUARY 2004
FOR TODAY AND SUNDAY.
THE NEXT SCHEDULED BULLETIN WILL BE ISSUED AT 1500 UTC SUNDAY.

ICE EDGE AT 1500 UTC ESTIMATED FROM NEWFOUNDLAND NEAR 4955N 5530W TO
4955N 5500W TO 5010N 5400W TO 5335N 5135W TO 5405N 5150W TO
5525N 5415W TO 5615N 5815W TO 6125N 6030W THEN NORTHEASTWARD.

SOUTH COAST
SOUTHEASTERN GRAND BANKS
NORTHERN GRAND BANKS
FUNK ISLAND BANK.
ICE FREE.

EAST COAST.
OPEN WATER.

NORTHEAST COAST.
3 TENTHS MAINLY GREYWHITE ICE WITH 1 TENTH FIRST YEAR ICE SHOREWARD
OF THE ICE EDGE. ELSEWHERE OPEN WATER.

BELLE ISLE BANK.
6 TENTHS MAINLY FIRST YEAR ICE WEST OF THE ICE EDGE. EAST OF THE ICE
EDGE ICE FREE.

BELLE ISLE EASTERN HALF.
9 TENTHS MAINLY FIRST YEAR ICE.

SOUTH LABRADOR COAST.
ICE WARNING IN EFFECT.
STRONG ICE PRESSURE ALONG THE COAST BETWEEN CARTWRIGHT AND SPOTTED
ISLAND IS EXPECTED TO CONTINUE THROUGH SUNDAY.
9 PLUS TENTHS MAINLY FIRST YEAR ICE.

MID LABRADOR COAST.
ICE WARNING IN EFFECT.
STRONG ICE PRESSURE ALONG THE COAST SOUTHEAST OF HOPEDALE
IS EXPECTED TO CONTINUE THROUGH SUNDAY.
7 TENTHS MAINLY FIRST YEAR ICE WITH A TRACE OF OLD ICE. COMPACTED
FIRST YEAR ICE ALONG THE COAST.

SOUTH LABRADOR SEA.
WEST OF THE ICE EDGE 4 TENTHS MAINLY FIRST YEAR ICE. ELSEWHERE
MAINLY BERGY WATER.

CONTACT ECAREG CANADA VIA MARINE RADIO FOR ROUTING ADVICE. THE EAST
COAST ICE ANALYSIS CHARTS CAN BE COPIED ON CFH AT 2222 UTC AND 0001
UTC AND ON VCO SYDNEY AT 1142 UTC AND 2331 UTC.

END/NH
```

Figure 14: Example of a Daily Ice Hazard Bulletin

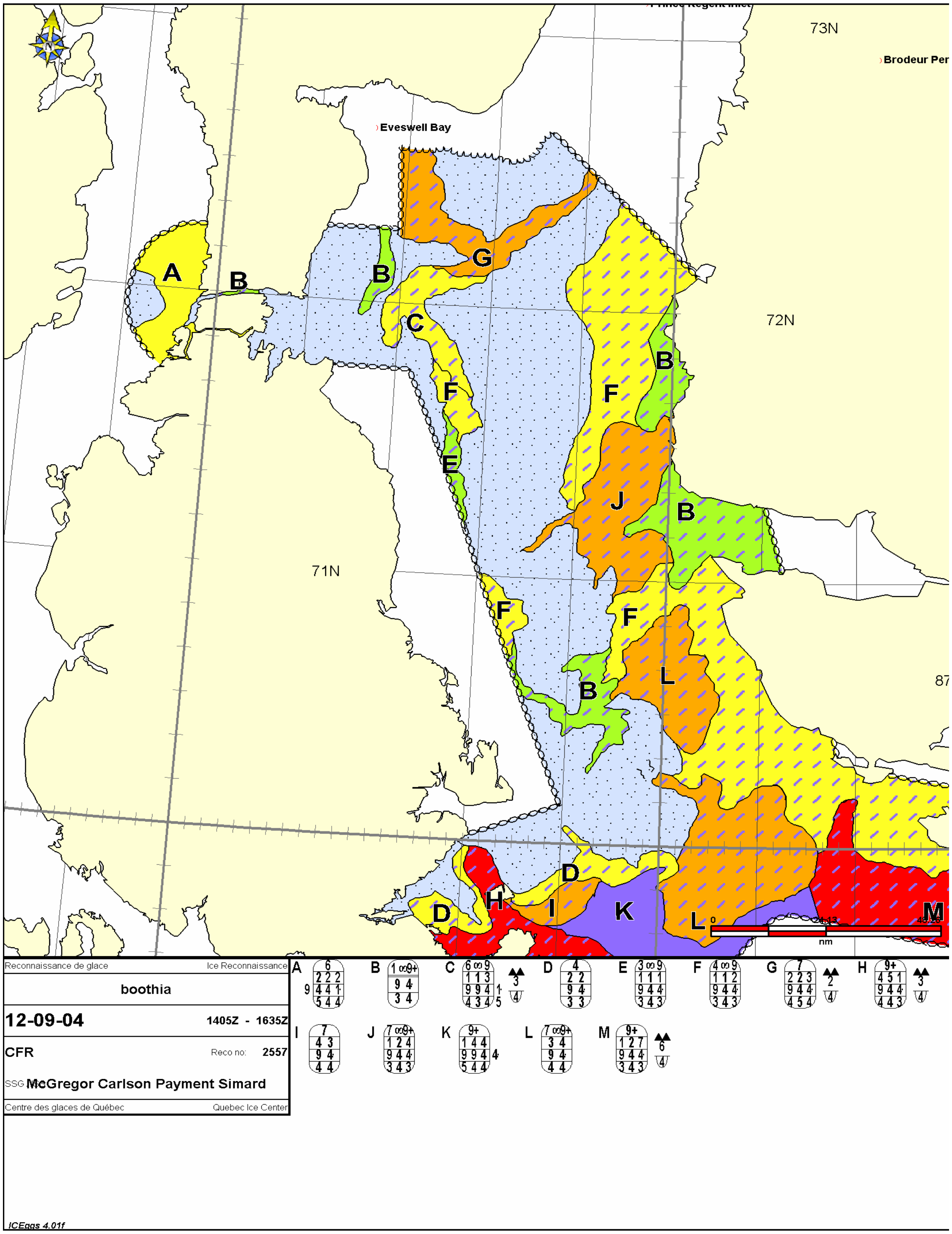


Figure 15: Ice Reconnaissance Chart - Gulf of Boothia

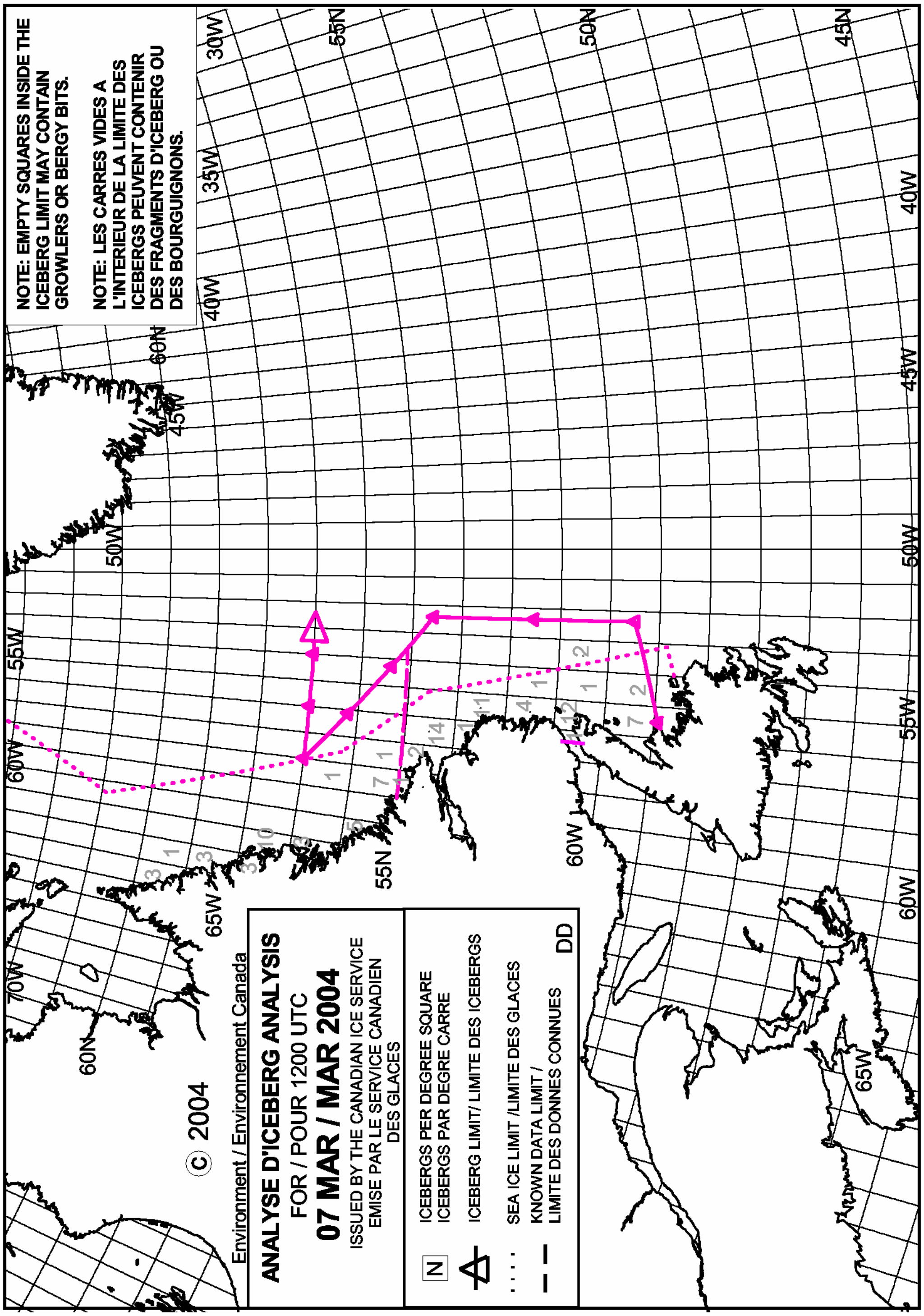


Figure 16: Daily Iceberg Analysis Chart – East Coast of Canada

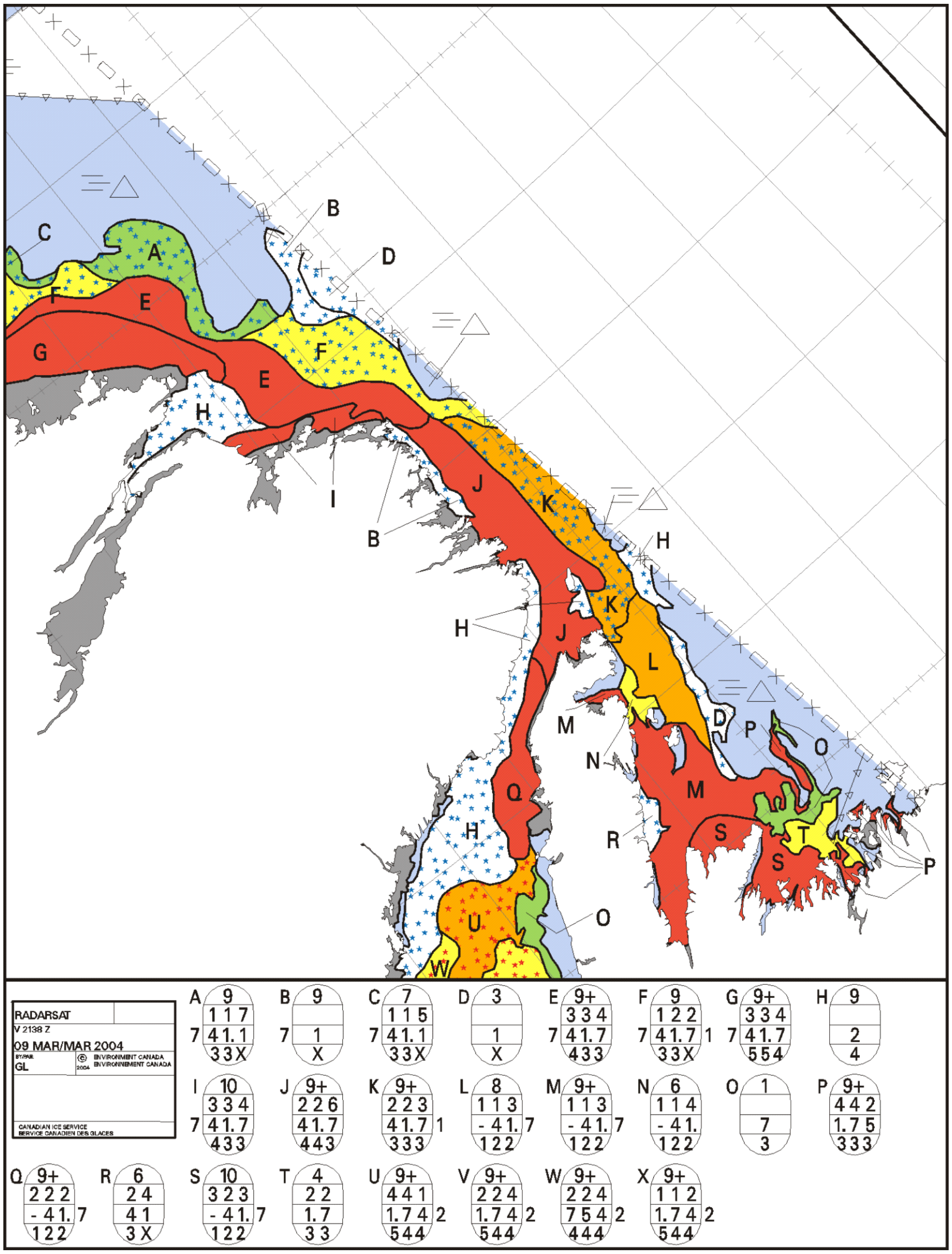


Figure 17: RADARSAT image analysis chart - Labrador Coast

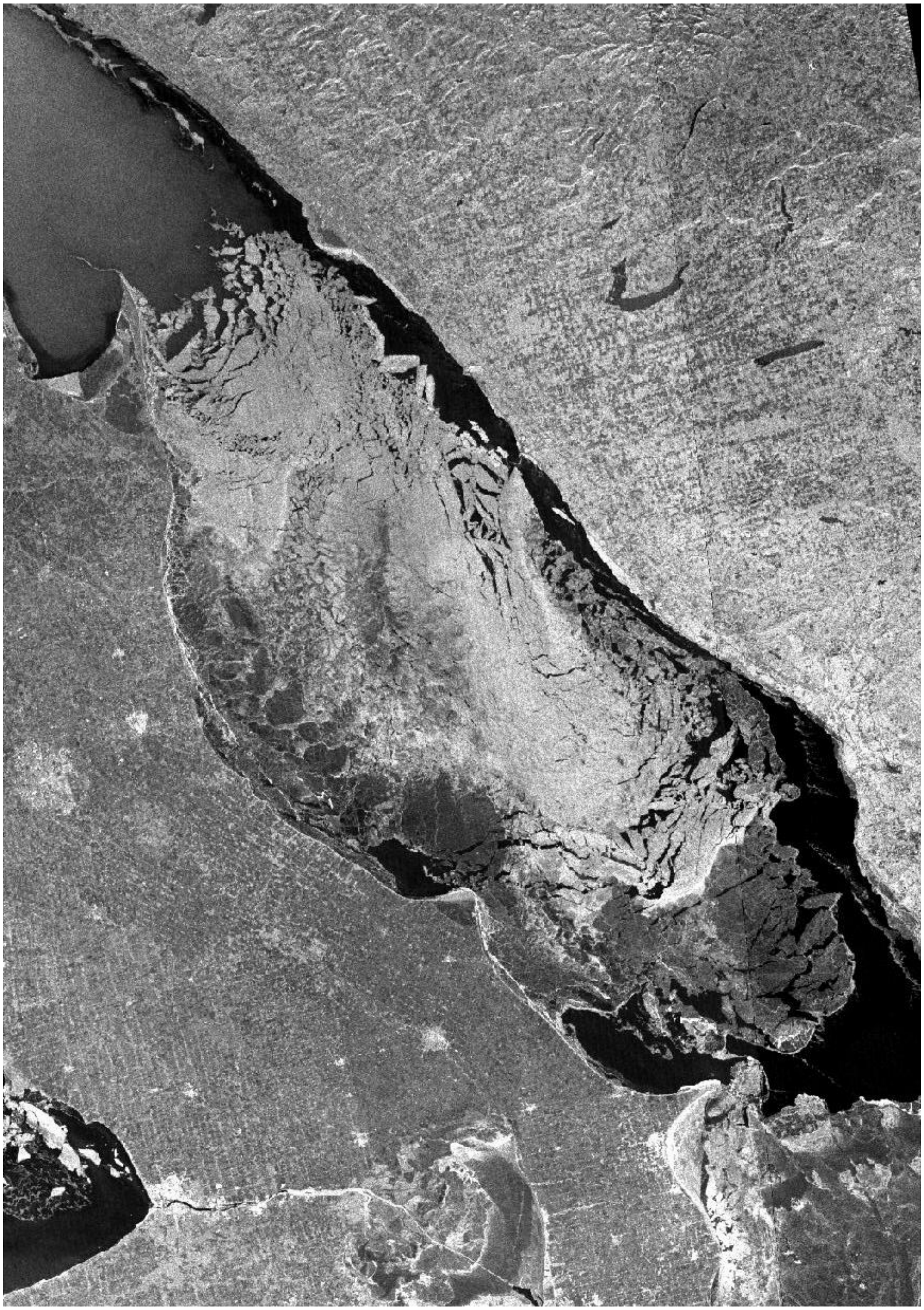


Figure 18: RADARSAT imagery - Lake Erie

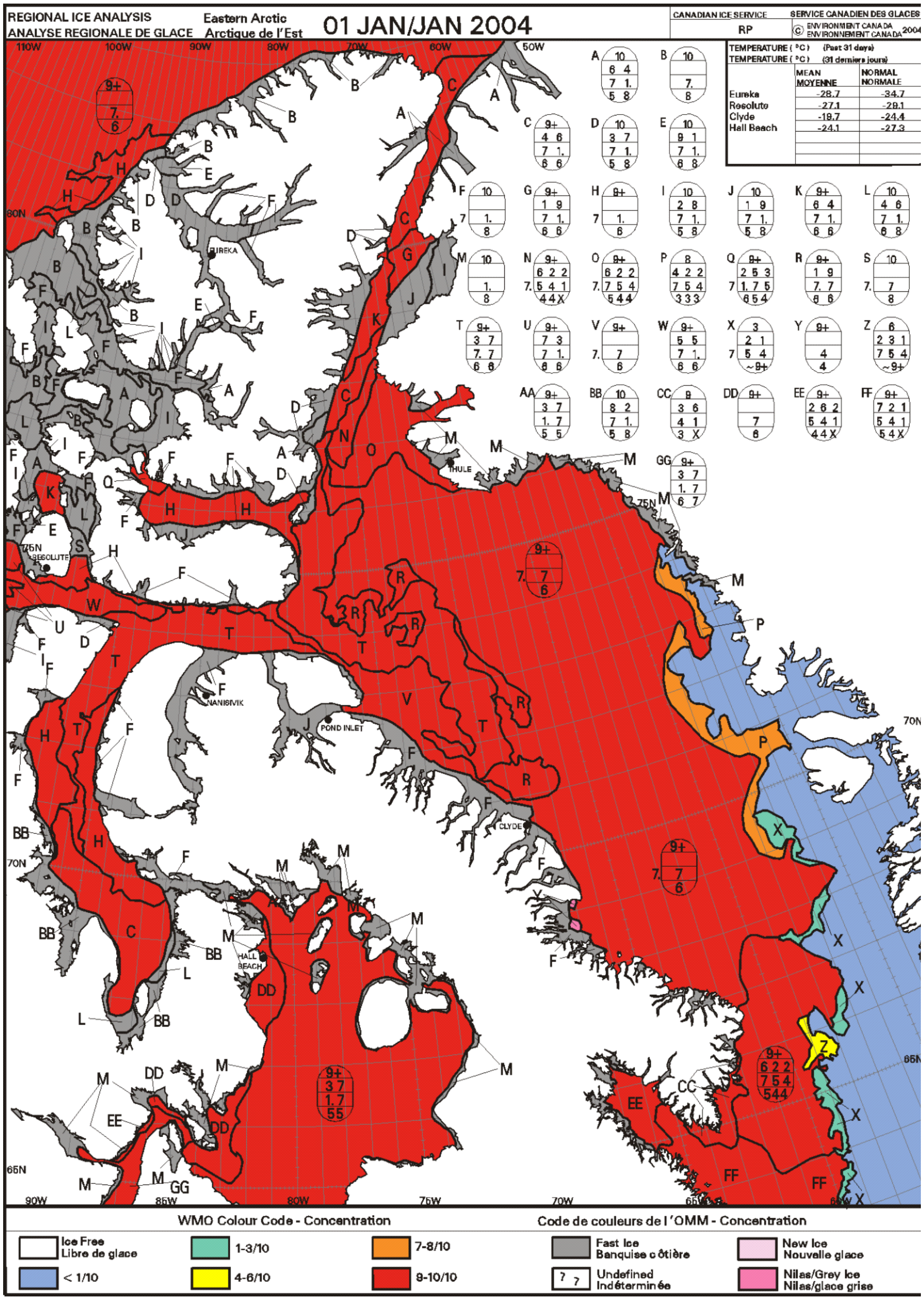


Figure 19: Regional Weekly Ice Chart – Eastern Canadian Arctic

5.0 CANADIAN COAST GUARD USE OF ICE INFORMATION

5.1 Introduction

Canada has more ice floating on its oceans and lakes than any other nation. Along the northern and eastern coasts and throughout the Great Lakes, ice affects economic activities and threatens human safety. The Oceans Act of 1997 (section 41) gives the Canadian Coast Guard the legislative authority to provide services for the safe, economical and efficient movement of ships in Canadian waters. The Act also stipulates that the services are to be provided in a cost-effective manner.

The Coast Guard provides a variety of icebreaking services to ensure that marine shipping moves in a safe, timely and efficient manner through or around ice-covered waters and to minimize the effect of flooding caused by ice jams on the St. Lawrence River. These services include ice routing and information, escort assistance, channel and track maintenance through shore-fast ice, harbour breakouts, flood control, northern resupply and Arctic sovereignty support. The mere presence of a guaranteed icebreaking service is one of the most important factors in sustaining the viability of many Eastern Canadian and Arctic economies and communities.

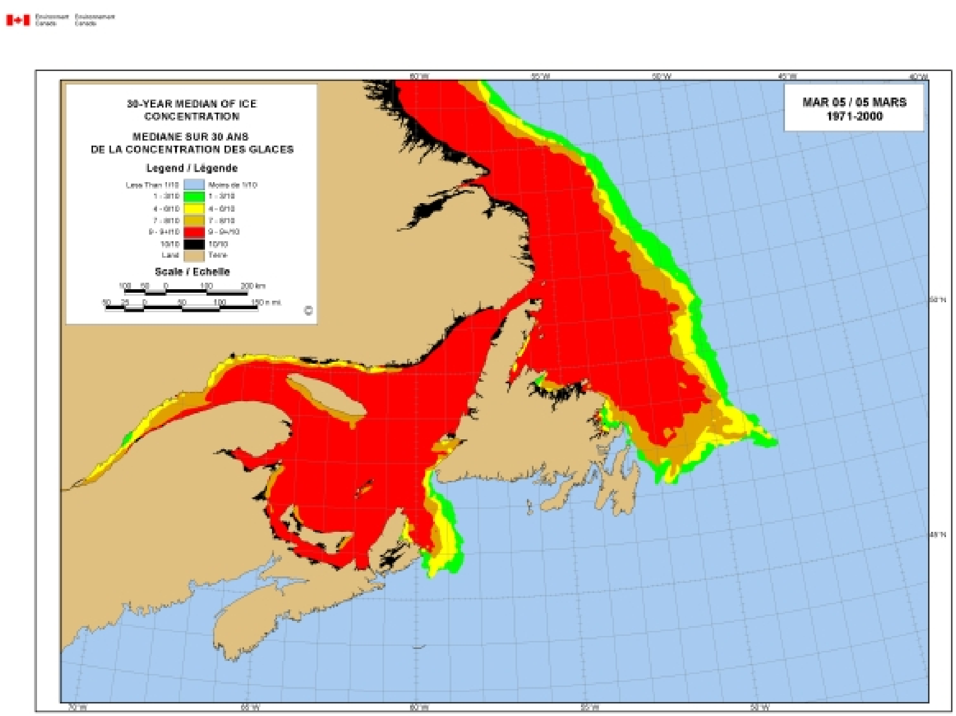


Figure 20: Chart: Excerpt from Climatic Ice Atlas – East Coast

Accurate and timely ice information is essential for the Icebreaking Program. For the past nine years, improved ice information and new technology has helped to optimize the efficiency of icebreakers. It has also resulted in improved ice routing advice to marine

shipping so that they may navigate safely around difficult areas of ice, therefore, reducing transit times, delays in ice, fuel consumption and the reliance on icebreaker support. The outcome has been reduced icebreaker escorts, improved effectiveness of commercial ship movements, increased client satisfaction and public confidence in the Coast Guard.
The overall performance of the Icebreaking Program during the winter 2003 showed the importance of accurate ice information in the preparation of Recommended Ice Routes. During the winter of 1993, recognized by the Canadian maritime industry as being a severe ice season, the CCG icebreaker fleet provided 1373 escorts, compared with 835 escorts during the winter of 2003, which experienced very similar ice conditions. This can be directly attributed to improved satellite imagery (RADARSAT, launched 1995) and the use of new technology such as Ice-Vu, the Ice Routing Computer Model and the ICEggs/Pen Computer system. The CCG has also developed the Integrated Ice System, a system of sensors, radars and video cameras along the St. Lawrence River to help monitor ice conditions and water levels to reduce the level of helicopter reconnaissance and icebreakers to detect potential ice jams and prevent flooding.

The current CCG icebreaking fleet consists of 5 dedicated icebreakers and 12 multi-tasked ice-strengthened vessels, which are operated out of 5 regions. There are two main operations seasons for the icebreaker fleet:

- Southern Operations: during the winter season from mid-December to the end of May in Eastern Canada, the Gulf, St. Lawrence River and the Great Lakes.
- Northern Operations: during the summer navigation season from late June to November in the Canadian Arctic.

The Coast Guard has a limited number of icebreakers with which to cover a large geographic area. There is competition for ship-time with other CCG and DFO programs such as Arctic Science, Search & Rescue and Fisheries Enforcement. The Icebreaking Program must balance the needs of commercial shipping and other user groups with considerations of the general public's interests, such as flood control and support to northern or remote sites. Delays caused by heavy ice conditions can mean a loss of over $25 thousand per day for a shipping company so timely and accurate ice information and effective ice routing can improve the transit time through or around ice.

Table 3: List of CCG Icebreakers

Name	Type	Len (m)	Power (kw)	Summer Operations	Winter Operations
LOUIS S. ST-LAURENT	1300	120	29,400	East Arctic	Gulf of St. Lawrence
TERRY FOX	1200	88	17,300	East Arctic	Gulf of St. Lawrence
HENRY LARSEN	1200	100	12,000	East Arctic	Newfoundland & Labrador
DES GROSEILLIERS	1200	98	10,142	East Arctic	St. Lawrence River
PIERRE RADISSON	1200	98	10,142	East Arctic	St. Lawrence River

AMUNDSEN	1200	98	10,142	Arctic Science	St. Lawrence River
ANN HARVEY	1100	83	5,250		Newfoundland & Labrador
EDWARD CORNWALLIS	1100	83	5,250		Gulf of St. Lawrence
SIR WILLIAM ALEXANDER	1100	83	5,250		Gulf of St. Lawrence
GEORGE R. PEARKES	1100	83	5,250		Newfoundland & Labrador
GRIFFON	1100	71	3,980		Great Lakes
SIR WILFRID LAURIER	1100	83	5,250	West Arctic	
MARTHA L. BLACK	1100	83	5,250		St. Lawrence River
EARL GREY	1050	70	6,500		Gulf of St. Lawrence
SAMUEL RISLEY	1050	70	6,360		Great Lakes
TRACY	1000	55	1,491		St. Lawrence River
WABAN-AKI	ACV	24.5	1,760		Lac St.-Pierre
SIPU MUIN	ACV	28.5	2,818		Lac St.-Pierre

TYPE 1300: **Heavy Gulf Icebreaker** - Large ship escort in severe Gulf of St. Lawrence and Atlantic ice and weather conditions. Capable of extended season operations through ice zone 6 or less severity.
TYPE 1200: **Medium Gulf / River Icebreaker** - Large ship escort operations in southern Canadian waters as well as Arctic areas during the summer.
TYPE 1100: **Major Navaids Tender / Light Icebreaker** - Buoy handling and medium cargo capacity; small to medium vessel escort in southern Canadian and sub-Arctic waters.
TYPE 1050: **Medium Navaids Tender / Light Icebreaker** - Buoy handling, restricted mainly to deck cargo; small to medium vessel escort in moderate ice conditions south of the Arctic.
TYPE 1000: **Medium Navaids Tender / Ice Strengthened** - Buoy handling and medium capacity cargo. Small to medium vessel escort in more restricted and shallow waters.
ACV: Air Cushion Vehicle - Icebreaking for flood control and seaway operation; small navaids tender.

Figure 21: CCG vessel in escort service

5.2 Ice Information Services

The Canadian Ice Service (CIS) works in partnership with the CCG to provide ice information to the marine community to enhance the safety and efficiency of marine operations in ice-covered waters. The CIS provides additional services to the CCG for the operation of the Icebreaking Program, for which it contributes funding each year. The specific services required by CCG are adjusted annually through joint operational planning between CCG Icebreaking Program, CCG Regions and the CIS.

CIS Ice Information Services provided to CCG include:

- Ice Service Specialists on-board icebreakers and in Ice Operations Offices
- Download of imagery, charts, forecasts and assimilation into a simple presentation
- Briefing and advice to Captain and Ice Office of ice conditions and impact of weather and currents on those conditions, advice on route planning
- Briefing and advice on future weather conditions for both ship and helo operations
- Performing Ice Observations flights onboard a CCG helicopter
- Providing observations to CIS for assimilation into regional charts
- Training and familiarization of all aspects of ice services to officers
- Airborne Ice Reconnaissance – operation of a fixed-wing aircraft for visual reconnaissance and image data collection

- Satellite Data Acquisition and Processing
- Analysis and Forecast Services
- Ice Information Systems, including Ice-Vu display systems
- Product Dissemination Services, including telecommunications equipment and services
- Applied Science (remote sensing and modeling, new product and service development)
- Program Management and Support (informatics and technology support, management of capital projects that support the joint program)
- Training, such as Ice Interpretation Courses.

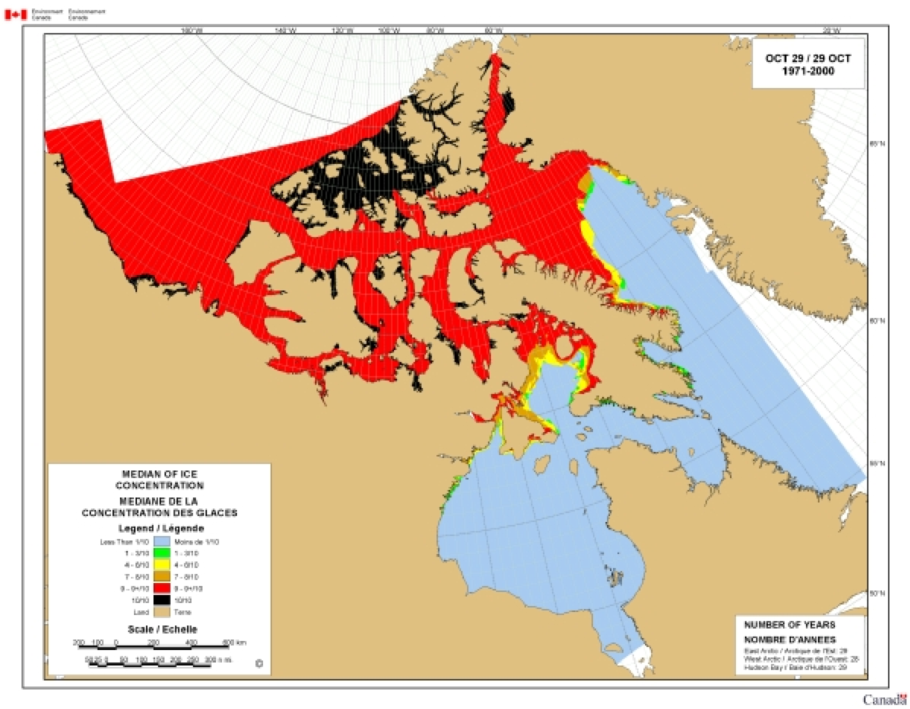


Figure 22: Ice concentration chart for the Arctic

5.3 *Use of Ice Information in Ice Operations Centres*

The Canadian Coast Guard has four Ice Operations Centres, located in St. John's, Newfoundland, Halifax, Nova Scotia, Québec City, Québec and Sarnia Ontario (for the Great Lakes and Arctic). During the ice seasons they are in operation 24 hours a day and are staffed with professional Ice Officers who have experience in the operation of icebreakers and ships in ice. The Centres work in conjunction with CCG Marine Communications and Traffic Services (MCTS), to provide up-to-date ice information, to recommend routes for ships to follow through or around ice, and to co-ordinate icebreaker assistance to shipping.

The CCG requires the most current, accurate ice information in order to:

- Monitor ice conditions
- Monitor the progress of shipping through ice
- Develop and provide Recommended Ice Routes to marine shipping
- Disseminate ice information (via MCTS Centres)
- Coordinate the movement and tasking of icebreakers using a zonal approach
- Coordinate aircraft reconnaissance, when and where required
- Provide support to Transport Canada's regulatory Ice Regimes
    - Arctic Ice Regime Shipping System (AIRSS): Providing responses to Ice Regime Routing Messages from commercial ships in Arctic Waters to acknowledge that the planned route and anticipated ice conditions appears appropriate.
    - Joint Industry Government Guidelines for the control of tankers in Ice Control Zones of Eastern Canada (JIGs): Activation of Ice Control Zones (i.e. Strait of Belle Isle, Northumberland Strait for the Confederation Bridge)
- Provide advice to shipping agents, ship owners, fishermen, charterers and port authorities as required
- Conduct client consultation

CCG Quebec, Maritimes and Newfoundland Regions coordinate icebreaking operations on the East Coast in order to task the icebreakers efficiently and effectively. Central and Arctic Region conducts icebreaking operations in the Great Lakes in collaboration with the United States Coast Guard. The zonal approach serves to maximize icebreaking support capability over a large geographic area. If an ice jam on the St. Lawrence River is severe, a request is made for tactical support from other regions. Likewise, when ice conditions are exceptionally bad along the east coast of Newfoundland, icebreakers from the Maritimes or Quebec Region are dispatched to the area. Regional Ice Offices provide regular communication briefings to clients and stakeholders throughout the winter season and will monitor the situation closely to ensure that any interruptions or delays for marine traffic are minimised.

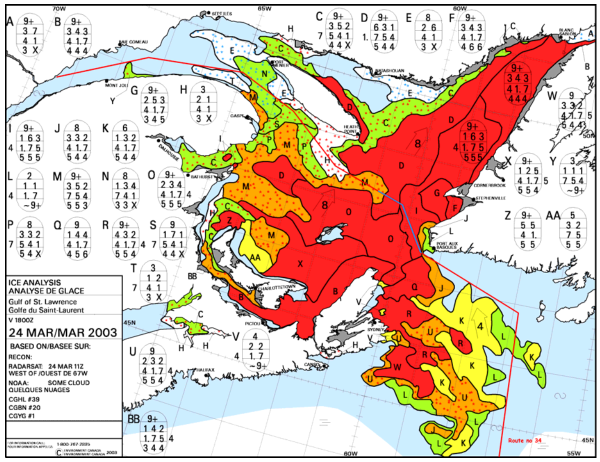


Figure 23: Recommended Ice Route Displayed on Ice Analysis Chart

5.4 Use of Ice Information by Icebreakers

Although icebreakers are able to navigate through ice according to their design capability, they are also affected by difficult ice conditions such as ridging, rafting and ice under pressure. The capability of the vessels under escort must be taken into consideration when choosing a route through or around the ice, i.e. a tanker, a tug towing a barge, a small sealing vessel, etc. On February 20, 2003, CCGS EARL GREY and the Maria Gorthon became beset at the entrance to Bay of Islands, Newfoundland. The two vessels were carried by the ice, wind and currents extremely close to the islands before the pressure eased off and the icebreaker was able to move it safely away from the rocks. Unfortunately it is difficult for the Canadian Ice Service and the CCG to expertly detect areas of extreme ice pressure which should be avoided.

Figure 24: Photograph showing an icebreaker attempting to free a vessel beset in ice under pressure.

Accurate and timely ice information is essential for an icebreaker for:

- Voyage/route planning: to assess ice conditions that the vessel is likely to encounter along the length of its planned route.
- Tactical navigation in ice: planning the route to take advantage of optimum ice conditions, including finding open water leads, finding first year ice in older ice fields, avoiding ridges, rafting and pressure.
- Provision of icebreaking services: escorts, channel/track maintenance, harbour breakouts, flood control, northern resupply and Arctic Sovereignty. Similar to tactical navigation, however, the icebreaker may have less control over route selection with very dynamic ice conditions, i.e. under the main span of a bridge, crossing a shear line into a harbour, navigating shallow channels, while dealing with the interaction of the ice with other objects, wind, currents and tides. Ice can represent a serious structural hazard to all ships, wharves and bridges.
- Advice to commercial vessels, fishermen, ferries and harbour/port authorities.
- Communication with Ice Operations Centres, other icebreakers and ice reconnaissance aircraft.
- Decision as to need for helicopter or aircraft reconnaissance to supplement existing ice information.

Communication costs for the transmission of ice information to and from the icebreakers in the Arctic, primarily for Inmarsat, have increased to more than $500K so various initiatives have been taken to reduce the costs, including the use of Bell Express-Vu to transfer data from the Canadian Ice Service. Inmarsat communications have limitations in the High Arctic. Reception may be lost temporarily due to the vessels proximity to high coastline or if the antenna is located in a blind sector of the ship's structure, such as a funnel. Moving the ship away from the shoreline or adjusting the ship's heading can improve reception but eventually the signal may be lost above latitudes 77° - 82°N. The Iridium Satellite System is the only provider of global, mobile satellite voice and data solutions completely covering the Earth including oceans, airways and Polar Regions. In addition to improved transmission methods, there is a need for improved compression techniques for high resolution images, which would also reduce the communication costs.

5.5 Use of Ice Information by the Icebreaking Program (National & Regional)

The Icebreaking Program uses various ice information products such as charts, imagery, forecasts and climatology atlases for:

- Client Consultation and Advice
- Policy/Standards Development, including Icebreaking Operations Levels of Service
- Icebreaking Service Fee (determination of zones and dates for the user fee)
- Climate Change (impacts on southern and Arctic operations, adaptation requirements)
- Research & Development (to assess the usefulness of new technology and innovations in improved ice information systems, cold weather equipment and ship design and construction).

5.6 CCG Development of Ice Information Systems

Canadian Coast Guard R&D activities look to the development, testing and evaluation, and application of projects and studies related to safety, marine environment and emergency response, communications and navigation systems, productivity, efficiency and effectiveness in its own operations; and support to other agencies responsible for oceans and marine safety issues. The CCG R&D Program draws on funds from several sources. The major source of funding is the internal reference level. Demands generally exceed the funds available from internal CCG resources. To promote the highest level of achievement, CCG personnel are also encouraged to work with other agencies, governments, clients and institutions to achieve additional "leveraged" funding and partnership or joint-venture arrangements leading to industrial product.

5.6.1 The Integrated Ice System (IIS)

To help improve the management of flood control operations on the St. Lawrence River, CCG, in partnership with the Canadian Hydrographic Services and Environment Canada, has installed a sophisticated data gathering network on Lac St. Pierre to monitor and measure water levels, velocity of the current, water flows, water and air temperature and direction, as well as wind speed and direction. Video cameras, radars and dynamometers are used to monitor and measure ice conditions at Lanoraie, Lavaltrie, Lac St. Pierre and at the Quebec bridges. This real-time information is available for the Ice Operations Centre in Québec to ensure improved coordination and tasking of icebreakers.

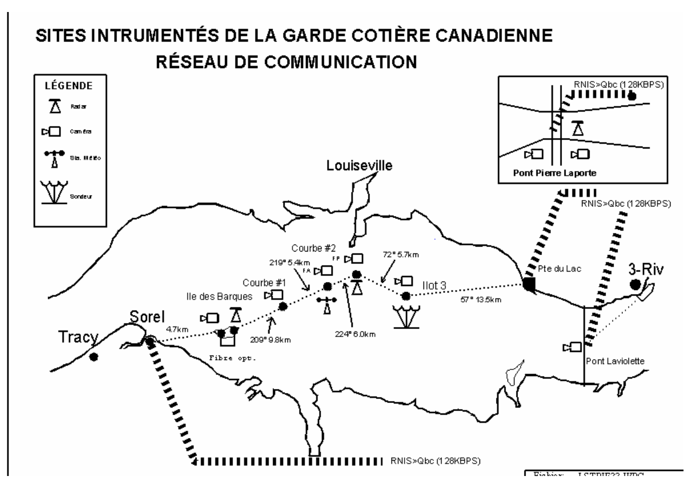


Figure 25: Illustration of the integrated ice system

5.6.2 Ice Routing Model

CCG Quebec and DFO's Maurice Lamontagne Institute have developed an Ice Routing Model to assist the Ice Operations Centre in determining the safest and most efficient route through the Gulf of St. Lawrence in the winter ice season. The surface currents, sea ice and water temperature forecast for the St. Lawrence are extracted from a three-dimensional model computing the oceanic circulation, under the influence of tides, the St. Lawrence river runoff, the atmospheric forcing, and the sea ice drift, growth and melt. The results of the model are provided in the form of animated graphic images of the chart of the Gulf of Saint Lawrence, which indicate the evolution of the forecast situation on a period of forty eight hours.

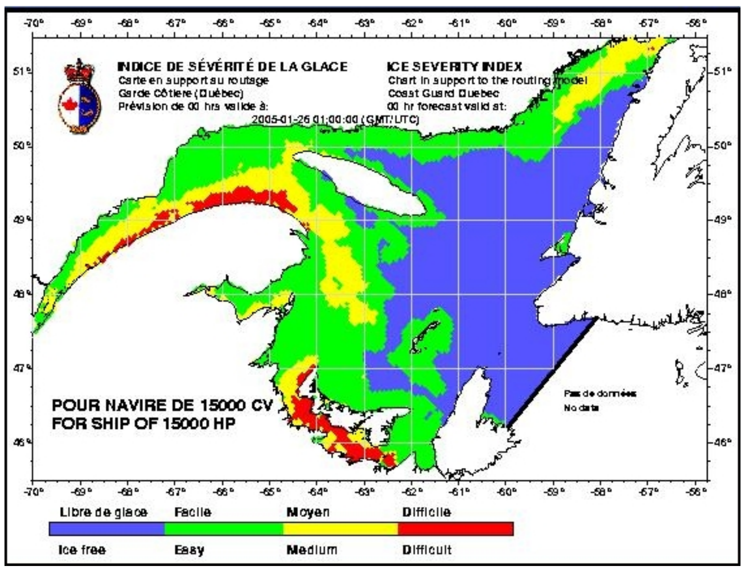


Figure 26: Illustration of the ice routing model and ice severity index

5.6.3 ICEggs

The CIS Ice Service Specialist (ISS) have traditionally created ice observation charts manually, by drawing on paper maps while on helicopter or aircraft reconnaissance flights. The charts were either delivered directly to interested personnel by way of a brief verbal résumé or, once the ISS had landed, scanned into a computer after the chart had been redrawn or cleaned up. This consumed a lot of time and human effort and, unfortunately, sometimes the chart was delayed to a point where it no longer met the needs of the Ice Offices, CIS and of the Marine community. Québec Region developed the ICEggs application which is utilized on a tablet computer connected to a GPS, to enhance the efficiency, effectiveness and the precision of aerial ice conditions observations and ice conditions data provision. It can reduce the chart development by two hours, is a more accurate representation of the ice conditions and is available immediately following the Ice Reconnaissance flight.

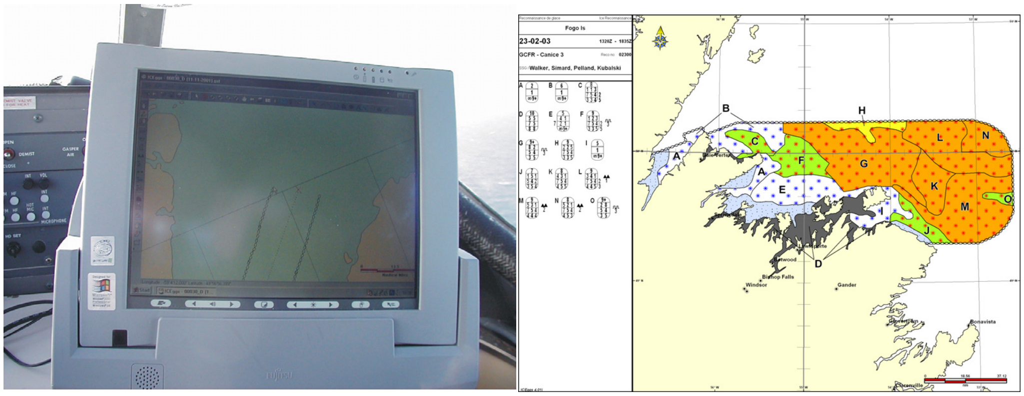


Figure 27: Illustration of the ICEggs system on a tablet computer and an ICEggs chart.

5.6.4 Ice Thickness Sensor

While satellite imagery can provide information on concentrations of the various ice types and on ridging, it cannot provide absolute ice thicknesses and the interpretation of the imagery is often ambiguous. In the 1990's CCG and Bedford Institute, DFO, developed a helicopter-borne electromagnetic-induction system to measure sea ice thickness. The probe can distinguish between First Year and Multiyear ice and it can distinguish between ice and snow, obtaining continuous ice thickness data over long traverses. It is able to distinguish between old ice ridges and new ice ridges by identifying or distinguishing between compressed and loose ridge keels. It provides real-time data to Ice Centre and CCG, which will result in improved quality of the ice information and will also improve ice and ocean models being designed for short and long term ice forecasting and climatology. A fixed mount probe was built in 2000 to facilitate landing on CCG icebreaker flight decks.

Figure 28: Illustration of the fixed mount ice thickness sensor

5.6.5 Cross Polarized Radar

CCG contributed to R&D to improve the real-time detection of multi-year ice by a cross-polarized marine radar and to investigate low-cost means of implementing cross-polarized radar systems on board commercial vessels. A prototype was developed and lab tested, using a low-cost fishing radar modified to receive the vertical component of the cross-polarized radar system. A prototype azimuth slaving controller was also developed and refined. The radar was installed on the Fednav Ltd. vessel *MV Arctic* for trials in 2003-04. A number of technical problems were overcome to finally achieve a functional prototype.

6.0 SURVEY OF ICEBREAKER CAPTAINS

6.1 Background Information

The authors felt that the best approach for determining the needs for ice information systems was to talk to knowledgeable Captains of vessels that regularly travel in ice conditions. Since the authors have considerable experience with Arctic shipping operations, a list of potential Captains was developed. In addition, it was felt that to get a balanced approach for discussions with the Captains, a set of interview questions were developed. The questions covered four basic topics as follows:

1 - Ice Parameters of Interest:

- Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

2 - Sources of Ice Information

- Where do you get ice information while onboard your vessel?
- How do you display and use ice information on your ship?

3 - Present Day Situation

- Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?
- If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?
- How frequently would you like to get an ice information update?
- How far in advance do you plan your route?
- Have you had a situation where better ice information would have been useful?

4 - View to the future.

- Where would you like to see efforts placed toward improving ice information?
- Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

The scope of this project was discussed at both the CMAC-Northern meeting and the CCG Post-Arctic Meeting that were held in Montreal. The basic project was outlined and the input from Captains was solicited. There was a very good response from both Industry and the CCG. Based on this positive response, two of the authors (Timco and Gorman) contacted the Captains to discuss this issue. Since the time frame for this work was relatively short, it was not possible to contact all of the Captains. However, there were a good number of interviews conducted and all of the Captains were extremely helpful. In total, fourteen Captains were interviewed as listed in Table 4.

Table 4: List of Captains Interviewed

Captain	Organization	Vessel Name	Type of Vessel
Barry Acorn	Nunavut Eastern Arctic Shipping	Aivik	Supply Vessel
Dave Snider	Independent		Tankers & Cruise Ships
Doug Camsell	NTCL		Type Vessels
Germain Tremblay	CCG	Amundsen	Icebreaker
John Cowan	Fednav (Canarctic)		CAC & Type Vessels
John Vanthiel	CCG	Henry Larsen	Icebreaker
Keith Jones	Independent		Tankers & Cruise Ships
Mark Taylor	CCG	Sir Wilfrid Laurier	Icebreaker
Marvin Kean	Fednav (Canarctic)	MV Arctic	Ice Class Bulk Carrier
Michel Bordeau	CCG	Pierre Radisson	Icebreaker
Norm Thomas	CCG	Sir Wilfrid Laurier	Icebreaker
Peter Dunderdale	Independent		Icebreakers and Tankers
Richard Dubois	CCG	Des Groseilliers	Icebreaker
Sean Sheppard	Nunavut Eastern Arctic Shipping	Umiavut	Supply Vessel

The complete details of the interviews are too lengthy to include in the main text, but they are all listed in Appendix A. It should be noted that although not requested by the Captains, it was felt that the interviews should be reported anonymously. Therefore the individual Captains names are not indicated in the replies to the questions. However, there is a short description of the experience of the Captain and the type of vessel that they operated.

During the interviews, the Captains were informed of the objective of the work, and they were asked to answer as a Captain of a large tanker in year-round operation in the High Arctic. This, however, was difficult for many of them and many of the responses reflect their current operational procedures. Thus, in the analysis of the responses, this aspect must be considered.

6.2 Analysis of the Interviews

6.2.1 Ice Parameters of Interest

There were a number of ice parameters identified by the Captains. In all cases, multi-year ice was identified as the key ice parameter. Following that, ice pressure, high ice concentration and ridging were identified by about one-half of the respondents. Other factors that were mentioned include growlers and bergy bits, floe size, first-year ice and knowledge of ice decay. Figure 29 shows a summary of the results. It is clear that multi-year (old) ice is the key ice parameter of interest.

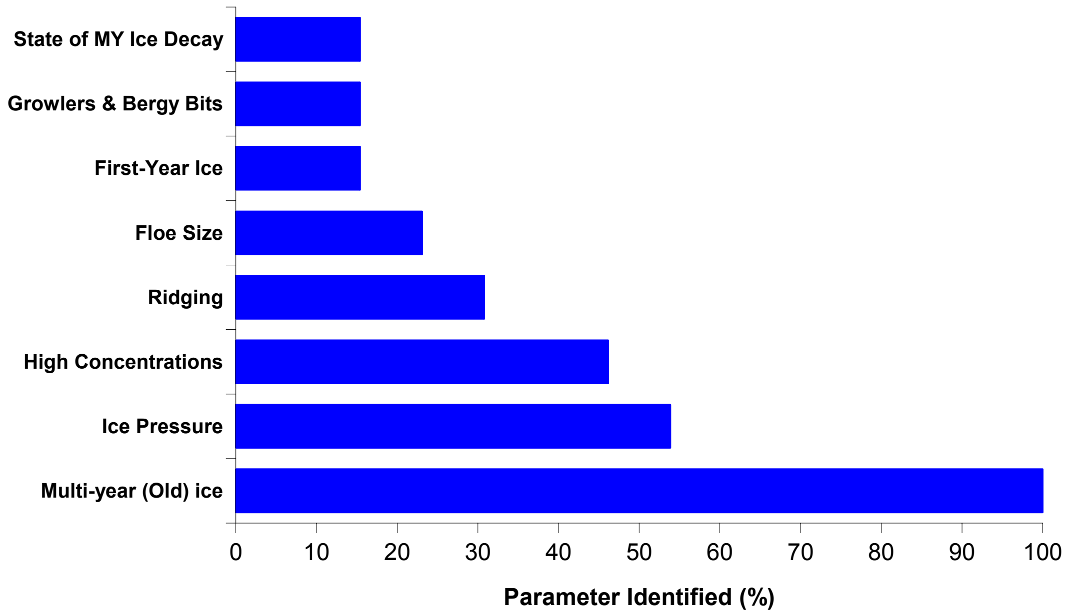


Figure 29: Ice parameters identified as the highest concern by the Captains during the survey

6.2.2 Sources of Ice Information

The Captains who were interviewed were a mix from CCG and Industry. The CCG receives excellent information from the Canadian Ice Service. They usually have an Ice Service Specialist onboard and they use IceVu to display the information. This includes ice charts and RADARSAT imagery. In Industry, there were two types of ice information systems – some used the Enfotec IceNav system and others used basic Ice Charts and radio communication. In total, about one quarter of those interviewed fall into the latter category. The survey is not representative of the general marine population, however, where most marine operators in the north do not use a geo-referenced system such as IceVu or IceNav.

The response to the Sources of Information included a wide range of sources. Figure 30 shows the sources and the number of times that they were mentioned. The Ice Charts were used by virtually everyone and many Captains mentioned the use of satellite imagery. It is interesting to note that only a few Captains mentioned marine radar and "looking out the window" as a source of information. Since these are two sources that are constantly used, it suggests that the Captains were answering the questions with a "bigger picture" in mind (i.e. thinking about external sources of information).

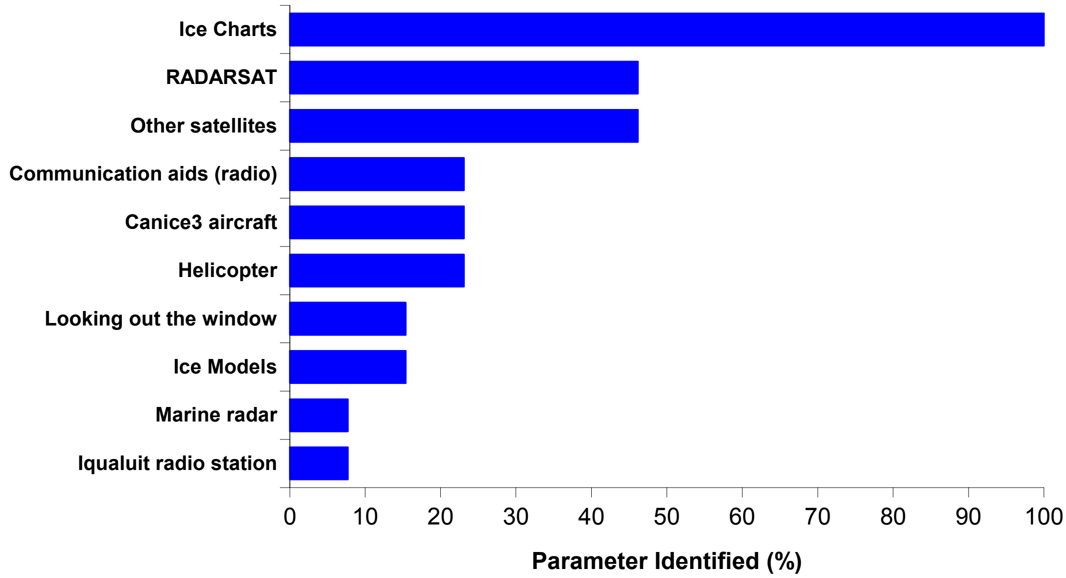


Figure 30: Plot showing the sources of ice information mentioned by the Captains.

6.2.3 Present Day Situation

There was a wide range of responses with respect to the present day situation. This could readily be categorized according to the availability of geo-referenced ice information. In general, the CCG Captains were relatively happy with the ice information, whereas some Industry Captains who did not have access to the RADARSAT imagery expressed much less enthusiasm for the present day situation.

Everyone stated that they would like more information with better resolution. There were a number of comments regarding RADARSAT. Although the Captains felt that it was good, there was some concern that it needed to be ground-truthed better. Also there were comments for higher resolution and more flexibility on choosing where images should be taken (i.e. the long lead time required to order an image). A large number of Captains commented that they would like more access to the images.

Some Captains mentioned that the current ice information for multi-year ice is not done properly. There are instances where multi-year ice occurred in regions where the Ice Charts indicated no MY ice.

A number of Captains mentioned that old ice information is useless. Some mentioned that they sometimes wait for the new information before proceeding if they are unsure of the ice situation.

There were several other factors mentioned including:

- More information on pressured regions would be desirable
- More detail in specific regions (e.g. passageways and ports)
- Identifying bergy bits & growlers
- The poor quality of the Ice Charts that are received by fax
- The lack of charts with forecasts
- Sometimes no Ice Charts are available (they tend to follow the CCG vessels)

6.2.4 View to the future.

Everyone wanted more information. There was a recurring theme that people wanted an integration of RADARSAT imagery with meteorological and oceanographic (winds and currents) for predictions of ice movement. Many expressed a desire to have more access to the raw data and not simply a chart processed in Ottawa. A number of Captains indicated that a system for detecting multi-year ice and small glacial ice locally would be very beneficial to them.

There were a number of specific points raised by the Captains. Since there were a wide range of suggestions, some general and some quite specific, it is instructive to look at each of them as listed below:

- Being able to receive more information
- Would like to see RADARSAT images with an overlay of wind and current vectors showing predicted drift of the ice. Showing the areas where pressure may be encountered in the future.
- Emphasis on improving existing technology such as RADARSAT and marine radar, such as the IceNav system with the radar interface.
- Emphasis on developing user friendly systems that can be used by the navigation officers. Now we cannot use the IceVu system when the Ice Observer is not available.
- The integration of RADARSAT and ice chart data with ECDIS would be very valuable.
- Important point is what ever is developed must be affordable.
- The best product we would like to see is an image with a chart overlay on the image so we can have both the interpretation as well as be able to actually see the imagery at the same time.
- Don't place much value on a forecast or models as the accuracy is in question. Predictions for 12 to 24 hours maybe but won't have much faith in a forecast beyond this.
- Training in ice navigation and the use of ice information will be critical. You can develop all the nice technology you can but if no one knows how to use it, it will all be for naught.
- Not much credence on model outputs now. Not my first priority for future research.

- The Cross-Polarized radar technology holds the best promise for the future for the detection of bergy bits and growlers in front of the vessel.
- Multi-year ice would be first since avoidance of potential damage must be rated as No. 1 issue.
- This could also apply to glacial ice (depending upon the location in the Arctic).
- Pressure is another one. However, being stuck in pressure would slow things but would not be catastrophic.
- Has the use of sonar been properly investigated? Can you mount one in the bow looking up for ½ mile to see if anything deep-keeled is in the way?
- Making RADARSAT cheaper
- More care (emphasis) on forecasting ice movement/change
- Multi-year ice – most damage caused by inadvertently hitting a piece of multi-year ice.
- New vessel locator on electronic charts – show ship identifier such that other ship(s) can be picked out in pack ice on charts and radar.
- Always show the position of the CCG Icebreakers on the charts.
- Offloading sometimes use a mile of floater hose – this is crazy – important to move vessel closer to the shore
- Don't have much faith in model forecasts. Would prefer to see images over ice charts. The egg is the average of the ice conditions in a zone but an image can give more subtle details than a chart can. Using satellite images that can improve ice type classification would be great – there is some ambiguity with RADARSAT now.
- Making the X-Pol radar work would be very interesting. Detecting old ice and growlers in from of the vessel is still a very difficult issue for the ship.
- More ice charts per day
- RADARSAT or (NOAA?) satellite imagery that shows photographs (this depends on cloud cover)
- Better local information would be useful (with a helicopter if available)
- System to detect ice that could cause damage in low ice conditions. (radar system?)
- Ice information is good today for our present mode of operation but it would not be adequate for year-round shipping in the Arctic.
- Daily ice charts as a minimum based on as close to real time info as possible. Chart accompanied by actually RADARSAT imagery in resolution that allows for identification of floes to 50 metres as a minimum. Real time is very important, the gap between RADARSAT passes that occurs at present is insufficient to meet changing operational needs of Arctic research ships.
- Better resolution radar satellite imagery. MODUS images I have seen are excellent but at present are not timely.
- Would like to see more raw data rather than processed data (i.e RADARSAT, weather info, etc. rather than a note from Ottawa that there could be pressure in a certain location)

- Efforts in more detailed satellite imagery. (Necessity to get a handle on where the RADARSAT images are processed. Quality of images processed in Alaska is very poor as compared to those processed in Gatineau. Most of the Alaskan processed ones are not useful).
- Multi-year ice characterization and detection
- Need to ensure that RADARSAT 1 is properly replaced with RADARSAT 2 in a timely manner. Did not get a good feel for how good ENVISAT images are
- Need greater flexibility in being able to change requirements for RADARSAT (1 or 2) images areas and schedules. It appears at the moment this can be done on 2 weeks notice, but there is a definite reluctance ($$$???)
- It appears that the capability of ground truthing what type of ice is being depicted on RADARSAT images via CANICE 3 will be lost shortly. Therefore we should work towards a better resolution of images, to better identify difference between MY and F/Y ice floes.
- As we are transiting North in Bering Straits we look ahead to ice conditions that are remote from the ship, and again prior to transiting the North Slope in both directions. During the season, we do a lot of "strategic guidance " of the tugs and other traffic (recreational) that may be remote from us. For these reasons the importance of getting the resolution of imagery down to say 100m should be worked towards. During the period of ops in Beaufort/QMG and Coronation up to Peel Sd we tend to operate on more of a "next day schedule" type of thing, where we will adjust Science/MNS work around the ice conditions, using helo as required.
- At the moment any ice info we need , the ISS is responsible for getting. If these specialists are done away with, we will need a fairly user friendly system of getting the ice charts from AES, the RADARSAT images and other info such as NOAA
- Satellite Ice Imagery from various sources (RADARSAT, MODIS, etc) be provided at higher resolution; more frequently. Also, this same imagery along with other information could be combined to provide updated ice predictory models which could include information of ice type; thickness; growth/deterioration; movement; pressure; etc.
- As per above: Generally data acquisition combined to provide predictory ice models which would be updated as real-time information is provided for comparison.
- Weather marine forecast: one to ten days for planning purpose.
- More detail satellite info.
- RADARSAT2!
- Better repeat coverage on the RADARSAT data. Need much better ground truthing on RADARSAT data. There is a lot of ambiguity in the interpretation of the imagery. Prefer an aircraft outfitted with high resolution radar that can downlink imagery directly to the vessel.

- A shipboard system that can be used by the officers would be helpful. A more user friendly system. IceVu is not a ship-specific tool, would like a ship-specific tool (taken to mean a more navigationally oriented system).
- Training of shipboard personnel very important. There is a need to have much more training in ice navigation and image interpretation than is the case at the moment.
- Liked the idea of hull sensors that tells the Captain when he is pushing the ship too much. The 1100 class is much more susceptible to damage so a system that alerts the Captain to this would be useful.

In summary there were two potential views to the future:

The first view was towards improved satellite imagery and the integration of several sources of raw and processed data. This could be, for example, a multi-layer system which includes on different layers, a satellite image, the corresponding Ice Chart, the weather forecast, the forecast wind magnitude and direction, the regional currents, the forecasted ice movement and pressure, etc. This would allow the Captains to see both the raw and processed information. This system, however, would have to be easy to use, inexpensive and have proper training in its use. This view was a very regional view that includes satellite information as the core.

The second view was the development of a system that would provide better local information on multi-year ice and large ice features, especially in poor visibility situations. This system must also be easy to use, inexpensive and have proper training and interpretation.

7.0 ICE INFORMATION WORKSHOP

7.1 Background Information

A Workshop was organized in Montreal to get more input and discussion on this issue. The Workshop was held at the Fednav offices in downtown Montreal on January 19, 2005. The Agenda of the Workshop was as follows:

1. Introduction - *G. Timco*
2. Welcome from Fednav – *T. Paterson*
3. Transport Canada Regulations – *G. Timco*
4. Current Ice Information Systems - *B. Gorman*
5. Ice Information from the Canadian Ice Service Operations - *J. Falkingham*
6. The CCG use of Ice Information - *B. O'Connell*
7. Summary of Ice Information Questionnaire of Vessel Masters - *G. Timco*
8. Open discussion on the way ahead - *(chaired by G. Timco)*

A general invitation was circulated for the Workshop to all Captains that were interviewed as well as various Industry participants. Also, key scientists who had an interest in this area were encouraged to attend. The following 14 people attended:

Sup. Barb O'Connell	Canadian Coast Guard
Capt. John Vanthiel	Canadian Coast Guard
Capt. Germain Tremblay	Canadian Coast Guard
Dr. Garry Timco	Canadian Hydraulics Centre, NRC
Dr. Michelle Johnston	Canadian Hydraulics Centre, NRC
Dr. Robert Frederking	Canadian Hydraulics Centre, NRC
Mrs. Ivana Kubat	Canadian Hydraulics Centre, NRC
Dr. Roger DeAbreu	Canadian Ice Service
Mr. John Falkingham	Canadian Ice Service
Mr. Bob Gorman	Enfotec
Mr. Tim Keane	Fednav (Canarctic)
Mr. Tom Paterson	Fednav
Mr. Doug Duggan	Natural Resources Canada
Mr. Mario Bonenfant	Petro-Nav

The Workshop started with presentations by the authors on various aspects of ice information technology. Bob Gorman gave an overview of ice information systems in use today, as well as some systems that were tried but were unsuccessful. John Falkingham discussed the operations and products of the Canadian Ice Service. Barb O’Connell presented an overview of the ice operations onboard Canadian Coast Guard icebreakers. Garry Timco provided a review of the interviews of the Captains and some general conclusions drawn from them. These presentations are presented in Appendix B of this report.

Following the presentations, the floor was open for general discussion chaired by G. Timco. To start the discussions, Timco presented a simple view of ice operations in ice conditions, based on going from a Long Term view (route planning) to the Daily (1-day) plan, and finally the Local (1 hour) planning to avoid multi-year ice and ice ridges. This was illustrated with a sketch as shown in Figure 31. A simple spreadsheet was generated which was used to capture the input for each of these planning time-frames (as shown in Figure 32). A general discussion followed using this approach.

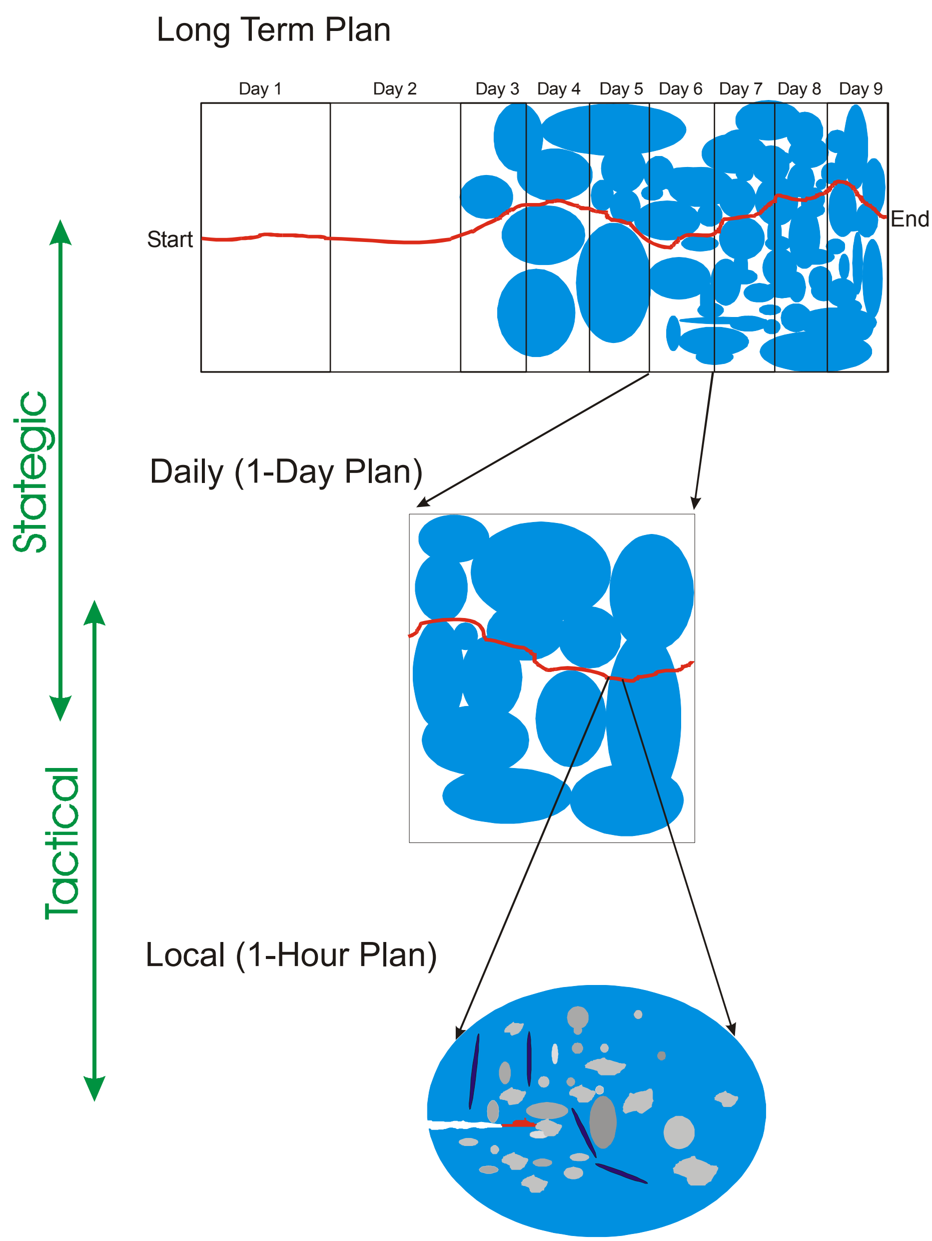


Figure 31: Schematic illustration of general planning for a voyage in ice conditions.

LONG TERM

What Type of Information Do I Need?					
Rate Importance (1-10 scale)					
How Do I Get It?					
Is it Adequate?					
Improvements?					
Overall Ranking of Importance for Improving					

Figure 32: Basic table framework for discussion used during the Workshop. There was a separate table for Long Term, Today and 1-Hour planning.

7.2 Results of the Workshop

The afternoon discussion period was quite interesting with several interesting observations and suggestions. Table 5 to Table 7 represent a summary of the discussion in terms of the Long Term, Today and 1-hour needs. It should be noted that these tables are not exhaustive; rather, they reflect the comments during the discussion. Although the original intent was to rank each of the parameters individually, this was difficult to do. However, in terms of the overall ranking for research priorities, it was clear that there were two primary ones:

1. Improve the detection of multi-year ice, both locally and from satellite imagery;

2. Provide better information on ice drift, leads and pressure.

Table 5 : Workshop Results - Long Term Requeirments

What Type of Information Do I Need?	Ice Edge	Historical Info (voyage)	Historical (project planning)	break-up dates	freeze-up dates	concentration	type
How Do I Get It?	weekly chart	break-up dates	break-up dates	seasonal outlook	seasonal outlook	ice charts	ice charts
	Daily Ice Chart	ice atlases	ice atlases	model	model	model	model
	NOAA Sat. Images	pilot books	image archive				
			ice chart archive				
Is it Adequate?	yes	yes	sort of	no	no	yes	yes
Improvements?		keep database current	keep database current	not port specific	not port specific		
		easer access to historical database					
Overall Ranking of Importance for Improving							

Table 6: Workshop Results - Today's Requirements

What Type of Information Do I Need?	type	concentration	thickness	floe size	leads	ridging	visibility	decay/strength	ice drift
How Do I Get It?	ice charts	ice charts		ice charts					
	RADARSAT	RADARSAT		RADARSAT	ice charts	RADARSAT	model	model	met model
	visual obs	visual obs		visual obs	RADARSAT		observations	observations	tidal pred.
					MODIS/NOAA				
				heli obs	heli obs	heli obs			
Is it Adequate?	no							no	
Improvements?	training	training	training	training	training	training		better understanding	
	climatology	climatology	climatology	climatology	climatology	climatology			
	alternate future satellite characteristics	alternate future satellite characteristics	alternate future satellite characteristics	alternate future satellite characteristics	alternate future satellite characteristics	alternate future satellite characteristics			
Overall Ranking of Importance for Improving	1								

Table 7: Workshop Results - 1-Hour requirements

What Type of Information Do I Need?	growlers bergy bits	old ice	leads	ridging	concentration	floe size	visibility	individual features	Drift	stumaka	weather
How Do I Get It?	visual	visual	visual	visual	visual	visual					
	impact	impact	marine radar	marine radar	marine radar	marine radar					
	marine radar	RADARSAT	heli recon	heli recon	heli recon	heli recon					
			video camera								
Is it Adequate?	no	no	no								
Improvements?	better radar	see through snow	extend radar range	better radar		better radar					
		better radar									
		better seasonal detection									
		better training									
		better shipboard sensors									
Overall Ranking of Importance for Improving	1	1	2						2		

8.0 ICE INFORMATION ROADMAP

This scoping study has pointed towards very specific factors that should be addressed to improve transportation in the High Arctic. Fourteen Captains who operate vessels in the Arctic were interviewed in the study. Unanimously, they picked the detection of multi-year (MY) ice as the key research area. This identification of MY ice must be possible on both a regional scale and local scale (i.e. in the immediate vicinity of the vessel). There remains a high risk of hull damage due to collision with undetected multi-year ice for even ice-strengthened hulls. Damage would lead to significant downtime for the tanker and expensive repairs. Any downtime would significantly impact the reliability and economics of the gas delivery system. Before any investment would take place for High Arctic gas, there would have to be a good level of confidence that multi-year ice could be detected and avoided to minimize this effect.

The second priority related to improved knowledge of ice drift, leads and pressure. Regions of high pressure would significantly slow the tanker. Internal ice pressure pushes against the sides of the tanker, and through a frictional effect, slows it down, as experience has shown. Since tankers are very long, the resultant drag can be significant and could stop the vessel. Having knowledge of where high pressure regions could potentially develop is essential. A slowing-down or stopping of the tanker would delay delivery, upsetting the delivery schedule. Unless this could be avoided, there would have to be redundancy in the delivery system (i.e. more tankers) which would be an expensive alternative. The CERI report indicates tankers would cost on the order of $350 Million.

Based on these results, a comprehensive research program could be developed that would significantly improve ice information in these areas. This program should have four major tasks that are inter-connected. They are:

1. Determine the year-round ice conditions that a tanker would encounter and determine the Polar Class of the necessary vessel based on Transport Canada regulations. This will have a pronounced influence on the cost of ship construction.

2. Collect detailed ground-truthed information on the presence and properties of multi-year ice and compare this information to predictions of ice conditions from satellite imagery. Data could be collected by the CIS Ice Service Specialists (ISS) on six CCG icebreakers. This would be a unique collection showing the many facets of multi-year ice. This will be a valuable input for Task 3 and also a training aid for future mariners.

3. Develop two types of sensors for the detection of multi-year ice. One sensor would be based on the cross-polarized (X-POL) radar that has been developed for the detection of small icebergs. It has been adopted by Fednav but requires further development, especially with respect to the best display algorithms. A second system could consist of a video system which should give better visibility in fog

conditions. These systems should be verified through dedicated field trails in the Arctic.

4. The fourth thrust will be the application of ice modeling to specific regions of the High Arctic to develop a framework for the prediction of ice drift, the presence of leads, and internal pressure in the ice. It is also important to investigate the historical ice drift patterns in the High Arctic.

A flow chart of a test program with all of these features is shown in Figure 33. There are several items that are interconnected in the plan. Furthermore, to be successful, there would have to be very good communication and co-ordination amongst all of the participants. This is essential.

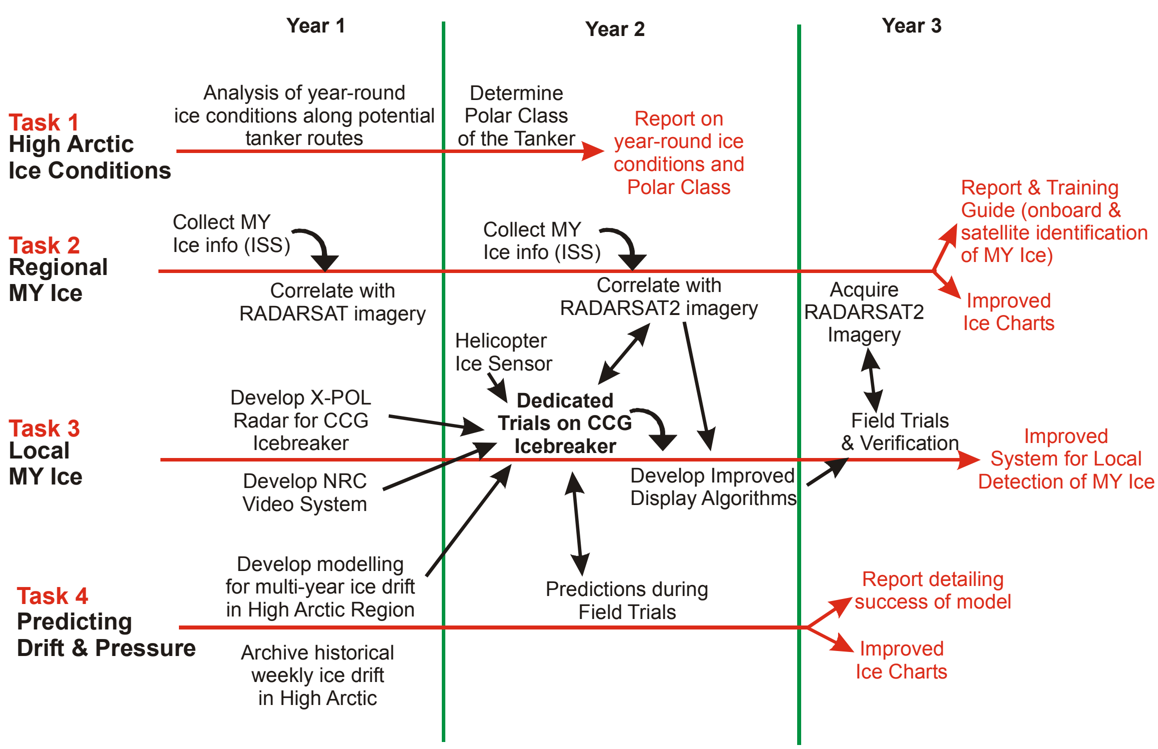


Figure 33: Schematic illustration of a proposed test program to improve ice information systems for shipping in the High Arctic.

9.0 ACKNOWLEDGEMENTS

The authors would like to thank the Climate Change Technology and Innovation Initiative (CCTII) Fund – Unconventional Gas Supply - for funding this project. They would also like to acknowledge the input of all of the Captains that participated in this survey, and to Fednav for hosting the Workshop in Montreal.

10.0 REFERENCES

CGPA, 2001. Canadian Gas Potential Committee, Natural Gas Potential in Canada – 2001. Geological Survey of Canada, SC Paper 83-31, Ottawa, Canada.

CERI, 2004. Economics of High Arctic Gas Development. Report prepared by the Canadian Energy Research Institute for Indian and Northern Affairs Canada.

Currie, B.W., Weber, P., Krasnor, C., Haykin, S., McLaughlin, H. and Worsfold, R. 1991. An Improved Marine Radar in International Conference on Ports and Ocean Engineering under Arctic Conditions (POAC'91), pp 964-979, St. John's, Canada.

de Bastiani, Pietro, 1987. Canarctic Arctic Marine Ice Atlas Winter 1986/87 contract report by Canarctic Shipping for Canadian Coast Guard Northern TP-8318-E Ottawa, Ontario.

de Heering, P., Friberg, D., Simpkin, P. 1985. Proof of Concept Tests: Data Acquisition and Analysis for Close Range Ice Hazard Detection contract report by Canadian Astronautics Ltd. for Canarctic Shipping and the Transportation Development Centre Transport Canada TP-6170-E Montreal, Quebec.

de Heering, P. and Sutcliffe P. 1987. Close Range Acoustic Ice Hazard Detection Phase II – Final Report contract report by Canadian Astronautics Ltd. for Canarctic Shipping and the Transportation Development Centre Transport Canada TP-8186-E Montreal, Quebec.

Gorman, R. 1987. Shipboard Ice Navigation Support System – Phase IV Final Report contract report by Canarctic Shipping for Executive Services Branch Marine Group Transport Canada TP-92158188-E, Ottawa, Ontario.

Gorman, R. 1988. Shipboard Ice Navigation Support System – Phase V Final Report contract report by Canarctic Shipping for Executive Services Branch Marine Group Transport Canada TP-9215-E, Ottawa, Ontario.

Gorman, R. and Zagon, T. 2005. Final Report – IceNav Virtual Marine Radar Integration of RADARSAT-Marine Radar contract report (in press) by Enfotec Technical Services for the Canadian Space Agency Saint-Hubert Quebec.

Gorman, R. and Flett, D. 1995. Shipboard Reception and Use of High Resolution Imagery Products contract report by Canarctic Shipping for the Transportation Development Centre Transport Canada TP-12434-E Montreal, Quebec.

Haykin, S., Lewis, E., Raney K. and Rossiter J. 1994. Remote Sensing of Sea Ice and Icebergs John Wiley and Sons Inc. New York ISBN 0-471-55494-4

Remotec, 1981. Field Evaluation of Sensors for Development of Ship-Mounted Ice Hazard Detection System contract report for Petro-Canada Exploration and the Transportation Development Centre Transport Canada TP-3506-E Montreal Quebec.

Robson J.M. 1982. Navigation in Darkness Study – Operational Evaluations of Night Viewing Devices. Report by Canarctic Shipping Ottawa Ontario.

Appendix A

Results of Interviews

Ice Information Systems for Navigation in the High Arctic

This Captain operates a low ice class vessel in summer only conditions providing supplies to the Arctic.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

- High ice concentrations and pressure in the ice
- Multi-year ice

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel?

- Radio telex fax – ice charts and the Iqualuit radio station
- Do this a couple of times a day

How do you display and use ice information on your ship?

- Use it on the Bridge – difficult to get good ice information

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you? If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive? How frequently would you like to get an ice information update?

- Conditions change during the day so more ice information would be useful
- Satellite info could be useful depending upon the area of coverage and the time when the image was taken

How far in advance do you plan your route?

Couple of days, maximum – constantly changing the routes and try to avoid the ice if possible.

Have you had a situation where better ice information would have been useful?

Yes when the ice forecast is not right

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

Being able to receive more information

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

Depends on the cost and the company operations. Receiving ice information is important. Today a typical ship does not have the methods for getting the best ice information.

Ice Information Systems for Navigation in the High Arctic

This is a Captain from the Canadian Coast Guard with experience in the Arctic.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

Multi-year ice is of greatest concern for the vessel. Need to avoid.

Also need to find areas with less pressure. Pressure caused by wind and tide can increase concentration from 5-7/10 (two engine operation) to 9+/10 (six engine operation) quickly. Need to be able to avoid this.

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel?

RADARSAT is the most important source of ice information. The accuracy of the ice charts has improved greatly since the use of RADARSAT. However, concerned about not having back-up to RADARSAT. Quick turn-around from imagery reception to getting on vessel very important. Get RADARSAT data about every two days in the Arctic.

Using helicopter much less now because of good RADARSAT imagery.

Dash-7 not as good as RADARSAT but was useful for the ground-truthing of RADARSAT.

How do you display and use ice information on your ship?

Use the IceVu system operated by the Ice Observer. System complicated to use and we don't us it when they are not around.

Marine fax not much use anymore with email. No future in marine fax. INMARSAT is OK but expensive. New systems may be better but not reliable yet.

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

RADARSAT is good but needs to be ground-truthed.

The old marine radar sets (phosphorous displays) provided better images of the ice around the vessel than does the new CRT displays used now which do not show ice very well.

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

High resolution RADARSAT data best.

How frequently would you like to get an ice information update?

Would like to get RADARSAT data once or twice a day.

How far in advance do you plan your route?

For a CCG vessel, difficult to plan long them because mission constantly changing depending on calls. For a transit the entire route is planned before departure then updated daily as new ice information is received.

Have you had a situation where better ice information would have been useful?

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

Would like to see RADARSAT images with an overlay of wind and current vectors showing predicted drift of the ice. Showing the areas where pressure may be encountered in the future.

Emphasis on improving existing technology such as RADARSAT and marine radar, such as the IceNav system with the radar interface.

Emphasis on developing user friendly systems that can be used by the navigation officers. Now we cannot use the IceVu system when the Ice Observer is not available.

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

The integration of RADARSAT and ice chart data with ECDIS would be very valuable.

Ice Information Systems for Navigation in the High Arctic

This Captain is the Western Arctic Operations Manager for a shipping company. He is responsible for co-ordinating the tug and barge sealift from the Mackenzie River to the western Arctic and Alaska. Prior to this, he worked on Gulf Canada icebreakers during the Beaufort Sea oil exploration.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

Because our tug and barges have no ice class we try and avoid all ice. Since our operation is finished prior to the onset of freeze-up we are primarily interested in avoiding first year and particularly old ice that drifts south along the west coast of Banks Island into Amundsen Gulf.

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel?

In addition to the facsimile ice charts, we email charts and images to the ships on a regular basis (NTCL uses Enfotec's IceNav system in their head office and forward data to the vessels). CANICE 3 was a very good source of ice information for us as the direct downlink of charts and talking with the observers gave us very good near-real-time information. The loss of this aircraft will hurt.

How do you display and use ice information on your ship?

Combination of paper charts and computer screen.

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

Always can use better and more frequent ice information. Day old ice info is not much use. Big problem now is that ice charts only follow the icebreakers around and once they pass an area like Alaska we don't get any more ice charts of that area.

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

There are specific areas and times where we know we run into ice trouble so focusing on these areas with better resolution data is ideal. Also, daily ice charts need to cover areas where operations are occurring, regardless of whether the CCG icebreaker is in the area or not.

How frequently would you like to get an ice information update?

At least once a day and more than once a day would be ideal.

How far in advance do you plan your route?

We know where we have ice problems (western entrance to Amundsen Gulf) so we watch the ice moving in this area all season to see if we will have problems.

Have you had a situation where better ice information would have been useful?

When ever we get stuck it would have been good to have had better ice information!

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

Important point is what ever is developed must be affordable.

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

The best product we would like to see is an image with a chart overlay on the image so we can have both the interpretation as well as be able to actually see the imagery at the same time.

Don't place much value on a forecast or models as the accuracy is in question. Predictions for 12 to 24 hours maybe but won't have much faith in a forecast beyond this.

Ice Information Systems for Navigation in the High Arctic

This Captain is the chief Ice Pilot for Fednav Limited. He is tasked with handling Fednav vessels of various ice class through ice covered waters in eastern Canada, Greenland and in the Baltic. He gained his original ice experience while working on Dome Petroleum/CANMAR icebreakers in the Beaufort Sea.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

Looking at a high ice class vessel the ice conditions to avoid would be multi-year ice and pressure/ridging in first year ice.

A particular concern is the ability to detect growlers and bergy-bits in a high sea state as well as in pack ice.

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel?

Combination of using IceNav (on ships so outfitted) and marine fax charts.

How do you display and use ice information on your ship?

IceNav when on ships so equipped.

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

When using RADARSAT imagery many of these ice conditions can be identified. Ice charts do not provide the same level of detail. The higher the image resolution the better.

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

The main concern is the identification of bergy bits and growlers in front of the vessel.

Local knowledge on historical ice distribution very valuable. Detailed weather information also very valuable. Forecasted wind arrows on ice information would be useful.

How frequently would you like to get an ice information update?

At least once or twice a day.

How far in advance do you plan your route?

Usually consider detailed ice information about two days from the ice edge. Only take a cursory overview before that.

Have you had a situation where better ice information would have been useful?

Ice information is always useful but when in pressure situations it is very useful.

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

Training in ice navigation and the use of ice information will be critical. You can develop all the nice technology you can but if no one knows how to use it it will all be for naught.

Note much credence on model outputs now. Now not be my #1 priority for future research.

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

The Cross-Polarized radar technology holds the best promise for the future for the detection of bergy bits and growlers in front of the vessel.

Ice Information Systems for Navigation in the High Arctic

Very experienced Captain of numerous vessels including icebreakers and ice management vessels with experience in several ice-covered waters world-wide.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

For a large NG tanker in year-round operation, there are issues with respect to explosions and breaching the NG tanks. This would require double or triple-hulled vessels to protect any type of damage.

In operation, pressure would be a key concern since tanker manoeuvrability would be limited due to the ship shape and size. You may have to limit the size of the craft to get the required manoeuvrability. If beset. You would have a better chance to free oneself.

First-year ice is not an issue if the vessel is designed for multi-year ice. FY ridges would not be a problem if the vessel is designed to ram and/or have adequate manoeuvrability.

The difference and strength and thickness of multi-year OR second year are only of importance if I have an icebreaker (of limited capability) and want to transit. If on a lesser class vessel I only need to know that it is 'old' ice and avoid it. If I have an icebreaker and know that it is decayed then I may attempt to transit depending on the alternate route (time saving) and how decayed it is. However, having been caught before - I would tend to avoid it. It's not funny if you misjudge or are misinformed concerning old ice thickness and strength, especially on a commercial vessel that loses big money for delays and/or damage.

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel? How do you display and use ice information on your ship?

- Ice Charts and Ice Maps (in Russia), satellite imagery, electronic charting. The Russian Ice Maps have information on pressure and ridging which is very useful (reprinted on next page).
- Electronic aids to determine where you are, marine radar, communication aids (sat telephones) should be mandatory.
- Sometimes aerial but visibility is often limited (low clouds, snow, fog). In many locations, 70% of the time there is poor visibility.

The number of people with ice navigation experience is going down.

RUSSIAN ICE CHART SYMBOLS

7	Concentration of sea ice zone (area coverage decimal points)
9-10 / 4 5 0-1	Total concentration Partial concentration of different development staged ice.

STAGES OF SEA ICE DEVELOPMENT (POINTS OF THICKNESS)

DESCRIPTION	THICKNESS	PACK ICE FORM	ICE COLORING	FAST ICE
Ice - free	0		blue	
Light nilas	5 cm		Dark blue	
Grey ice	10- 15 cm		Pink	
Grey - wite ice	15 - 30 cm		Violet	
Thin first - year ice	30 - 70 cm		Light green	
Medium first- - year ice	70 - 120 cm		Green	
Thick first - year ice	120 cm		Dark green	

FORMS OF FLOATING ICE (LINEAR DIMENSIONS)			VISUAL ICE RECONNAISSANCE SCALES	
	giant floe	10 km		hummocking scale: 5 points(20%coverage/point)
	vast floe	2 - 10 km	× 2	snow coverage scale:3 points
	ice breccia floe		—1—	compaccting of ice fields(3 points)
	big floe	0,5 - 2 km		rafting scale decimal coverage points
	medium floe	100 - 500 m	4	scales of melting stages(3-5 points)
	small floe	20 - 100 m		
	ice cake	2 - 20 m		
	brash ice	< 2 m		

POSITIONED SYMBOLS

	fracture		puddle
‡‡‡‡	crack area		wet snow patch
	straneded ice	V–V	rotten ice
	ridged ice	V	thaw hole
	ridged ice zone		dried ice
	grounded hummock,stamukha		ice lakes
	grounded ridges in fast ice		
120	measured ice thickness		

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

- Information on MY ice is not done properly.
- Pressure is a huge issue everywhere – forecasting pressure is very important for local conditions. This must include all variables – met, river outflows, currents, etc. Pressure can stop you dead in some cases and even carry you with it. If you can forecast it accurately, you can avoid it.
- There is a visibility issue with high Bridges – sometimes they can be 50 feet in the air which can give very limited view in fog conditions.
- Bergy bits and growlers are the main issues with respect to glacial ice – not icebergs. There is an issue on how they disperse from the main berg. There is a need to forecast the break-up in heavy weather or warm water. This includes how they calve off – what is the danger zone (i.e. given a major calving last week, where would be danger zone be).

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive? How frequently would you like to get an ice information update? How far in advance do you plan your route?

Information once a day is useful, twice is better. More than twice is too much. Usually do an initial routing plan with updates for a 2-day time period.

Have you had a situation where better ice information would have been useful?

- Situation of bad ice information is almost everywhere. Worst was around Barrow (example – the US info said that the ice was 3/10s but it was 10/10s with a snow melt and water on the surface).
- The training and interpretation of the people looking at this is very important.
- You can make a poor judgement if the ice information is incomplete or wrong.
- If ice info has been poor in the past, tend not to believe any of it and this can result in trouble.

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

This is difficult since there are several.

- Multi-year ice would be first since avoidance of potential damage must be rated as No. 1 issue.
- This could also apply to glacial ice (depending upon the location in the Arctic).
- Pressure is another one. However, being stuck in pressure would slow things but would not be catastrophic.

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

- Has the use of sonar been properly investigated? Can you mount one in the bow looking up for ½ mile to see if anything deep-keeled is in the way? [1]
- Making RADARSAT cheaper

---

[1] Following our discussions on the phone yesterday I looked up some old records and found that Ratheon were working on forward looking Sonar in 1998. There was an Ice Detection Study done based on the AVERT (Automated Vessel Alert System). After talking with Ratheon and receiving their published data I wrote a few notes regarding sonar for myself back then as follows:

- The sonar waves are transmitted and received by the sonar array from a cone shape ahead of the ship. The horizontal spread is 90 degrees (7 degrees above and below the horizontal). This 7-degree vertical angle translates into a dead zone where targets are lost ahead of the ship. Multiplying 8 times the draft can approximate the dead zone forward of the ship. For example, at a draft of 14 meters – the dead zone is about 112 meters. Both vessel pitching and high sea states will affect detection inside the cone.
- Small targets need more transducers than large targets and use a higher frequency of sound transmission than that incorporated in the present system. An increase in frequency will probably result in a reduction in range. The system is expected to receive an alarm for ice that extends below the surface by 5 to 10 meters within one half mile, and detection of ice that extends 40 meters below the surface at over 2 miles.
- The sonar does not have any vertical discrimination which means that in shallow water a small uncharted sea-bed feature could alarm the system as a piece of surface ice or debris.

The management of Raytheon was discussing the feasibility of making a field trip into bergy waters to test a system in 1999 and obtain more detailed data, I don't know if this was done, I did not hear any more on it. You may want to follow up – for LNG tanker transits in various ice forms I think this would be very useful if fully developed.

Ice Information Systems for Navigation in the High Arctic

This Captain has several years of experience operating in ice-covered waters in both the Arctic and Antarctic. He has captained icebreakers and acted as an Ice Pilot to cruise ships in the north.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

- 7/10ths + with MY and TFY
- 8/10ths on final approach for tankers (when sea room/route allows it, avoid it altogether)
- Fog can make even 3/10ths a problem
- Watch for multi-year and thick first-year
- Can't always avoid the problem ice, especially in ports
- Info on ice decay is important especially for thick first-year and multi-year ice
- Icebreaker support (escort) very important

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel?

- Ice Charts via radio-fax and web
- Ship-to-Shore for local (port entry)

How do you display and use ice information on your ship?

- Transfer ice charts w/points of regime patterns into nautical charts particularly for middle and final approaches
- Hand sketch features to see if it's moving
- Processing –still likes to this himself – more confidence in the results
- Look 2 to 3 ship lengths ahead continually

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

- Usually good – sometimes ask for better scale (zoom in) for close quarters
- Ice charts and RADARSAT are generally good but sometimes there are problems

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

- More detail for final approaches

- Ice charts – lat/long sometimes difficult to see – quality is the issue
- Charts with forecasting is a good idea
- High resolution modelling in selected areas - brilliant

How frequently would you like to get an ice information update?

- Normally once daily is okay although the dynamics are often faster than this. We do our own "anticipated" movement forecast based on drift arrows and currents

How far in advance do you plan your route?

- One to two days "rolling" and then look out the window
- Route planning – concentration is most important

Have you had a situation where better ice information would have been useful?

- Yes – sometimes the ice is worse or better than reported on the ice charts

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

- More care (emphasis) on forecasting ice movement/change
- Multi-year ice – most damage caused by inadvertently hitting a piece of multi-year ice.

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

- New vessel locator on electronic charts – show ship identifier such that other ship(s) can be picked out in pack ice on charts and radar.
- Always show the position of the CCG Icebreakers on the charts.
- Offloading sometimes use a mile of floater hose – this is crazy – important to move vessel closer to the shore

Ice Information Systems for Navigation in the High Arctic

This Captain is the Master of the world's highest ice class bulk carrier. Prior to this, he worked as an Ice Pilot for Fednav Limited working on a wide range of ships of various ice class.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

First year ice is not really the issue. The detection and avoidance of multi-year ice is the most important. Floe size is also very important as it is important to avoid the big floes, particularly old ice floes. Ice pressure and, in particular, shear zones should be avoided.

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel?
How do you display and use ice information on your ship?

We use the Enfotec IceNav system to receive and display all ice and weather data on the vessel. Since most of our heavy ice voyages occur outside of the season when the CIS/CCG provide services, we need IceNav to complete the voyages.

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

The technology does not presently exist to allow me to detect old ice and growlers in front of the vessel when in pack ice. I must rely on good visibility for this.

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

I would like to see if the X-Pol radar system that's being experimented with on the MV Arctic can detect old ice and growlers in front of the vessel. The present experimental system is very difficult to use and navigation officers don't have the time to use it properly. The system should be set-up so that it is easy to use and the display of the detection of the old ice and growlers is easy to see.

How frequently would you like to get an ice information update?

Obviously the more often the better! In really tight situations a couple of times a day would be ideal. Less often when conditions are not difficult.

How far in advance do you plan your route?

There is no point getting detailed ice information for an area you will not reach for four or five days or more. Winds, tides and currents change the ice situation so much between these time periods. Knowing the ice conditions near your destination before you leave port does not really alter the situation of the voyage that much.

Have you had a situation where better ice information would have been useful?

The common situation where more ice information is useful is when the ship is in an area of large floes and pressure. Knowing to avoid these areas helps.

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

Don't have much faith in model forecasts. Would prefer to see images over ice charts. The egg is the average of the ice conditions in a zone but an image can give more subtle details than a chart can. Using satellite images that can improve ice type classification would be great – there is some ambiguity with RADARSAT now.

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

Making the X-Pol radar work would be very interesting. Detecting old ice and growlers in from of the vessel is still a very difficult issue for the ship.

Ice Information Systems for Navigation in the High Arctic

This Captain originally went to the Arctic in the mid-1980s but for the past 12 years has been operating supply vessels in the summer-only conditions in the Arctic.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

- Multi-year ice and second-year ice (Old Ice)
- Size of the floe (if longer than a ship length, it is difficult to manoeuvre around it)
- Pressure can be a concern but it can come and go quickly. It is usually observed by seeing floes tipped on edge. It is hard to predict but could perhaps forecast it if the winds and tidal components are known. It is often unavoidable.

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel?

- Radio fax from Iqualuit
- Reception and radio wave propagation in the Arctic is poor
- Sometimes call on satellite phone for information – there is a need to improve transmitters.

How do you display and use ice information on your ship?

- Look at ice charts on the Bridge with other officers
- Look at egg code to concentration of old ice and new ice
- Ice officer in Iqualuit gives ice routing based on ice conditions – this is very helpful
- Do not have a dedicated ice information person onboard.

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

- Ice information for our purposes is pretty good (ice charts and ice routing from Iqualuit)
- Steady improvement in ice information since the mid 80s.
- If ice chart is too old, can get into a bad situation (especially if the weather changes).
- Important to keep in contact with Iqualuit since they can notify you if there are changes.

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

- As much ice information as you can get
- In ice, things go slowly so large regional info not as important as local information.
- Locally, the problem is often visibility
- It would be a great help if ridges, etc, could be detected in fog conditions
- Regular 3 cm radar is okay but often difficult to detect things from the clutter.

How frequently would you like to get an ice information update?

- Could be improved – twice a day is okay but three times a day would be better.

How far in advance do you plan your route?

- Depends on operation and ice conditions – in summer when the ice coverage is less, it is easier to plan the route and estimate the time for the trip.
- The planning is only as good as the ice information

Have you had a situation where better ice information would have been useful?

Yes – in the mid 80s we were told to take the southern route through Lancaster Sound (based on information on an old ice chart). We encountered 9+ ice and were stuck. The Lady Franklin came in (through the north side). The next ice chart was improved since they had local information from the vessel.

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

- More ice charts per day
- RADARSAT or (NOAA?) satellite imagery that shows photographs (this depends on cloud cover)
- Better local information would be useful (with a helicopter if available)

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

- System to detect ice that could cause damage in low ice conditions. (radar system?)
- Ice information is good today for our present mode of operation but it would not be adequate for year-round shipping in the Arctic.

Ice Information Systems for Navigation in the High Arctic

This Captain is a former Coast Guard officer who now provides ice navigation expertise to foreign vessels.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

Multiyear ice in general causes greatest concern as vessels are Ice Strengthened, Type A or B Concentrations of 2^{nd} year and thicker ice greater than 3/10ths. Operational guidelines from owners indicate preference to avoid thick first year in concentrations greater than 3/10ths.

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel?

Because vessel does not always operate within areas that CIS consistently provides maps on other than weekly regional basis (because no CCG assets are in those areas at the time), we rely on more regular (twice weekly) American maps and visual satellite imagery when available. If CIS charts ARE available they are preferred due to accuracy.

Downloads are made from CIS Site http://ice-glaces.ec.gc.ca
NOAA http://pafc.arh.noaa.gov/ice for ice Alaskan edge charts
www.natice.noaa.gov/products/arctic

How do you display and use ice information on your ship?

Both computer images and printed colour images are used. If georeferenced the images are used for computer navigation planning. Info both graphic and text is used in strategic planning as well as tactical planning.

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

Often this is not the case, as CIS is unable to produce daily charts for all areas of the Canadian Arctic. The vessels often operate remote from locations in which CCG assets are situated and thus not within the covereage area that CIS provides. CIS prices to have charts produced in areas not CCG supported were considered prohibitive to the vessel owners. Often times the US charts are out of date when made available on the web.

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

Regional and Local charts are required on weekly and often daily basis. Would like to see as a minimum the radarsat interpretation charts made available for all areas (particularly Beaufort right to Alaskan Border and preferably to Point Barrow, and northward at least 25 miles past pack ice edge). Would like to see radarsat images themselves posted as local interpretation onboard is often advantageous, but primarily because georeferenced images allow for on screen computer navigation planning.

How frequently would you like to get an ice information update?

Daily or at least as soon as new information (radarsat) is available. However, often times the period between radarsat passes and the time to interpret the imagery and post to the web site makes planning difficult. Timely info is often required daily.

How far in advance do you plan your route?

Strategic planning is often done up to 21 days in advance while approaching the areas of intended operation, then daily strategic planning occurs within 2-3 days of and while operationg within an ice regime.

Have you had a situation where better ice information would have been useful?

Many times. The latest CIS policy of producing charts only when a CCG unit (or major client?) is in an area has negatively impacted operations on our vessels.

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

Daily ice charts as a minimum based on as close to real time info as possible. Chart accompanied by actually radarsat imagery in resolution that allows for identification of floes to 50 metres as a minimum. Real time is very important, the gap between radarsat passes that occurs at present is insufficient to meet changing operational needs of Arctic research ships.

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

Better resolution radar satellite imagery. MODUS images I have seen are excellent but at present at not timely.

Ice Information Systems for Navigation in the High Arctic

CCG Captain with many years of experience in the western and high arctic.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

- Multi-year ice
- Ridges not as important – can usually navigate around them or break through them
- Concentration and thickness is also important, depending upon the operation

T1100 safe ops are mainly in FY with occasional forays into MY, although avoidance as allowed is the preferred option. Concentrations of less than 10/10ths sometimes give us more grief than 10/10th as it allows lateral movement from 1 floe to the next, thus exposing out weaker ship's sides/cheeks to significant forces

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel? How do you display and use ice information on your ship?

RADARSAT, Ice Charts, ice observers, helicopters, CanIce 3

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

Present day – usually not too bad – usually can get what is required through contributions from all sources.
Would like more flexibility in RADARST image locations (not planning a week in advance)

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

Regional information is best since can use the helicopter to get more local information. However if a helicopter was not available, might re-think this priority.

How frequently would you like to get an ice information update? How far in advance do you plan your route?

Some planning a week in advance, but usually daily is okay.

Have you had a situation where better ice information would have been useful?

Coming around Barrow is sometimes difficult

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

- Would like to see more raw data rather than processed data (i.e RADARSAT, weather info, etc. rather than a note form Ottawa that there could be pressure in a certain location)
- Efforts in more detailed satellite imargey. (Necessity to get a handle on where the Radarsat images are processed. Quality of images processed in Alaska is very poor as compared to those processed in Gatineau. Most of the Alaskan processed ones are not useful).
- Multi-year ice characterization and detection
- Need to ensure that RADARSAT 1 is properly replaced with RADARSAT 2 in a timely manner. Did not get a good feel for how good ENVISAT images are
- Need greater flexibility in being able to change requirements for RADARSAT (1 or 2) images areas and schedules. It appears at the moment this can be done on 2 weeks notice, but there is a definite reluctance ($$$???)
- It appears that the capability of ground truthing what type of ice is being depicted on RADARSAT images via CANICE 3 will be lost shortly. Therefore we should work towards a better resolution of images, to better identify difference between MY and F/Y ice floes.
- As we are transiting North in Bering Straits we look ahead to ice conditions that are remote from the ship, and again prior to transiting the North Slope in both directions. During the season, we do a lot of "strategic guidance " of the tugs and other traffic (recreational) that may be remote from us. For these reasons the importance of getting the resolution of imagery down to say 100m should be worked towards. During the period of ops in Beaufort/QMG and Coronation up to Peel Sd we tend to operate on more of a "next day schedule" type of thing, where we will adjust Science/MNS work around the ice conditions, using helo as required.

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

At the moment any ice info we need , the ISS is responsible for getting. If these specialists are done away with. we will need a fairly user friendly system of getting the ice charts from AES, the RADARSAT images and other info such as NOAA

Ice Information Systems for Navigation in the High Arctic

Captain of a CCG Icebreaker with several years of experience in many ice conditions.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

- Any type ice under pressure
- Generally the following conditions may be of concern on their own. But, when a combination of two/three of these conditions exist within a field then avoidance of same is considered prudent:
- Moving ice;
- concentration 8/10 or greater;
- floe size med or larger;
- heavy ridged/rafted ice;
- multi-year ice;
- and, of course unknown, (snow covered – unable to distinguish characteristics until into the ice itself.

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel?

- ISS downloads several products of interest including RADARSAT imagery (and similar products); Daily Ice Charts; Ice models; digital photography etc.
- Locally generated ice chartlets provided by ISS through ice reccos (use of vessel's helo, and surveillance from ship's bridge)

How do you display and use ice information on your ship?

- RADARSAT and ice charts displayed on a monitor (may or may not overlay geographically referenced cartography).
- Ice charts; ice warnings; ice forecasts available in hard copy on Navigation Bridge

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

90 - 95% of the time our information is sufficient

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

On occasion, availability of higher resolution Sat imagery may have assisted in analysis of ice conditions and been critical in route planning.
NOTE: Higher resolution is always appreciated. But, download time and limited coverage limits our requests until a higher critical situation arises.

How frequently would you like to get an ice information update?

Generally, three day updates through ice analysis charts are satisfactory. However, abnormal weather situations (high winds; heavy seas, sustained wind direction; etc) create abnormal ice conditions. This in turn results in a requirement for increased frequency of ice information (every 12 or 24 hours in some situations)
Also, as soon as a significant change is either forecasted (predicted) or observed – the information should be broadcast

How far in advance do you plan your route?

Some of our routing is planned 7 to 14 days in advanced based on historic ice information (example voyage from Labrador Coast to Thule, Greenland mid July). Pending vessel assignments, most other voyages have a limited preparation period (24 – 72 hours). However, the majority of ice mariners will review ice information and prepare contingency transits on a daily basis (if not more frequent).

Have you had a situation where better ice information would have been useful?

Several occasions – The ice information for Baffin Bay and Davis Strait is usually limited in reliability due to age of information in mid June to mid July of each season. It is recognized that vessel traffic in this area at this time is minimal. And, fog conditions limit aerial observations during this same period. However, this same for also limits any kind of local recco and subsequently both strategic and tactical ice information is limited and/or too aged to be beneficial.

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

Satellite Ice Imagery from various sources (RADARSat, MODUS, etc) be provided at higher resolution; more frequently. Also, this same imagery along with other information could be combined to provide updated ice predictory models which could include information of ice type; thickness; growth/deterioration; movement; pressure; etc.

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

As per above: Generally data acquisition combined to provide predictory ice models which would be updated as real-time information is provided for comparison.

Ice Information Systems for Navigation in the High Arctic

This is the Captain in the Canadian Coast Guard who operates an Arctic icebreaker.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

Multiyear ice,/ growlers,/ any kind of concentration of ice/ the easiest route to avoid any concentration of ice.

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel?

From the ice services technician.

How do you display and use ice information on your ship?

Available electronic and paper chart presented by ice field service personnel.

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

Yes**.**

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

Satellite imagery converted to ice-chart.

How frequently would you like to get an ice information update?

When required.

How far in advance do you plan your route?

5 days in case of a voyage to the high arctic.

Have you had a situation where better ice information would have been useful?

Yes, ice deterioration by melt regarding ice strength (the degree of resistance of the ice).

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

Weather marine forecast: one to ten days for planing purpose.

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

More detail satellite info.

Ice Information Systems for Navigation in the High Arctic

This is a Canadian Coast Guard Captain with several years of experience in the Arctic.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

Multi-year ice will be the main problem. If there is a high ice concentration, then the vessel speed will be low and the risk of damage is less. For a NG tanker in the winter, the ice will be mostly landfast with operation in a track. During the spring, summer and fall, good knowledge of the ice will help to avoid it.

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel?

From the CIS. It is downloaded into IceVu. This includes the ice charts and RADARSAT imagery. Since we have this information, we don't use the helicopter very much.

How do you display and use ice information on your ship?

We use IceVu, but this is too complex for mariners. IceNav is the best way to go for this – it is designed for mariners. With IceVu, if you haven't used it in awhile, you have to relearn how to use it.

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

You need the ice information to plan a route and to help identify the ice regime that you will be traversing. The ice information is generally good for this..

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

More satellite imagery. For a tanker in the Arctic twenty years from now, the satellite imagery should be very good. It is important for the satellite to give information for the whole route and follow the vessel.

How frequently would you like to get an ice information update?

Depends on the weather pattern. If winds and currents not too strong, then once a day is enough. Ice modelling is pretty good to help with this. Once a day with a forecast would be good.

How far in advance do you plan your route?

Depends on where you are. In the north, I plan a couple of days in advance. As soon as new information is available, I update my plan. If I'm stuck, I need more information.

Have you had a situation where better ice information would have been useful?

One has to be patient. For example, transiting Norwegian Bay or the NWP one needs the best information. Old information is no good and sometimes we wait to get the most recent satellite imagery. With new information, you are okay.

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

RADARSAT2! Satellites are the way of the future. It has to go through clouds, fog and darkness. Better resolution would be an improvement.

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

Get the IceNav system

Ice Information Systems for Navigation in the High Arctic

CCG Captain with many years of experience onboard an icebreaker in the western and high Arctic regions.

1 - Ice Parameters of Interest:

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel? That is, what is the range of ice conditions that you are looking to avoid?

2 - Sources of Ice Information

Where do you get ice information while onboard your vessel?

Ice information is provided by the ISS and include RADARSAT data, daily ice charts as well as observations from CANICE 3. Also use the helicopter but this is limited by weather, fuel, and flying hours allowed.

How do you display and use ice information on your ship?

Ice information is displayed on the IceVu system operated by the ice observer. Too complicated for the officers to use. Even some of the older ISS's have trouble with it.

3 - Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

No.

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

RADARSAT data is useful but it often does not cover the area we are interested when we need it. The repeat cycle is such that we can't rely on getting RADARSAT data exactly when we need it. Also, the requirement for RADARSAT data to be processed trough Alaska takes too long such that the data isn't of much use once we get it. We also need higher resolution RADARSAT data and there is a need for better ground truthing of the RADARSAT images.

The ice charts come out too late in the day to be of much use. We make our decisions on the day's escort early in the morning and need the up-to-date info then, not in the late afternoon. There is a problem with the accuracy of the ice charts.

The quality of ice information received now is not sufficient to make the AIRSS work properly. There is no way to properly implement AIRSS with today's ice information.

How frequently would you like to get an ice information update?

At least once or twice a day, preferably in the early morning.

How far in advance do you plan your route?

Usually look three days out in advance to see what we are going to encounter.

Have you had a situation where better ice information would have been useful?

All the time. The Martha Black a few years ago became stuck and damaged in ice because of inaccurate ice charts.

4 - View to the future.

Where would you like to see efforts placed toward improving ice information?

Better repeat coverage on the RADARSAT data. Need much better ground truthing on RADARSAT data. There is a lot of ambiguity in the interpretation of the imagery. Prefer an aircraft outfitted with a high resolution radar that can downlink imagery directly to the vessel.

A shipboard system that can be used by the officers would be helpful. A more user friendly system. Icevu is not a ship-specific tool, would like a ship-specific tool (taken to mean a more navigationally oriented system).

Training of shipboard personnel very important. There is a need to have much more training in ice navigation and image interpretation than is the case at the moment.

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

Liked the idea of hull sensors that tells the Captain when he is pushing the ship too much. The 1100 class is much more susceptible to damage so a system the alerts the Captain to this would be useful.

Appendix B

Workshop Presentations

CCTII Workshop:

Ice Information Requirements for Marine Transportation of Natural Gas from the High Arctic

Garry Timco
Bob Gorman
John Falkingham
Barb O'Connell

Project carried out for the Climate Change Technology and Innovation Initiative – CCTII (NRCan)

- **Long-term approach for Unconventional Gas – Frontier regions**
- **High Arctic contains significant amounts of natural gas – 10tcf**
- **Transportation would be a major issue**
- **Scoping Study carried out to look improvements to ice information systems**
- **Results to form the basis for a new submission (3-year program).**

Issues:

- Largest Challenge
- Major Uncertainty
- Major Expense
- Must be Reliable
- No Downtime
- No Damage

How do you gain confidence in shipping?

Analysis of Zone-Date System indicates Arctic Class 7 vessel

Workshop Program

- **Current Ice Information Systems - *B. Gorman***
- **Ice Information from the Canadian Ice Service Operations - *J. Falkingham***
- **The CCG use of Ice Information - *B. O'Connell***
- **Summary of Ice Information Questionnaire of Vessel Masters - *G. Timco***

Open discussion on the way ahead - *(chaired by G. Timco)*

NRC·CNRC
From Discovery to Innovation...

Current Ice Information Systems

Workshop on Ice Navigation Systems for Arctic Navigation

Montreal, January 19, 2005

Robert Gorman
Enfotec Technical Services

Outline

- History of Ice Navigation Systems Development
  - Systems Remote to the Vessel (Aircraft and Satellite)
  - Ship-based Systems
- View to the Future

The Aircraft Era 1970's to 1995

- The use of aircraft for ice reconnaissance dates back many decades. The first successful systems were based on large four engine long-range reconnaissance aircraft outfitted with Side-Looking Airborne Radars (SLAR).
- In Canada the Electra and Dash-7 aircraft were used.

CANICE 3

The Aircraft Era 1970's to 1995

Sometimes the close tactical support was very close!

The Aircraft Era 1970's to 1995

- The first airborne systems were Side-Looking Airborne Radars (SLAR) which are "real-aperture" radars.
- Systems in use included the Motorola APS-94, Terma Mappr and CAL-100.
- These systems were "relatively" inexpensive to purchase compared to Synthetic Aperture Radars but provided lower resolution imagery. However, they were still adequate for ice reconnaissance providing resolutions in the range of 30 to 200 metres.

The Aircraft Era 1970's to 1995

The Aircraft Era 1970's to 1995

- A significant improvement to the resolution of airborne radars came with the introduction of the Intera STAR (Sea Ice and Terrain Assessment Radar) Synthetic Aperture Radar (SAR) in 1984. The system was used operationally for ice reconnaissance in the Beaufort Sea and by Canarctic in the 1980's and by the Canadian Ice Service with the Comprehensive Ice Reconnaissance Service (CIRS) and CANICE 5 between 1990 and 1995.

The Aircraft Era 1970's to 1995

- Airborne SAR imagery provided very high resolution imagery (from 25 to better than 10 metres) and proved very useful for ice navigation

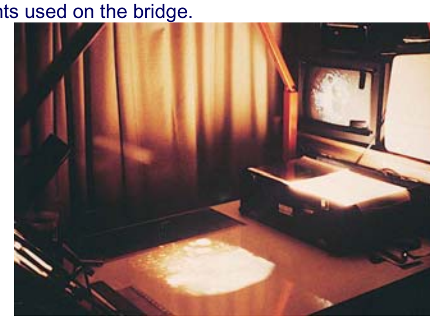
NRC·CNRC

The Aircraft Era 1970's to 1995

- The shipboard equipment required to receive the direct downlink of airborne radar imagery from the ice reconnaissance aircraft was custom-built and very expensive - $300-500K (in 1982$!)
- This equipment required a dedicated operator on board the ship at all times

The Aircraft Era 1970's to 1995

- Early use of airborne radar imagery was with hard copy prints used on the bridge.



CNRC

The Aircraft Era 1970's to 1995

- The use of airborne SAR radar imagery culminated with the use of the STAR-VUE system, first tested on MV Arctic between 1986 to 1989 and installed on the larger Canadian Coast Guard icebreakers between 1990 to 1995 as part of CIRS

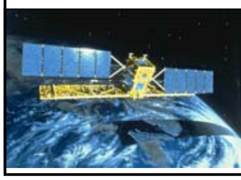
The End of the Aircraft Era

- Airborne ice reconnaissance systems were successful in satisfying the ice navigation needs of ships. They were responsive to the "near-real-time" needs for ice information and provided very high resolution imagery.
- The downfall of the airborne systems were the very high costs of operations and the difficulty a plane has in covering a large area. With the launch of RADARSAT in November 1995, the aircraft systems were scrapped.
- Experiments were run in the early 1990's by CIS, Canarctic and TDC (with PERD support) that demonstrated with ERS-1 data that it was possible to use satellite SAR data for vessel navigation in ice.

NRC·CNRC

The RADARSAT Era 1995 to Present

- With the launch of RADARSAT in November 1995, a drastic change to ice navigation systems occurred.
- Most of the expensive to operate ice reconnaissance aircraft (both Gov't and private) were scraped.
- Overnight, the expensive and complicated shipboard equipment became obsolete and new shipboard systems were needed.

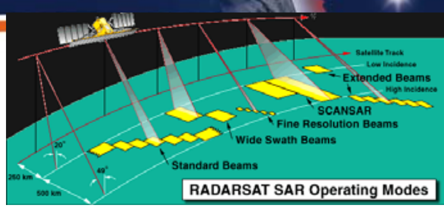


- No more real-time downlink.
- No more dedicated coverage.

The RADARSAT Era 1995 to Present

- RADARSAT has resulted in significant cost savings for ice information over the aircraft it has replaced. However, there is a lead time required to plan the coverage as well as a delay in getting the imagery from the satellite to the ship. There is also the loss of dedicated "coverage when needed".
- RADARSAT is highly flexable and is capable of higher resolution imaging than the aircraft it replaces.
- There is also the benefit that other satellite data (NOAA, MODIS, ENVISAT) can also now be sent out to the vessels using the same shipboard technology along with RADARSAT data.

The RADARSAT Era 1995 to Present



- There is much flexibility to the RADARSAT system but getting data exactly when and where you want it is still a problem. Still very difficult to plan over short time horizons.

The RADARSAT Era 1995 to Present

- Ice navigation systems have been developed to utilize RADARSAT data on board ice-going vessels such as
  - IceNav (Enfotec)
  - Icevu (CIS)
  - IcePlot (Finland)
- Ice navigation systems are now based on inexpensive PC systems that cost as little as 1% of the cost of the airborne downlink systems they replace. They also provide much more flexibility in terms of functionality and data they can handle, including the ease to which they can be integrated into the navigational environment on the bridge.

Ship-based Sensors

- A significant amount of work has been completed on the development of ship-based sensors for ice detection and avoidance. These include:
  - Advanced marine radars
  - SONAR
  - Radiometers
  - Thermal/low light devices
  - Helicopter sensors

Ship-based Sensors

"It seemed like a good idea at the time"

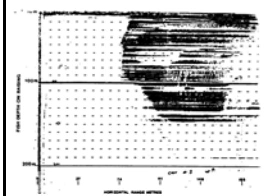
- SONAR
- Low light and IR sensors
- Shallow-angle marine radar

NRC·CNRC

Ship-based Sensors

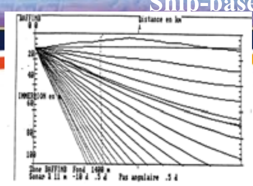
SONAR

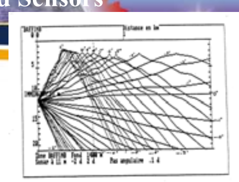
- A significant amount of research has been completed on the use of SONAR as an ice hazard detection device, including on the MV Arctic in 1985/86.



NRC·CNRC

Ship-based Sensors





- The conclusions from the SONAR trials were:
  - Medium to large icebergs were easily detected
  - SONAR returns were complex, with significant scatter effect from the ship's hull, sea bottom as well as under sea ice limiting the detection of smaller objects
  - Changing temperature and salinity profiles in Arctic sea water made the modeling of the SONAR equation difficult.
  - Sea ice impacts damage the transducer requiring expensive re-engineering. The cost of solving these limitations was high and would not likely to result in a usable system.

NRC·CNRC

Ship-based Sensors

Low-light and IR Sensors

- Low light (image intensifiers) as well as Infra Red camera have been tested in ice covered waters (on MV Arctic as well as by Petro Canada).
- The findings of these studies was that darkness is not a limitation to ice navigation but sea smoke, fog and snow is, which also limits low-light and IR devices.
- It was found that very high powered Xeon Arc searchlights were much more effective.

NRC·CNRC

Ship-based Sensors

- High powered searchlights are by far the most effective way of dealing with navigation in darkness, such as these 64 million (each) candle light Xeon Arch lights on the MV Arctic

NRC·CNRC

Ship-based Sensors

Shallow-angle Marine Radar

- Experiments were conducted on the MV Arctic in the 1980's at mounting a radar scanner on the bow to see if a shallow incident angle would improve the detection of ice hazards in from of the vessel.

NRC·CNRC

- Although some success in detecting ice hazards in front of the vessel by the increased shadow cased, the bow environment proved to be too harsh for a radar scanner!

NRC·CNRC

Ship-based Sensors

Advanced Marine Radars

- The most promising results on research in ship-based sensors has come with marine radars.
- Sea and glacial ice displays unique properties when illuminated at radar frequencies making this technology the most attractive for ice detection and avoidance.
- A detailed review of this topic would take days so a brief overview of what has been accomplished will be described.

NRC·CNRC

Ship-based Sensors

- Marine radars were originally developed as target detectors (other ships, coastlines) and not imaging devices. Using a marine radar in ice navigation is applying the technology in an application for which it wasn't designed (duct tape principle). However, we can change the parameters to make it very effective in ice.
- The parameters of interest are:
  - Frequency (X-Band - 3cm, S-Band-10cm, and others)
  - Polarization
  - RPM and PRF (pulse repetition frequency)
  - Coherency
  - Display Resolution

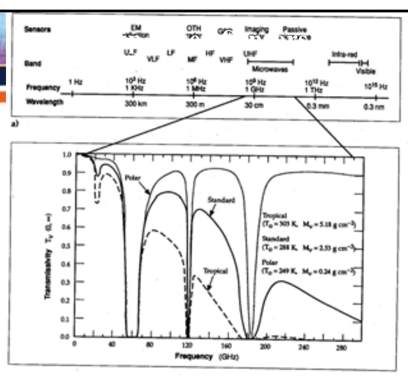
NRC·CNRC

Ship-based Sensors

Frequency

- X-Band (3 cm) has been selected as the optimum frequency for marine radars as it combines both good resolution with good rain and sea clutter penetration as well as limited loss due to atmospheric vapour.
- However, within an ice cover (especially under Arctic conditions) there is no sea or rain clutter to worry about and atmospheric vapour is very low so an "ice radar" does not need to be restricted to X-Band.
- Higher frequencies (such as K_u 16.5 GHz and K_a 35.0 GHz and others) provide higher resolution potential.

NRC·CNRC



- The transmissivity of the atmosphere to radar frequencies is much higher in Polar regions.

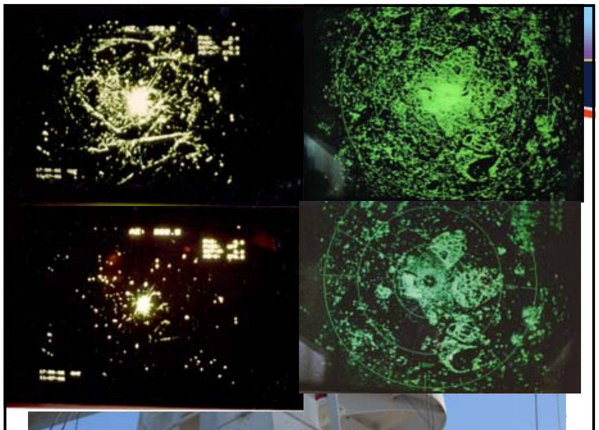
NRC·CNRC

Ship-based Sensors

Polarization

- Horizontal polarization has been found to also limit rain and sea clutter on radar displays. However, like frequency, these are not limitations in ice covered waters.
- In addition, comparing cross transit and receive polarizations has shown some interesting results in ice detection. We have been experimenting with horizontal transmit and vertical receive polarizations on the MV Arctic for many years that has revealed significant results.

NRC·CNRC



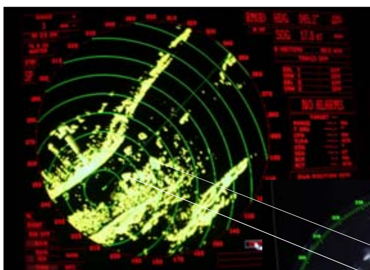
Ship-based Sensors

Rotation, Pulses and Display

- Marine radars rotate at 30 RPM but this is no longer an operational requirement.
- RPM, PRF and screen resolution are all artifacts of old technology and the fact that the marine radar is a target detector and not an imaging device.
- Increasing the digitization of the signal to 256 grey levels from 4 and altering the rotation, PRF, scan averaging etc.. can greatly increase the imaging potential of the marine radar.

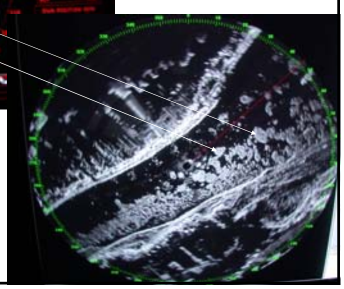
NRC·CNRC

IceNav Marine Radar Module



- Standard ‘two bit” marine radar display

- Enhanced marine radar image from the same radar digitized to 256 grey levels.



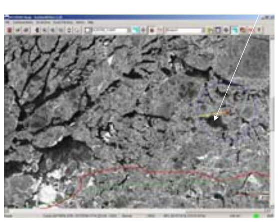
Ship-based Sensors

- There is a great deal of potential to improve the marine radar as an ice detection and avoidance.
- The combination of space radar (RADARSAT) with enhanced marine radar technology shows great potential as demonstrated with Enfotec’s IceNav-VMR system.

NRC·CNRC

IceNav-VMR Dual Screen Display

Finding common ice features allows leads in front of the vessel to be located



IceNav Display with RADARSAT Image

Integrated Enhanced Marine Radar Display correlating with the RADARSAT Image

ICE NAV

ENFOTEC

IceNav Ice Navigation Console on MV Arctic

Canada

View to the Future

View to the Future

- Many ice navigation technologies have been tried and, although showing promise, have been abandoned due to the high cost of development and/or implementation such as:
  - Airborne SAR/SLAR
  - SONAR
  - Coherent marine radars
- There is great promise in space-based sensors as well as the development of the Ice Navigation Marine Radar.

NRC · CNRC

Ice Information Production at the Canadian Ice Service

Arctic Navigation Workshop

Montreal January 19, 2005

John Falkingham

Environment Canada Environnement Canada

Ice - A National Issue

- Canada claims the world's:
  - longest coastline
  - greatest area of ice
- Annual variation in extent of ice is ≈ ½ the area of Canada (4M km^2)
- Seasonal effects on:
  - safety and efficiency of marine transportation
  - weather and climate
  - marine ecosystems

Environment Canada Environnement Canada

The Canadian Ice Service

- Ice information service in support of:
  - Ship routing
  - Icebreaking operations
  - Climate monitoring
- Reconnaissance
- Analysis and Forecasts
- Product Distribution and Archive
- Informatics
- Applied Science

Environment Canada Environnement Canada

Major Clients

- Canadian Coast Guard
  - mandate for marine safety in Canadian waters
  - variety of specialized services

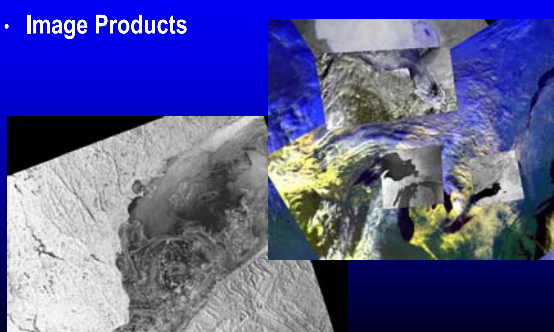
Others

- Marine Shipping and Insurance
- Offshore oil, gas and mining
- Research, consultants, tourism
- Canadian Meteorological Centre
- Fishing
- National Defence
- Port Authorities
- Int'l Ice Centres
- Int'l Ice Patrol

Environment Canada Environnement Canada

Products and Services - Daily

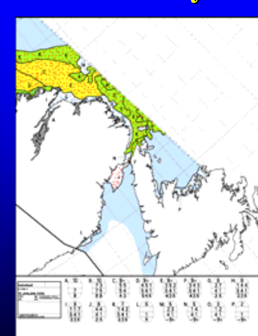
- Image Products



Environment Canada Environnement Canada

Products and Services - Daily

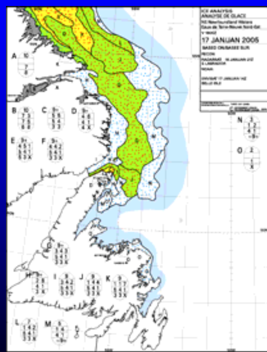
- Image Products
- Image Analyses



Environment Canada Environnement Canada

Products and Services - Daily

- Image Products
- Image Analysis Charts
- Ice Analysis Charts
-



Environment Canada Environnement Canada

Products and Services - Daily

- Image Products
- Image Analysis Charts
- Ice Analysis Charts
- Ice Hazard Bulletins

FICN18 CWIS 181633 ICE HAZARD BULLETIN FOR THE EAST COAST OF NEWFOUNDLAND AND LABRADOR ISSUED BY ENVIRONMENT CANADA AT 1500 UTC TUESDAY 18 JANUARY 2005 FOR TODAY AND WEDNESDAY.

THE NEXT SCHEDULED BULLETIN WILL BE ISSUED AT 1500 UTC WEDNESDAY.

NO WARNINGS IN EFFECT UNLESS NOTED.

LIGHT TO MODERATE ICE PRESSURE MAY OCCUR IN ANY ICE CONDITIONS.

ICE EDGE AT 1500 UTC ESTIMATED FROM NEWFOUNDLAND NEAR 4840N 5305W TO 4940N 5330W TO 5025N 5515W TO 5045N 5245W TO 5420N 5230W TO 5700N 5710W TO 6025N 5845W TO 6200N 5830W THEN NORTHEASTWARD.

SOUTH COAST.
OPEN WATER.

EAST COAST.
OPEN WATER EXCEPT WEST OF ICE EDGE 1 TENTH NEW ICE.

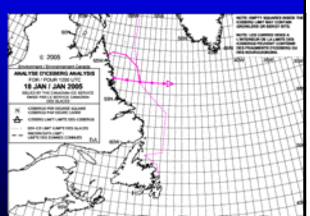
NORTHEAST COAST. ICE FREE EXCEPT WEST OF ICE EDGE 3 TENTHS NEW ICE INCLUDING 1 TENTH GREY ICE.

BELLE ISLE EASTERN HALF
SOUTH LABRADOR COAST.
9 TENTHS GREY ICE INCLUDING 2 TENTHS GREYWHITE ICE.

...

Products and Services - Daily

- Image Products
- Image Analysis Charts
- Ice Analysis Charts
- Ice Hazard Bulletins
- Iceberg Analysis Charts



Environment Canada Environnement Canada

Products and Services - Daily

- Image Products
- Image Analysis Charts
- Ice Analysis Charts
- Ice Hazard Bulletins
- Iceberg Analysis Chart
- Iceberg Bulletins

FICN11 CWIS 181530 ICEBERG BULLETIN FOR EAST COAST WATERS ISSUED BY ENVIRONMENT CANADA AT 1600 UTC TUESDAY 18 JANUARY 2005 FOR 1200 UTC TODAY.

THE NEXT SCHEDULED BULLETIN WILL BE ISSUED AT 1600 UTC WEDNESDAY.

ICEBERG LIMIT ESTIMATED AT 1200 UTC FROM LABRADOR AT 5700N 6125W TO 5700N 5700W THEN EASTWARD.

BELLE ISLE
NORTHEAST GULF
GULF-PORT AU PORT
SOUTH COAST
EAST COAST
NORTHEAST COAST
BELLE ISLE BANK
FUNK ISLAND BANK
NORTHERN GRAND BANKS
SOUTHEASTERN GRAND BANKS
SOUTHWESTERN GRAND BANKS
SOUTH LABRADOR COAST
MID LABRADOR COAST
SOUTH LABRADOR SEA.
NO KNOWN ICEBERGS.

EAST LABRADOR SEA.
LESS THAN 10 ICEBERGS EXCEPT SOUTH OF ICEBERG LIMIT
NO KNOWN ICEBERGS.

...

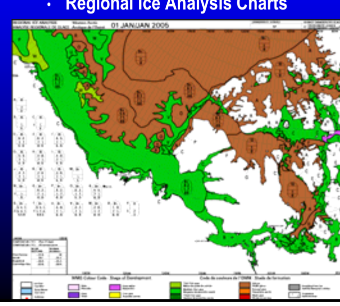
Products and Services - Daily

- Image Products
- Image Analysis Charts
- Ice Analysis Charts
- Ice Hazard Bulletins
- Iceberg Analysis Chart
- Iceberg Bulletin
- Telephone consultation with CCG Ice Offices, Icebreakers (3-10 calls per day)

Environment Canada Environnement Canada

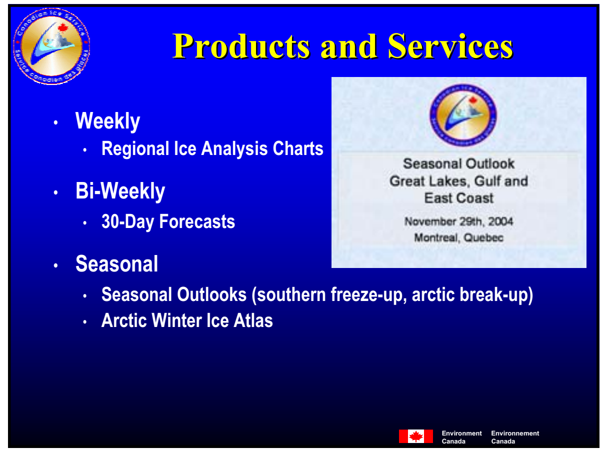
Products and Services

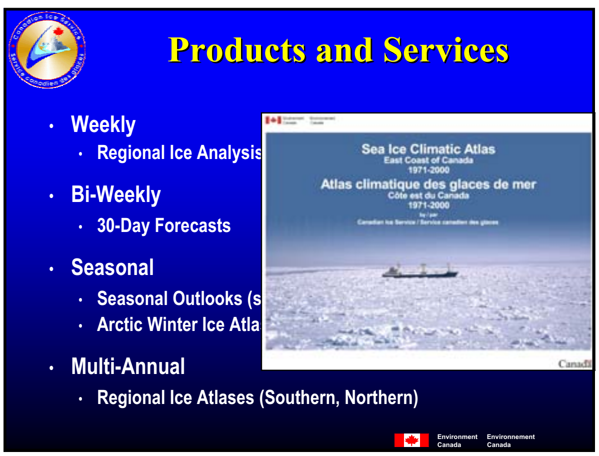
- Weekly
  - Regional Ice Analysis Charts

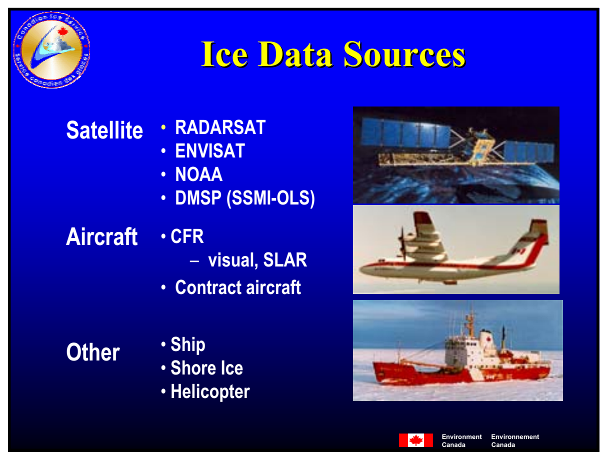


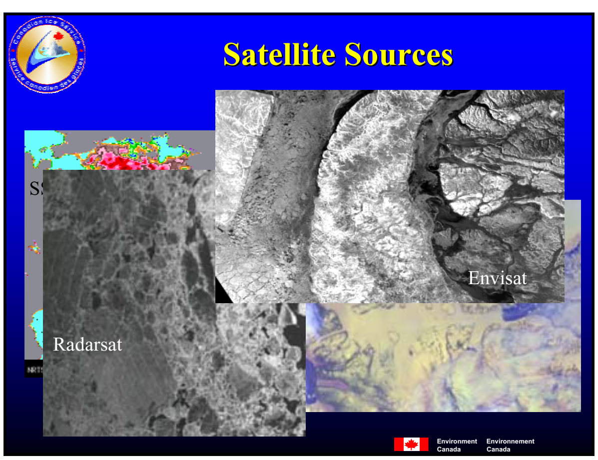
Environment Canada Environnement Canada

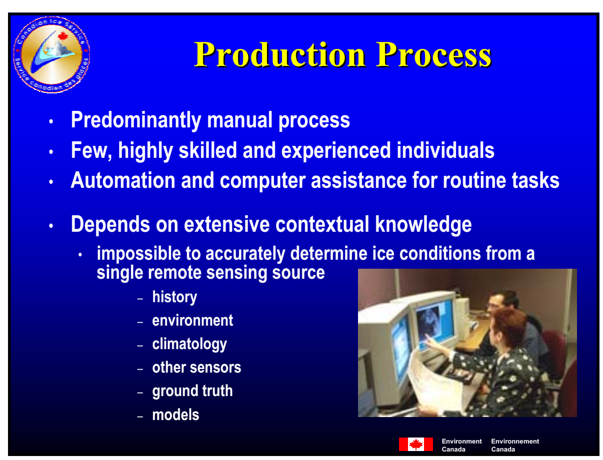

Products and Services
Weekly
Regional Ice Analysis Charts
Bi-Weekly
30-Day Forecasts
FECN01 CWIS 152100 THIRTY DAY FORECAST FOR THE GULF OF ST LAWRENCE FOR JANUARY ISSUED BY ENVIRONMENT CANADA FROM CANADIAN ICE SERVICE IN OTTAWA ON 5 JANUARY 2005. THE NEXT 30 DAY FORECAST WILL BE ISSUED ON 19 JANUARY 2005.
DURING THE LAST TWO WEEKS OF DECEMBER, TEMPERATURES WERE NEAR TO BELOW NORMAL OVER THE ESTUARY AND THE NORTH-WESTERN PORTION OF THE GULF. ELSEWHERE IN THE GULF TEMPERATURES WERE ABOVE NORMAL. AS A RESULT, THE ICE EXTENT IN THE ESTUARY IS NEAR NORMAL WHEREAS THE REST OF THE REGION HAD LESS THAN NORMAL ICE EXTENT.
FORECAST ICE CONDITIONS FROM JANUARY 5TH TO JANUARY 15TH.
A SERIES OF STORMS TRACKING OVER THE GULF OF ST LAWRENCE WILL CAUSE THE TEMPERATURES TO FLUCTUATE FROM BELOW NORMAL TO ABOVE NORMAL. HOWEVER TEMPERATURES WILL AVERAGE SLIGHTLY BELOW NORMAL OVER THE NEXT TWO WEEKS. 1. THE ESTUARY AND THE GASPE PASSAGE – GREY AND NEW ICE WILL CONTINUE TO DRIFT EASTWARD AND REACH THE WESTERN PORTION OF THE GASPE PASSAGE ALONG THE GASPE PENINSULA DURING THE FIRST WEEK OF JANUARY. BY THE MIDDLE OF JANUARY, THE ICE WILL COVER
…
Environment Canada Environnement Canada


Products and Services
Weekly
Regional Ice Analysis Charts
Bi-Weekly
30-Day Forecasts
Seasonal
Seasonal Outlooks (southern freeze-up, arctic break-up)
Arctic Winter Ice Atlas
Seasonal Outlook
Great Lakes, Gulf and
East Coast
November 29th, 2004
Montreal, Quebec
Environment Canada Environnement Canada


Products and Services
Weekly
Regional Ice Analysis
Bi-Weekly
30-Day Forecasts
Seasonal
Seasonal Outlooks (s
Arctic Winter Ice Atla
Multi-Annual
Regional Ice Atlases (Southern, Northern)
Sea Ice Climatic Atlas
East Coast of Canada
1971-2000
Atlas climatique des glaces de mer
Côte est du Canada
1971-2000
Environment Canada Environnement Canada


Ice Data Sources
Satellite
RADARSAT
ENVISAT
NOAA
DMSP (SSMI-OLS)
Aircraft
CFR
– visual, SLAR
Contract aircraft
Other
Ship
Shore Ice
Helicopter
Environment Canada Environnement Canada


Satellite Sources
Envisat
Radarsat
Environment Canada Environnement Canada


Production Process
Predominantly manual process
Few, highly skilled and experienced individuals
Automation and computer assistance for routine tasks
Depends on extensive contextual knowledge
impossible to accurately determine ice conditions from a single remote sensing source
– history
– environment
– climatology
– other sensors
– ground truth
– models
Environment Canada Environnement Canada

Integration of Information

Satellite
Optical
NOAA AVHRR
DMSP OLS

Microwave
RADARSAT
ENVISAT
QUIKSCAT
DMSP SSM/I

Airborne
Visual Obs
SLAR/SAR

Surface
Buoys
Ship Reports
Shore Obs

Models
Weather
Ice

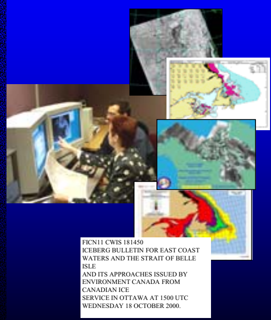


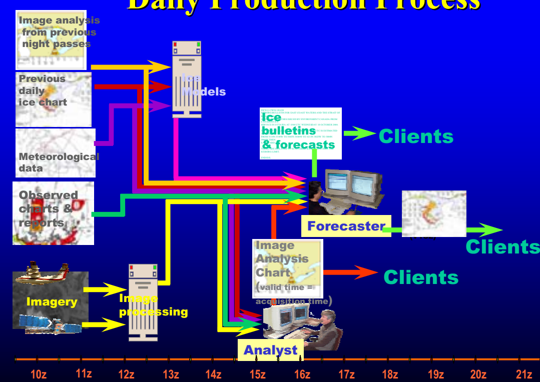
Image Products
Analysed images

Chart Products
Daily tactical ice analyses
Weekly strategic ice analyses

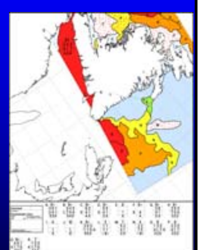
Climatological Products
Ice Atlases
Normals / Extremes

Text Products
Ice hazard warnings
30-day forecasts
Seasonal Outlooks

Daily Production Process



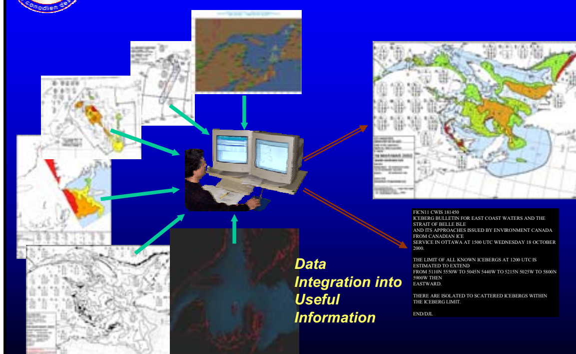
The Analysts' Role



- Image analysis chart valid at time of image and extends only to image boundaries
- Serves as input to the data integration for the daily/weekly ice analysis chart

Environment Canada Environnement Canada

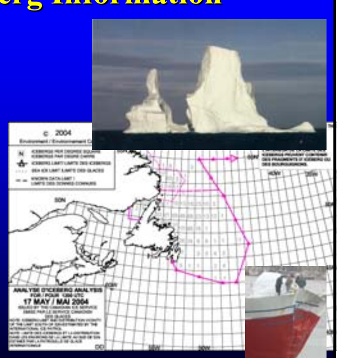
Forecasters' Role



Environment Canada Environnement Canada

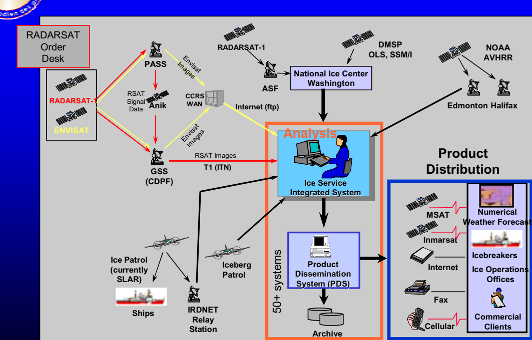
Iceberg Information

- Icebergs are treated differently than sea ice
  - point targets
- Iceberg program tightly integrated with International Ice Patrol
  - But focused on Canadian waters
- Highly visible program but lower economic / environmental value



Environment Canada Environnement Canada

Infrastructure



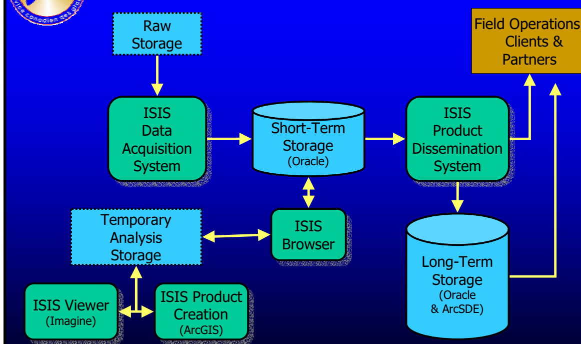
Environment Canada Environnement Canada

Data Ingest

- A continuous feed of raw data (24x7)
- Raw imagery is bulky (30Mb to 300Mb each)
- Considerable variation in scale, resolution, format and coordinate-systems
- Every piece of data is geo-coded upon ingest

Environment Canada Environnement Canada

Production Data Flow



Environment Canada Environnement Canada

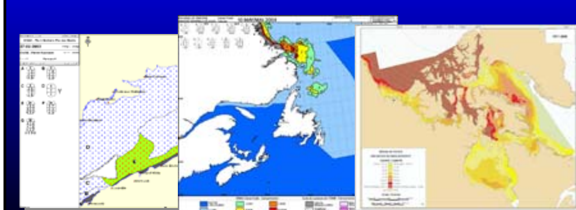
ISIS – Ice Service Integrated System

- Unique architecture to meet unique needs
  - Considerable variation in operational scales
    - ⇒vector-based GIS system
  - Display of satellite imagery
    - ⇒Raster-based image analysis system
  - Detailed analysis of satellite imagery
    - ⇒Vector drawing on top of raster images
- ISIS is a marriage of ESRI ArcGIS and LEICA Imagine
  - Off-the-shelf software customised to the CIS need

Environment Canada Environnement Canada

A Core Set of Products

- A set of chart products are generated daily
- Produced with multiple scales, palettes, formats
- Product appearance standardized by 100+ templates
- Chart creation is fully automated



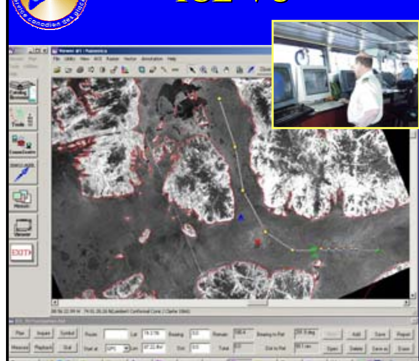
Environment Canada Environnement Canada

Product Formats

- Internal format standards
  - Image format standard is Imagine .img
  - Vector (chart) format standard is ESRI .e00
- Product format standards
  - jpg
  - gif
  - mrsid … jpeg 2000
  - Pdf
- Plan to evolve to "mapping on demand" over net few years
- Must maintain delivery capabilities to ships at sea

Environment Canada Environnement Canada

ICE-VU



- Receive CIS chart and image products via ftp
- Receive chart and radar data directly from aircraft via S-Band downlink
- Update ship's position in real time using GPS
- Plan route based on surrounding ice conditions
- Track ship's progresss against planned route

Environment Canada Environnement Canada

Canadian Coast Guard Use of Ice Information

Barb O'Connell

Montreal Workshop
January 19, 2005

Ice Information Services

- CCG Icebreaking Program is influenced by:
  - size of the fleet, crew size, operational profile, cost-effectiveness and sound financial management
  - marine shipping and government expectations
  - science and technology
- Ice Information Requirement:
  - increased quality and accuracy
  - higher level of detail and
  - more frequent ice information updates

Ice Information Services

- Ice Service Specialists (Ice Observers)
- Tactical Aircraft Support
- Ice Charts, Bulletins, Warnings
- Satellite Imagery
- Communications
- Ice Information Systems
- Ice Modelling
- Training to CCG Officers (ad hoc and formal)

Ice Operations Centres

- Monitoring ice conditions
- Monitoring of shipping
- Development/provision of Recommended Ice Routes
- Dissemination of ice information (via MCTS)
- Coordination/tasking of icebreakers (zonal approach)
- Coordinating aircraft reconnaissance
- Support to Transport Canada's Ice Regimes
  - AIRSS Ice Regime Routing Messages
  - JIG: Activation of Ice Control Zones (i.e. Strait of Belle Isle)
- Client consultation

Icebreakers

- Voyage/route planning
- Tactical navigation in ice
- Provision of icebreaking services: escorts, channel/track maintenance, harbour breakouts, flood control, northern resupply
- Advice to commercial vessels, fishermen, ferries and harbour/port authorities
- Communication with Ice Operations Centres other icebreakers and ice reconnaissance aircraft
- Decision as to need for helicopter recco

Icebreaking Program

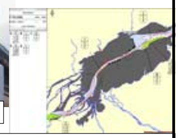
Use of Charts, Images, Forecasts, Climatology for:

- Client Consultation and Advice
- Policy/Standards Development
- Icebreaking Service Fee (zones, dates)
- Climate Change (impacts, adaptation)
- Research & Development

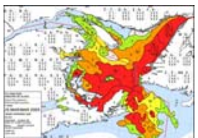
CCG R&D

- ICEggs
- Ice Routing Model
- Ice Thickness Sensor
- Cross Polarized Radar

Tablet PC with ICEggs



Ice chart produced with ICEggs



Ice Route displayed on Ice Chart

Ice Thickness Probe

Limitations in Arctic

- Inmarsat costs
  - Need for improved transmission methods
  - Need for improved compression techniques
- Coverage above Latitudes 77° - 82°N
  - Proximity to high coastline
  - Ship's structure (i.e. funnel) – adjust ship's heading
- Improved processing (Western Arctic)

Summary of Ice Info Needs

- Timeliness of products: reduce delays by processing, interpretation and integration of ice data
- Quality and accuracy is important
- Ground-truthing of satellite data by aircraft or helicopter is still required
- Improved transmission methods
- User-friendly Ice Info Systems

SURVEY OF ICEBREAKER CAPTAINS

- Best approach was to talk to knowledgeable Captains of vessels that regularly travel in ice conditions.
- A list of potential Captains (both CCG and Industry) was developed
- Set of Interview Questions were developed
- Sought support at CMAC-Northern Meeting and CCG Post-Arctic Meeting
- Very positive response from Captains
- Timco and Gorman conducted the interviews

Basis for Interview Questions

1 - Ice Parameters of Interest

2 - Sources of Ice Information

3 - Present Day Situation

4 - View to the future.

Captains Interviewed

Captain	Organization	Vessel Name	Type of Vessel
Barry Acorn	Nunavut Eastern Arctic Shipping	Aivik	Supply Vessel
Dave Snider	Independent		Tankers & Cruise Ships
Doug Camsell	NTCL		Type Vessels
John Cowan	Fednav		CAC & Type Vessels
John Vanthiel	CCG	Henry Larsen	Icebreaker
Keith Jones	Independent		Tankers & Cruise Ships
Mark Taylor	CCG	Sir Wilfrid Laurier	Icebreaker
Marvin Kean	Fednav (Canarctic)	MV Arctic	Ice Class Bulk Carrier
Michel Bordeau	CCG	Pierre Radisson	Icebreaker
Norm Thomas	CCG	Sir Wilfrid Laurier	Icebreaker
Peter Dunderdale	Independent		Icebreakers and Tankers
Randy Rose	Fednav (Canarctic)	MV Arctic	Ice Class Bulk Carrier
Richard Dubois	CCG	Des Groseilliers	Icebreaker
Sean Sheppard	Nunavut Eastern Arctic Shipping	Umiavut	Supply Vessel
Germain Tremblay	CCG	Amundsen	Icebreaker

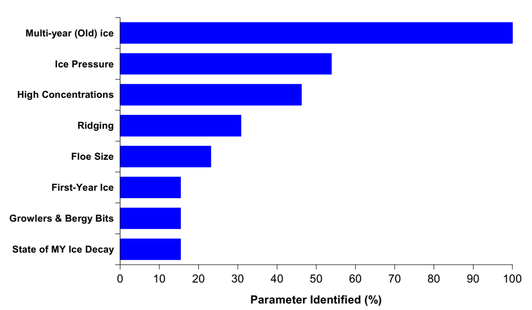
15 in total from a wide range of experience and background

Question 1: Ice Parameters of Interest

Specifically, what is the type and arrangement of ice that gives you the most concern for the operation of your vessel?

That is, what is the range of ice conditions that you are looking to avoid?

Question 1: Ice Parameters of Interest



Question 2: Sources of Ice Information

Where do you get ice information while onboard your vessel?

How do you display and use ice information on your ship?

Question 2: Sources of Ice Information

Mix of responses:

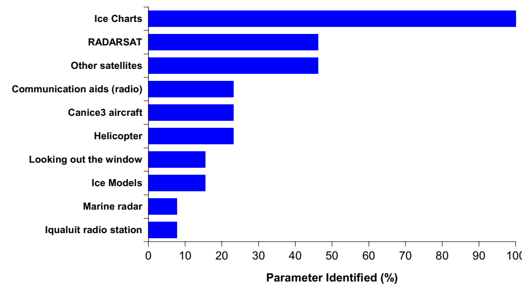
CCG had very high quality information

Industry had two streams

1 - High quality information (IceNav)

2 - Basic information (e.g. Ice Charts & Radio)

Question 2: Sources of Ice Information



Question 3: Present Day Situation

Is the ice information you presently receive adequate and sufficiently detailed for each of the ice types that are a concern for you?

If not, what type and level of detail (i.e. very local, regional, satellite imagery, etc.) would you like to receive?

How frequently would you like to get an ice information update?

How far in advance do you plan your route?

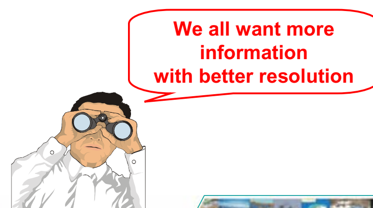
Have you had a situation where better ice information would have been useful?

Question 3: Present Day Situation

Two different responses:

1 - Those with geo-referenced information (IceVU, IceNav) were generally happy

2 - Those with basic information expressed less enthusiasm



Question 3: Present Day Situation

1. More RADARSAT images – better ground-truthing
2. More flexibility in choosing RADARSAT images
3. Better details on multi-year ice
4. Old information is useless – sometimes wait for new info
5. More information on pressured regions would be desirable
6. More detail in specific regions (e.g. passageways and ports)
7. Identifying bergy bits & growlers
8. The poor quality of the Ice Charts that are received by fax
9. The lack of charts with forecasts
10. Sometimes no Ice Charts are available (they tend to follow the CCG vessels)

Question 4: View to the future.

Where would you like to see efforts placed toward improving ice information?

Do you have any ideas on what technologies should be pursued to improve ice navigation (the emphasis being on new technology for extended season operation in Arctic waters)?

Question 4: View to the future.

Many suggestions on what is lacking and what could be improved

For our discussion, they are all included on the following slides:

Being able to receive more information

Would like to see RADARSAT images with an overlay of wind and current vectors showing predicted drift of the ice. Showing the areas where pressure may be encountered in the future.

Emphasis on improving existing technology such as RADARSAT and marine radar, such as the IceNav system with the radar interface.

Emphasis on developing user friendly systems that can be used by the navigation officers. Now we cannot use the IceVu system when the Ice Observer is not available.

The integration of RADARSAT and ice chart data with ECDIS would be very valuable.

Question 4: View to the future.

Important point is what ever is developed must be affordable.

The best product we would like to see is an image with a chart overlay on the image so we can have both the interpretation as well as be able to actually see the imagery at the same time.

Don't place much value on a forecast or models as the accuracy is in question. Predictions for 12 to 24 hours maybe but won't have much faith in a forecast beyond this.

Training in ice navigation and the use of ice information will be critical. You can develop all the nice technology you can but if no one knows how to use it, it will all be for naught.

Note much credence on model outputs now. Now not be my #1 priority for future research.

The Cross-Polarized radar technology holds the best promise for the future for the detection of bergy bits and growlers in front of the vessel.

CHC National Research Council Canada Conseil national de recherches Canada Canada

Question 4: View to the future.

Multi-year ice would be first since avoidance of potential damage must be rated as No. 1 issue.

This could also apply to glacial ice (depending upon the location in the Arctic).

Pressure is another one. However, being stuck in pressure would slow things but would not be catastrophic.

Has the use of sonar been properly investigated? Can you mount one in the bow looking up for ½ mile to see if anything deep-keeled is in the way?

Making RADARSAT cheaper

More care (emphasis) on forecasting ice movement/change

Multi-year ice – most damage caused by inadvertently hitting a piece of multi-year ice.

New vessel locator on electronic charts – show ship identifier such that other ship(s) can be picked out in pack ice on charts and radar.

Always show the position of the CCG Icebreakers on the charts.

CHC National Research Council Canada Conseil national de recherches Canada Canada

Question 4: View to the future.

Offloading sometimes use a mile of floater hose – this is crazy – important to move vessel closer to the shore

Don't have much faith in model forecasts. Would prefer to see images over ice charts. The egg is the average of the ice conditions in a zone but an image can give more subtle details than a chart can. Using satellite images that can improve ice type classification would be great – there is some ambiguity with RADARSAT now.

Making the X-Pol radar work would be very interesting. Detecting old ice and growlers in from of the vessel is still a very difficult issue for the ship.

More ice charts per day

RADARSAT or (NOAA?) satellite imagery that shows photographs (this depends on cloud cover)

Better local information would be useful (with a helicopter if available)

System to detect ice that could cause damage in low ice conditions. (radar system?)

CHC National Research Council Canada Conseil national de recherches Canada Canada

Question 4: View to the future.

Ice information is good today for our present mode of operation but it would not be adequate for year-round shipping in the Arctic.

Daily ice charts as a minimum based on as close to real time info as possible. Chart accompanied by actually RADARSAT imagery in resolution that allows for identification of floes to 50 metres as a minimum. Real time is very important, the gap between RADARSAT passes that occurs at present is insufficient to meet changing operational needs of Arctic research ships.

Better resolution radar satellite imagery. MODUS images I have seen are excellent but at present at not timely.

Would like to see more raw data rather than processed data (i.e RADARSAT, weather info, etc. rather than a note from Ottawa that there could be pressure in a certain location)

Efforts in more detailed satellite imagery. (Necessity to get a handle on where the RADARSAT images are processed. Quality of images processed in Alaska is very poor as compared to those processed in Gatineau. Most of the Alaskan processed ones are not useful).

CHC National Research Council Canada Conseil national de recherches Canada Canada

Question 4: View to the future.

Multi-year ice characterization and detection

Need to ensure that RADARSAT 1 is properly replaced with RADARSAT 2 in a timely manner. Did not get a good feel for how good ENVISAT images are

Need greater flexibility in being able to change requirements for RADARSAT (1 or 2) images areas and schedules. It appears at the moment this can be done on 2 weeks notice, but there is a definite reluctance ($$$???)

It appears that the capability of ground truthing what type of ice is being depicted on RADARSAT images via CANICE 3 will be lost shortly. Therefore we should work towards a better resolution of images, to better identify difference between MY and F/Y ice floes.

During the season, we do a lot of "strategic guidance " of the tugs and other traffic (recreational) that may be remote from us. For these reasons the importance of getting the resolution of imagery down to say 100m should be worked towards. During the period of ops in Beaufort/QMG and Coronation up to Peel Sd we tend to operate on more of a "next day schedule" type of thing, where we will adjust Science/MNS work around the ice conditions, using helo as required.

CHC National Research Council Canada Conseil national de recherches Canada Canada

Question 4: View to the future.

At the moment any ice info we need , the ISS is responsible for getting. If these specialists are done away with, we will need a fairly user friendly system of getting the ice charts from AES, the RADARSAT images and other info such as NOAA

Satellite Ice Imagery from various sources (RADARSAT, MODUS, etc) be provided at higher resolution; more frequently. Also, this same imagery along with other information could be combined to provide updated ice predictory models which could include information of ice type; thickness; growth/deterioration; movement; pressure; etc.

As per above: Generally data acquisition combined to provide predictory ice models which would be updated as real-time information is provided for comparison.

Weather marine forecast: one to ten days for planning purpose.

More detail satellite info.

RADARSAT2!

Question 4: View to the future.

Better repeat coverage on the RADARSAT data. Need much better ground truthing on RADARSAT data. There is a lot of ambiguity in the interpretation of the imagery. Prefer an aircraft outfitted with a high resolution radar that can downlink imagery directly to the vessel.

A shipboard system that can be used by the officers would be helpful. A more user friendly system. IceVu is not a ship-specific tool, would like a ship-specific tool (taken to mean a more navigationally oriented system).

Training of shipboard personnel very important. There is a need to have much more training in ice navigation and image interpretation than is the case at the moment.

Liked the idea of hull sensors that tells the Captain when he is pushing the ship too much. The 1100 class is much more susceptible to damage so a system the alerts the Captain to this would be useful.

Question 4: View to the future….

First Theme – Regional with Satellite Technology

Improved satellite imagery and the integration of several sources of raw and processed data.

This could be, for example, a multi-layer system which includes on different layers, a satellite image, the corresponding Ice Chart, the weather forecast, the forecast wind magnitude and direction, the regional currents, the forecasted ice movement and pressure, etc.

This would allow the Captains to see both the raw and processed information.

This system would have to easy to use, inexpensive and have proper training in its use.

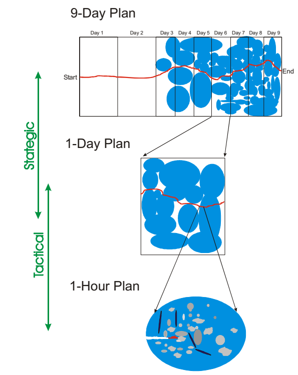
Question 4: View to the future….

Second Theme – Local Knowledge of Multi-year Ice

Development of a system that would provide better local information on multi-year ice and large ice features.

Especially important in poor visibility situations.

This system must also be easy to use, inexpensive and have proper training and interpretation.



LONG TERM

What Type of Information Do I Need?					
Rate Importance (1-10 scale)					
How Do I Get It?					
Is it Adequate?					
Improvements?					
Overall Ranking of Importance for Improving					

CHC
National Research Council Canada
Conseil national de recherches Canada
Canada