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YEAR-ROUND SHIPPING IN THE CANADIAN ARCTIC: ICE CONDITIONS AND REGULATORY REQUIREMENTS

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ABSTRACT

Extensive drilling programs took place in the High Arctic between 1969 and 1987. Large gas reserves were discovered with estimates of undiscovered potential up to 60 Tcf. Recently, the Canadian Energy Research Institute (CERI) evaluated the economics for development of gas reserves for Indian and Northern Affairs Canada (INAC) and concluded that development could be viable. One of the main difficulties is to ensure that a reliable transportation system exists for bringing the gas to southern markets. Large tankers are a potential method for transit; therefore it is important to determine the year-round ice conditions that a tanker would encounter and determine the regulatory requirements based on Transport Canada Regulations. This will have a pronounced influence on the safety and on the cost of ship construction.

In this paper, the historical ice conditions in shipping routes in the Canadian Arctic are analyzed. The coverage of the shipping lanes by multi-year ice is evaluated. Based on the knowledge of the year-round ice conditions that a tanker would encounter and applying Transport Canada Regulations, CAC2 is recommended as the lowest vessel class to operate on a year-round basis.

INTRODUCTION

Canada's High Arctic contains large reserves of natural gas. During the drilling program in the Svedrup Basin between 1969 and 1987, discovered reserves of 16 Tcf were identified and a potential of undiscovered reserves up to 60 Tcf was estimated (CERI, 2004). Major gas fields were discovered on Melville Island in the Drake Point field and Hecla field. The marketable gas reserves there were estimated as 7.7 Tcf. Canadian Energy Research Institute (CERI) carried out a study for Indian and

Northern Affairs of Canada on economics of gas development in the High Arctic (CERI, 2004). The factors such as cost for the project scale, remote location, harsh climate conditions, and increase in the price of the gas were evaluated. The study suggested that production and ship-borne transportation of natural gas from Melville Island is economically feasible. However, such transportation represents a large challenge since the ships have to be designed and constructed to cope with severe ice conditions in the High Arctic. In addition, the shipping time represents a large uncertainty in the project. The variability of ice conditions encountered in each season influences the required number of ships. Severe ice conditions could restrict and slow the transit. If a ship is beset in ice, the assistance of an icebreaker may be required. Also deliveries could be reduced if a ship is damaged and has to be repaired. Additional ships will be required to avoid flaring of the gas that could not be transported. This would increase the anticipated cost. To preclude that, tankers capable of operating on a year-round basis should be used.

Another factor to be considered is a potential climate change. A number of studies have reported a decrease of ice extent and indicated that there is an apparent trend in first-year (FY) ice melt in the Canadian Arctic Archipelago (Wilson et al. 2004, Howel and Yackel 2004, Melling 2002, Falkingham et al. 2001, Comiso 2002, Flato and Boer, 2001). An increase in length of the shipping season is therefore expected. However, melting of first year ice in Canadian Arctic Archipelago will allow more multi-year ice to reach the Northwest Passage and the Beaufort Sea pack ice to shift south. This will make shipping in the Northwest Passage just as challenging and hazardous as today even if the climate warms.

Confidence in year-round shipping is based on two factors - the capability of the tanker to operate in different ice conditions, and good ice information and routing to minimize the risk of damage and transit time. These were addressed in the scoping study on ice information requirements for marine transportation of natural gas from the High Arctic (Timco et al., 2005). Within the framework of that project, the year-round ice conditions that a tanker would encounter were analyzed. Based on Transport Canada Regulations, the Polar Class of a vessel, capable of year-round shipping, was determined. Results of this study are presented in this paper.

REGULATORY SHIPPING SYSTEMS

Transport Canada has the responsibility for regulating Arctic shipping in Canada as part of the Arctic Shipping Pollution Prevention Regulations (ASPPR). Under the ASPPR, shipping is regulated by the Zone/Date System (ZDS) and by the Arctic Ice Regime Shipping System (AIRSS). The ZDS and the AIRSS are described in detail in ASPPR (1989) and in AIRSS (1996), respectively. In both Systems vessels are assigned vessel classes. In the ZDS these relate to the vessel performance, while in the AIRSS vessel classes are assigned based on vessel strengthening. Type vessels (up to Baltic 1AS) are designed for first year ice conditions and can use both systems. Older Arctic Class (AC) vessels and newer Arctic Category, Canadian Arctic Class (CAC) vessels are designed to operate in severe ice conditions. Only CAC vessels can use AIRSS. This System reflects the actual ice conditions in the shipping lane in which a vessel is operating. AIRSS is based on calculation of an Ice Numeral (IN) for each ice regime. An Ice regime is a region with similar ice conditions, i.e. ice type, thickness, and concentration. An Ice Numeral equals the sum of the product of ice type and ice multiplier (IM) specific for each vessel class/type. The Ice Multiplier indicates a risk of damage to a vessel by different ice types. They are different for different classes of vessels and are given by a table of Ice Multipliers. If IN is zero or positive then a vessel is allowed to proceed through the ice regime; if IN is negative then the transit is not allowed. At present, AIRSS is used outside the dates of the Zone/Date System. In this study, the INs were used to determine what vessel class can operate in the Canadian Arctic on a year-round basis without a risk of damage.

SCENARIOS

Two possible scenarios were considered: 1 - shipping the gas to a terminal in the Beaufort Sea and then by a pipeline to Southern Canada (Western route) and 2 - delivering the gas to a terminal on the East Coast of Canada (Eastern route). Fig. 1 shows the potential shipping routes for transporting the gas from Bridport on Melville Island. Both the Western and Eastern routes have two segments with one common to both, the Bridport route. The Bridport route leads from Bridport Inlet through Viscount Melville Sound to Barrow Strait with two options of going around Lowther Island. The Western route connects to it in Barrow Strait and follows the Northwest Passage through Peel Sound, Franklin Strait, Victoria Strait, Coronation Gulf and Amundsen Gulf. A shorter route would be through McClintock Channel or through Prince of Wales Strait, however the ice conditions there are more severe than those in Peel Sound and Franklin Strait. Eastern route connects to Bridport route in Barrow Strait, leads through Lancaster Sound, Baffin Bay and Davis Strait where it follows the boundary of the Zone-Date System.

Vessel Class Based on the Zone-date System

The Zone-Date System (ZDS) consists of sixteen geographic regions (Zones) and an associated Table that indicates the dates that each class of vessel is allowed in each geographical region. The severity of ice conditions in the Zones is determined by a number assigned to each Zone, having the most severe Zone numbered 1 and the least severe Zone numbered 16 (Fig. 1). The ZDS is described in detail in ASPPR (1989).

The most severe ice along the shipping routes is encountered in the vicinity of Melville Island (Bridport route), which lies in Zone 6. For the Western route the ship will proceed through Zones 6, 7, 11, and 12 to arrive at a terminal in the Beaufort Sea. For the Eastern route, the vessel will proceed through Zones 6, 13, 9, and 10 to get to a terminal at the East Coast of Canada. The most severe Zone crossed by both routes is Zone 6. According to the Zone-Date System to operate in this Zone on year-round basis an Arctic Class 7 vessel will be required. This analysis is very trivial. However, since the Zone-Date system is based on historical ice conditions with an assumption that the nature does not change from year to year, and since the ice conditions haven't been updated since the Zone-Date System was established, such analysis does not reflect a risk of damage to vessels by ice. To include this factor in the analysis, the AIRSS is used to determine a class of a tanker for year-round shipping.

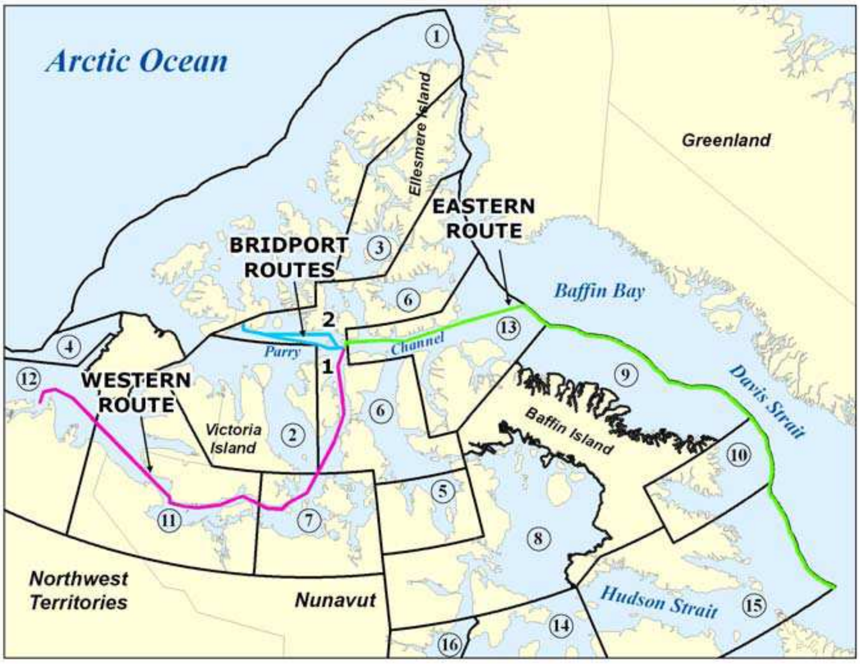

Fig. 1 Shipping routes for transporting gas from Melville Island

Vessel Class Based on the AIRSS

The historical ice conditions in shipping routes in the Canadian Arctic were analyzed. Information on ice conditions was obtained from the Canadian Ice Service from historical digital ice charts. Only the ice charts after 1982 could be used for the analysis since the ice charts produced prior to 1982 do not provide information on various types of first year ice, i.e. do not divide the first year ice according to its thickness as thin, medium, and thick ice. Information on different types of first year ice is needed for the calculation of Ice Numerals.

The analysis to evaluate ice conditions and the operability of different vessel classes throughout the year in the selected shipping routes is based on a methodology described in detail in Kubat et al. (2005). The routes were defined as lines based on actual navigation route coordinates. These lines (trajectories) were buffered into 1 km wide polygons using ArcView GIS software. Digital Regional weekly ice charts from the Canadian Ice Service (CIS) were also imported into ArcView and intersected with the trajectory maps.

Kubat and Timco (2003) analyzed damage to vessels operating in the Canadian Arctic and found that in 73% of damage events analyzed, damage occurred in ice regimes where multi-year ice was present. For Canadian Arctic Class (CAC) vessels, designed to operate in severe ice conditions, there are few damage events, but virtually all those that did occur had ice regimes with multi-year ice present. The data also showed that damage is more severe in ice regimes that contain multi-year ice. Therefore the occurrence of MY ice in the shipping lanes was analyzed. This was done by normalizing the percentage of MY ice coverage in each ice regime to the whole length of the shipping route. Basically, the area of the shipping route (i.e. trajectory buffered into 1 km wide polygon using the ArcView GIS) crossing the corresponding ice regime was calculated. Then the area covered by MY ice in the ice regime was calculated and normalized to the whole length of the route. The same was done for the FY ice coverage.

Fig. 2 shows the ice coverage in Bridport 1 route during year 1987. The ice coverage is presented in percents and is split into the Old Ice and first year ice coverage. The line with the circle symbol represents the coverage by Old Ice, the line with the triangle symbol represents the total coverage by Old Ice and FY ice.

Based on the ice information obtained from the CIS ice charts, the Ice Numerals (IN) for different ice class vessels were calculated for each ice regime the shipping route encountered. The ice conditions in every second year between 1985 and 2005 were analyzed and INs were calculated for Type A, Type B, CAC4, and CAC3 vessels. Type B vessel was selected as a baseline since it is the lowest class of a vessel allowed into the shipping lanes in the Northwest Passage according to the Zone-Date System. Fig. 3 shows the lowest values of Ice Numerals calculated for Type B, Type A, CAC4, and CAC3 vessels based on the information from the ice charts. The Regional ice charts for the Canadian Arctic are issued monthly in the winter/spring season and weekly in the summer/fall season. The circles represent the Ice Numerals. In some instances the values of Ice Numerals are superimposed, therefore a number indicating a count of Ice Numerals at that particular value was printed on the circle. Circles without numbers represent a single Ice Numeral for that particular value. A line is drawn at a zero value of IN to highlight the boundary between positive and negative INs. The negative value of IN (below zero line) indicates that a vessel is not allowed to proceed through the ice regime. The INs calculated for a vessel capable to operate on year-round basis have to be equal to zero or have to be positive throughout the whole year.

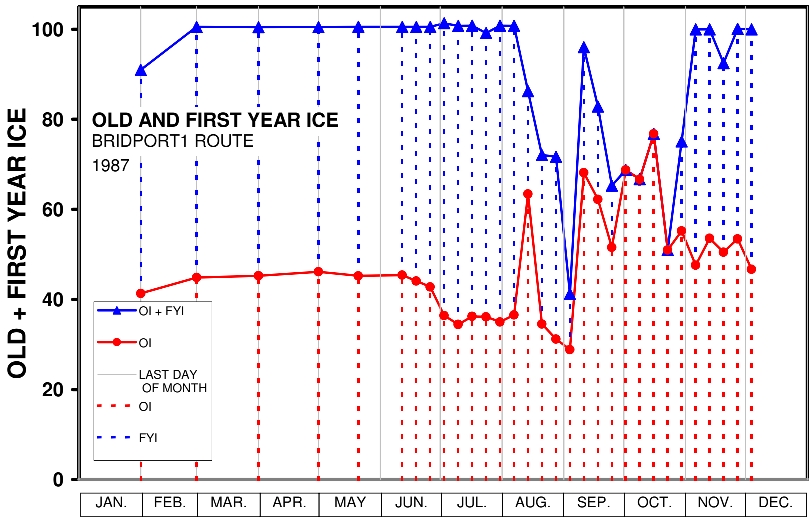

Fig. 2 The ice coverage in the Bridport route, year 1987

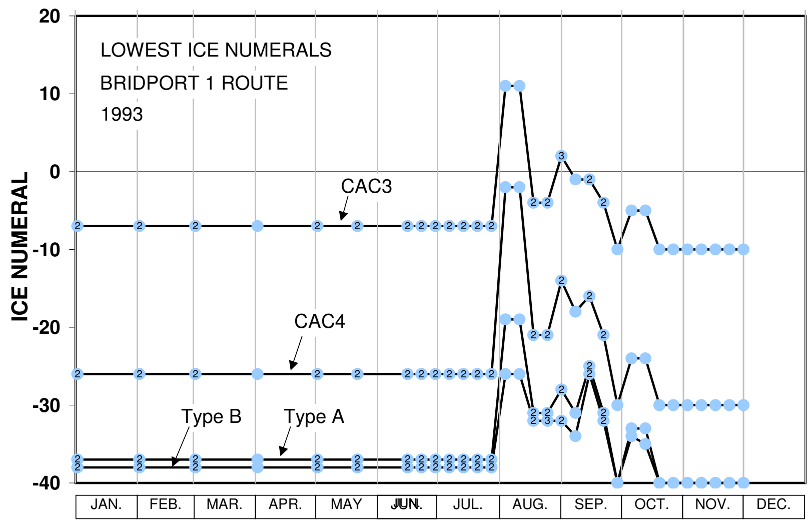

Fig. 3 Lowest Ice Numerals calculated from CIS ice charts for Type B to CAC3 vessels throughout year 1993 (Bridport 1 approach route)

RESULTS

The analysis was done for every second year between 1985 and 2005. The results showed that there is a high inter annual variability in ice conditions encountered in shipping lanes. It was interesting to note that during some warmer years the ice conditions were worse than during some colder years. It is due to ice conditions of the previous year, i.e. should the year be cold with severe ice then the ice doesn't melt completely during summer. It becomes more severe during winter, and a longer time is then needed for ice to melt in the following year, even if the year is relatively warm. Also, in a warm year the FY ice melts faster and the old ice floes are allowed to drift into shipping lanes. As a result the ice conditions during the shipping season might be worse than those in the previous colder year.

The most severe ice conditions are in the Bridport routes, which are common to both the Eastern and the Western route. MY ice is present throughout the whole year in the shipping lanes and the amount varies largely from year to year. In 1987, 30% of the Bridport 1 shipping lane was covered by MY ice throughout the whole year (45% from January to the end of June, 35% in July, 60% at the beginning of August decreasing to 30% at the end of August, 70% in September and October, and 50% the rest of the year). On the other hand in 1999, less than 5% of the shipping lane was covered by MY ice throughout the whole year. 1999 is the year that follows the warmest (1998) on record in Canadian Arctic history. The ice plugs in the Nansen Sound and the Svedrup Channel of Queen Elizabeth Islands (QEI) broke. The only years these plugs broke were 1962 and 1998 (Agnew et al. 2001, Jeffers et al. 2001). Except for 1999 and 2005, MY ice coverage in the shipping lanes didn't decrease below 10%. Bridport 2 route experienced slightly less coverage by MY ice, but the same amount of total coverage by ice. In all years the amount of MY ice in the shipping lanes during summer (July to September) is much higher than in winter (January to end of June). In winter and spring (January to end of June) both routes were covered in 100% by a combination of FY and MY ice, except for 1995 and 2005 when the routes in January were covered by ice in 95%. The ice cover in the shipping lanes decreases rapidly from the end of July during each year analyzed (1985 to 2005).

The coverage of the Western shipping route by MY ice also varies significantly from year to year. Except for years 1999 and 2001, MY ice was present in the shipping lane throughout the whole year. The percentage of shipping lane covered by ice in winter versus summer also varies from year to year. For example in 2005, 20% of the shipping lane was covered by MY ice from January to the end of July; in August and September MY ice covered 10% of the shipping lane. In 2001 only about 2% of the shipping lane was covered by MY ice from January to the end of July; in August the coverage by MY ice increased to 10%. In both these years 100% of the shipping lane was covered by a combination of FY and MY ice from January to May. The ice cover in the shipping lanes decreases rapidly from the end of July during each year analyzed (1985 to 2005).

The presence of MY ice in the Eastern shipping route again varies from year to year as well as the ratio of the MY ice coverage of the shipping lane between winter and summer. The shipping lane is covered by a combination of FY and MY ice in more than 90% every year from January to the end of April. The ice cover decreases rapidly either from the beginning or from the middle of June, and except for 1993 the shipping lane is in September covered by ice in less than 10%.

There is not unity in severity of ice conditions for all the routes. For example in 2005 the ice conditions in the Bridport routes are quite light (i.e. much less MY ice is present in the shipping lanes) compared to other years, while in the Western and Eastern routes the conditions are more severe than in previous years. Mostly the ice conditions in the Western route are more severe than in the Eastern route, however during 1995 and 2001 more MY ice was present in the Eastern shipping lane than in the Western.

The high presence of MY ice in all shipping lanes indicates potential danger to vessels, mainly to Type class vessels, and consequently increases requirements for a vessel class. The results of this study showed that even a CAC 3 vessel cannot operate on a year-round basis in either of the routes. The shipping window in the Eastern route is significantly wider for a CAC3 vessel, the limiting ice occurs alternately in September, October, and November. However, the access to Bridport through Viscount Melville Sound is still quite limited for a CAC3 vessel, particularly in winter when the ice is not decayed. Results suggest that a vessel will have to be built to a CAC2 class to operate on a year-round basis. In the scenarios we assume that the tanker will be built to comply with Transport Canada Regulations without the support of an icebreaker. A demand for a CAC2 vessel can be eased if an icebreaker is used in the region with the most severe ice conditions, i.e. Viscount Melville Sound. Safe shipping in the Western route will still require a CAC2 vessel. In the Eastern route, a CAC3 vessel cannot be used as a year-round tanker either, since there is a short time period in September/October (2 to 6 weeks) when the ice conditions give negative Ice Numerals.

According to the Zone-Date System, an Arctic Class 7 vessel is required for transporting gas from Melville Island on a year-round basis. Using the AIRSS, CAC2 vessel is necessary for such transportation.

The International Maritime Organization (IMO) system of Guidelines for Arctic Shipping incorporates a set of Polar Classes, PC1 to PC7. Polar Class 7 (PC7) classifies a vessel for summer/autumn operation in thin first-year ice which may include old ice inclusions; Polar Class 1 (PC1) classifies a vessel for year-round operation in all Polar waters. The Polar Classes are the basis for the International Association of Classification Societies (IACS) Unified Requirements for construction of Polar Class Ships that apply to vessels intended for navigation in ice-infested waters with the exclusion of icebreakers. Transport Canada Regulations will have to accommodate the IACS Polar Ship Rules. At the present time, Transport Canada is in the process of integrating the Polar Classes and vessel classes defined in AIRRS (Kendrick, 2005). Although a detailed analysis has not been prepared to date, the authors anticipate that a CAC2 vessel would be approximately equivalent to a Polar Class PC2 vessel.

SUMMARY AND CONCLUSIONS

In this paper, the historical ice conditions in shipping routes in the Canadian Arctic are analyzed. Western and Eastern routes were defined for transportation of gas to the southern markets. The coverage of the shipping lanes by MY ice was analyzed. Based on the knowledge of the year-round ice conditions that a tanker would encounter and applying Transport Canada Regulations, the vessel class of a vessel capable of year-round shipping was determined.

The results showed that there is a high inter annual variability in ice conditions encountered in shipping lanes. The most severe ice conditions are in Viscount Melville Sound, the approach routes to Bridport Inlet, which are common to both the Western and Eastern shipping routes. MY ice is present throughout the whole year in the shipping lanes of the Western route and the approach routes to Bridport Inlet and the amount of it varies largely from year to year. With the exception of few years, these routes were in winter and spring (January to end of June) covered in 100% by combination of FY and MY ice. The ice cover in the shipping lanes decreases rapidly since the end of July during each year analyzed (1985 to 2005). The presence of MY ice in the Eastern shipping route again varies from year to year as well as ratio of the MY ice coverage of the shipping lane between winter and summer. The shipping lane is covered by a combination of FY and MY ice in more than 90% every year from January to the end of April. The ice cover decreases rapidly alternatively from the beginning or from the middle of June. The high presence of MY ice in all shipping lanes indicates potential danger to vessels, mainly to Type class vessels, and consequently increases requirements for a vessel class.

According to the Zone-Date System, an Arctic Class 7 vessel is required for transporting gas from Melville Island on a year-round basis through the Western and Eastern routes. This is a trivial approach, which does not take into account the actual ice conditions a tanker would encounter during the transportation and therefore does not reflect a risk of damage to vessels by ice. To include this factor in the analysis, the AIRSS was used to determine a class of a tanker.

The results of this study showed that even a CAC 3 vessel cannot operate on a year-round basis in either of the routes. The shipping window in the Eastern route is significantly wider for a CAC3 vessel, the limiting ice occurs alternately in September, October, and November. However, the access to the Bridport Inlet through the Viscount Melville Sound is still quite limited for CAC3 vessel, particularly in winter when the ice is not decayed. A scenario with the icebreaker support in Viscount Melville Sound was evaluated. Safe shipping in the Western route will still require a CAC2 vessel mainly due to ice conditions in the Peel Sound and Franklin Strait. In Eastern route, a CAC3 vessel cannot be used as a year-round tanker either, however the shipping window is significantly larger with the shipping restricted mainly in October. To operate safely in the Canadian Arctic on a year-round basis and in accordance to the existing Transport Canada Regulations, a vessel will have to be built to a CAC2 class specifications.

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REFERENCES

Agnew, T.A., Alt, B., De Abreau, R., Jeffers, S.(2001). The loss of decades old sea ice plugs in the Canadian Arctic Islands. Proc. 6th Conference on Polar Meteorology and Oceanography, San. Diego, Calif., American Meteorological Society (AMS), Boston, Massachusetts.

AIRSS(1996). Arctic Ice Regime Shipping System (AIRSS) Standards. Transport Canada, June 1996, TP 12259E, Ottawa, Ont., Canada.

ASPPR(1989). Proposals for the Revision of the Arctic Shipping Pollution Prevention Regulations. Transport Canada Report TP 9981, Ottawa. Ont., Canada.

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

Comiso, J.C.(2002). A Rapidly Declining Perennial Sea Ice Cover in the Arctic. Geophysical Research Letters.29(20):.17-1 – 17-4.

Falkingham, J.C., Chagnon, R., McCourt, S.(2001). Sea Ice in the Canadian Arctic in the 21st Century. Proceedings 16th International Conference on Port and Ocean Engineering under Arctic Conditions, Ottawa, Ontario, Canada.

Flato, G.M., Boer, G.J.(2001). Warming Asymmetry in Climate Change Simulations, Geophysical Research Letters,28(1):195-198.

Howell, S.E.L., Yackel, J.J.(2004). A Vessel Transit Assessment of Sea-ice Variability in the Western Arctic, 1969-2002: Implications for Ship Navigation. Canadian Journal of Remote Sensing. 30(2):205-215.

Jeffers, S., Agnew, T.A., Alt, B.T., DeAbreu, R., McCourt, S.(2001). Investigating the anomalous sea-ice conditions in the Canadian High Arctic (Queen Elizabeth Islands) during summer 1998. Annals of Glaciology, .33:507-512.

Kendrick, A.(2005). Integration of Polar Classes and Arctic Ice Regime Shipping System, 8319C.FR Report prepared by BMT Fleet Technology Ltd. for National Research Council of Canada, March 2005.

Kubat, I. , Timco, G.W.(2003). Vessel Damage in the Canadian Arctic. Proceedings 17th International Conference on Port and Ocean Engineering under Arctic Conditions, Trondheim, Norway.

Kubat, I., Collins, A., Gorman, B., Timco, G.W.(2005). A Methodology to Evaluate Canada's Arctic Shipping Regulation. Proceedings 18th International Conference on Port and Ocean Engineering under Arctic Conditions, Potsdam, NY, USA.

Melling, H.(2002). Sea ice of the Northern Canadian Arctic Archipelago. Journal of Geophysical Research 107(C11), 3181, doi:10.1029/2001JC001102, 21.

Timco, G.W., Gorman, B., Falkingham, J., O'Connell, B.(2005) Scoping Study: Ice Information Requirements for Marine Transportation of Natural Gas from the High Arctic, Prepared for: Climate Change Technology and Innovation Initiative Unconventional Gas Supply, Technical Report CHC-TR-029 February 2005.

Wilson , K.J., Falkingham, J., Melling, H., De Abreau, R.(2004). Shipping in the Canadian Arctic, Other Possible Climate Change Scenarios. Proc. International Geoscience and Remote Sensing Symposium (IGARSS), Anchorage, Alaska, USA.