DET NORSKE VERITAS

Report

Heavy fuel in the Arctic (Phase 1)

PAME-Skrifstofan á Íslandi

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MANAGING RISK

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Summary:

The Arctic Council working group on the Protection of the Arctic Marine Environment (PAME) at its meeting in Copenhagen in March 2010, agreed to carry out Phase I of a project to identify the environmental risks related to the use and carriage of heavy oil fuel (HFO) by ships in the Arctic region.
DNV has been asked to carry out the work accordingly and this report sums up the results of the work carried out.
The study uses data from the AISSat-1 satellite capable of collecting over the entire Arctic region. The data provides the basis for the traffic analysis and by combining data from different sources the study has identified the vessels among the Arctic fleet likely to operate on HFO.

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SUMMARY

The Arctic Council working group on the Protection of the Arctic Marine Environment (PAME) at its meeting in Copenhagen in March 2010, agreed to carry out Phase I of a project to identify the use and carriage of heavy oil fuel (HFO) by ships in the Arctic region. The objective of project as stated by PAME has been to prepare a report which summarizes the current traffic in the Arctic region as well as identifying the proportion of this traffic operating on HFO. In addition the risks related to the use and carriage of HFO in the Arctic is discussed and which mitigation strategies are available. Finally the status of international regulations regarding the use of HFO is discussed.

In the study DNV has applied satellite based AIS (Automatic Identification System) data made available from the Norwegian Coastal Administration from August through November 2010, for describing the traffic pattern. Fuel sample data from DNV Petroleum Services (DNVPS) have been applied in order to identify vessels and vessel types likely to use HFO, in addition to identify Arctic ports where HFO bunkering operations occur. Finally, ship data from the DNV ship data base as used to fill inn with machinery details necessary for carrying out the study.

Main findings:

- Using HFO in Arctic waters may require an additional need for heating of the fuel to ensure correct liquidity of the bunker oil. However it is not in general considered technically or practically inappropriate for use in cold climates. The choice of HFO versus lighter products is basically based on the same considerations as for operation in other areas, such as machinery characteristics, price and availability.
- The vessels operating in the Arctic region are dominated in number by the fishing vessels – followed by a diverse group of vessels within the category “Other activities” such as different service ships and research vessels, in addition to local community support vessels (cargo ships) and passenger vessels. The vast majority of the vessels are smaller ships (less than 5000 GT).
- Out of a total of 954 AIS-registered vessels in the Arctic during the relevant period, 189 were identified as most likely running on HFO. The vessels applying HFO typically include the larger cargo/tanker and passenger ships, similarly to what may be experienced in other regions.
- The amount of transport of HFO within the Arctic region is uncertain. Based on available bunker samples from the DNVPS data base we identify that HFO bunkering is carried out mainly in the vicinities of the Arctic region with only a few samples registered within the region. Based on the traffic pattern of tankers, it is likely that parts of this traffic involve transport of HFO.
- The forecasted changes in shipping activities in the Arctic region will likely influence the pattern of HFO utilization. As discussed in this study, the majority of the vessels identified in the Arctic today are of a type and size that can be expected to run on distillate fuel rather than HFO. The potential increase in global commercial transit of cargo via the northern sea routes, in addition to a increased Arctic petroleum activities, will eventually result in an increased number of the larger cargo ships and oil/LNG tankers which

traditionally, and as shown by this study, are HFO users. The use of HFO is fully possible from the practical/technical perspective and under the current legislation. However, the future picture of HFO use versus distillates will also be governed by how the global and regional environmental legislation influence the fuel markets in general.

- Certain common particular polar conditions can be summarized of relevance for the risks from pollution from shipping, including ice and snow, temperature and light, remoteness and characteristics of the natural resources. Of particular importance is the fate of oil spills in ice covered waters, and our abilities for effective spill response and clean-up under the Arctic conditions. Trapping of oil in ice makes the pollution longer-lasting, and makes it possible for the oil to be transported over long distances. The limited ability to effectively clean up is a critical component of the risk equation and should be emphasized in the further discussion on the use of HFO in arctic waters. Relevant risk mitigating strategies should therefore focuse on preventing accidents and spill of oil, particularly of HFO and other emulsifying oils. In light of the particular HFO properties, significant risk reduction will be achieved if the onboard oil type is of distillate type rather than HFO.
- Ship exhaust generates emissions of substances such as sulphate and other aerosols; BC/soot and other particulate matter that may affect local/regional climate forcing processes and accelerated ice melting by influencing solar radiation in air masses and on snow/ice. In general, the use of HFO generate higher emissions of PM and SO2 than MDO.
- There are currently no international regulations prohibiting the use of HFO in the Arctic. However, national legislation within the Svalbard archipelago (Norway) has been adopted.

1 INTRODUCTION

The Arctic Council working group on the Protection of the Arctic Marine Environment (PAME) at its meeting in Copenhagen in March 2010, agreed to carry out Phase I of a project to identify the use and carriage of heavy oil fuel (HFO) by ships in the Arctic region. It has been agreed that Phase I shall focus on drawing a picture of the current traffic pattern and the associated use and carriage of HFO. DNV has been asked to carry out consultancy work in connection with Phase I.

2 PHASE 1 OBJECTIVE

The objective of Phase I of this project is, by the use of existing information, to prepare a report which summarizes the following areas of concern related to the use or carriage of HFO by ships in the Arctic;

- Identify known risks associated with use or carriage of HFO within the Arctic marine transportation system,
- Consider potential risk mitigation strategies.
- Examine the current state of the marine transportation industry in the Arctic region and its reliance on HFO, including forecasting trends related to commercial shipping and trade expansion and the implementation of recent or anticipated standards.
- Summarize the status of international regulations regarding the use or carriage of HFOs by vessels.

3 METHODOLOGY

3.1 General

The objective of identifying ships operating on HFO and tankers transporting HFO in the Arctic is obtained by collecting and pairing several data sources holding specific information on ship movements, ship engine details and data from sampling and analysis of fuel oil qualities.

Additional considerations are made regarding environmental risk for the use of HFO in an Arctic perspective. Based on review of existing studies and assessment programs, as well as in-house knowledge and experience within the field of Environmental Risk and Arctic Shipping. Of particular relevance and importance has been the broad range of scientific and industry based knowledge compiled under the Arctic Council's different environmental assessment programs, such as the Arctic Marine Shipping Assessment (ref /1/) and others (ref /2/, /3/ and /4/). In addition, user experience from selected Arctic/cold climate ship operators has been collected by interviews.

3.2 Arctic waters delimitation

It is evident that a clear and agreed geographical definition of the waters to be included in the term "Arctic" is of key importance for this study. During the process following the interim report (September 2010), PAME decided that the IMO's Guidelines for Ships Operating in Ice-Covered

Waters should provide the limits for this study. As regards geographical application, 'Arctic ice-covered waters' is defined in Section G-3.2 as:

[waters] located north of a line from the southern tip of Greenland and thence by the southern shore of Greenland to Kape Hoppe and thence by a rhumb line to latitude 67º03'9 N, longitude 026º33'4 W and thence by a rhumb line to Sørkapp, Jan Mayen and by the southern shore of Jan Mayen to the Island of Bjørnøya, and thence by a great circle line from the Island of Bjørnøya to Cap Kanin Nos and thence by the northern shore of the Asian Continent eastward to the Bering Strait and thence from the Bering Strait westward to latitude 60º North as far as Il'pyrskiy and following the 60th North parallel eastward as far as and including Etolin Strait and thence by the northern shore of the North American continent as far south as latitude 60º North and thence eastward to the southern tip of Greenland; and in which sea ice concentrations of 1/10 coverage or greater are present and which pose a structural risk to ships.

The definition of the Arctic Ocean is shown graphically in Figure 3.1.

Figure 3.1 The definition of the Arctic as applied in the IMO guidelines for ships operating in the Arctic (from Jensen, Ø 2007. FNI Report 2/2207. Fritjof Nansens Institutt).

3.3 Heavy fuel oil definition and fuel descriptions

In this report, heavy fuel oil (HFO) is regarded equivalent to oil with characteristics as specified by IMO in the amendments to MARPOL considering the protection of Antarctica from pollution from heavy grade oil, including:

- crude oil having a density, at 15°C, higher than 900 kg/m3;
- oil, other than crude oil, having a density, at 15°C, higher than 900 kg/m3 or a kinematic viscosity, at 50°C, higher than 180 mm2/s; or
- bitumen, tar and their emulsions.

HFO under this definition will typically include residual marine fuel or mixtures containing mainly residual fuel and some distillate fuel (such as intermediate fuel oil - IFO), corresponding to the RM(A, B, D .. etc) qualities under the ISO 8217 Specification of Marine Fuel. In industry terminology, such fuel may be called by different names, such as "heavy fuel oil", "heavy diesel oil", "residual fuel", "bunker", or just "fuel oil", or other.

Lighter products that do not exceed the specifications in the above definition will typically include distillate fuel - in this report referred to as marine gas oil (MGO) and marine diesel oil (MDO), or just distillates, normally corresponding to qualities within the DM(X, A, Z, B) of ISO 8217. Although the term marine diesel oil (MDO) as applied in this report refers to distillate fuels, MDOs may contain a small fraction of residuals, however not to an extent posing the specific environmental challenges associated with heavy fuel oil spills as described in Section 8.1. Marine gas oil (MGO) represents pure distillate fuels.

3.4 Application of AIS data

The introduction of an Automatic Identification System (AIS) for ships created a relative simple way of collecting detailed information on ship operations. The requirements for carriage of an AIS transponder is set by the SOLAS convention, making it mandatory for all ships above 300 gross ton, fishing vessels above 45m and all tankers and passenger vessels in international trade. The system was introduced by IMO to enhance the safety of ships and the environment and to improve civil traffic surveillance at sea. The AIS signals include information about the ship such as IMO number, ship details, course, speed, position, etc. The AIS signals are sent and captured (by land base stations) and results in a comprehensive database of ship movements.

AIS-coverage in Arctic waters has previously been limited or non-existent. However, in first half of 2010 a new satellite (AISSat-1) was launched enabling for world wide AIS coverage. The AISSat-1 project is a collaboration between the Norwegian Space Centre as owner, the Norwegian Coastal Administration (NCA) as data receiver and the Norwegian Defence Research Establishment (FFI) as responsible for the technical implementation. The satellite started collecting information in August 2010 and it circumnavigates the Earth 4 times a day. Hence data is collected with 6 hours cycles.

With support from the Norwegian Coastal Administration, DNV has been able to generate a relatively complete picture of the traffic pattern in the Arctic region over the months August through November 2010. There are seasonal variations in the Arctic shipping, and ideally an entire year should be covered. However, this study provides a comprehensive overview of vessels operating in the region, when the ice coverage is at its minimum between August - November. The data is made available to DNV under the strict agreement that only aggregated data is presented and on single vessels may be identified in the data.

As AIS transponders are not required for all ships, certain ship types may be underrepresented in the material. It may however be assumed that this is mainly small vessels. Still, the data analysis shows that a considerable number of the vessels identified are not required to carry an AIS transponder, by still have the system installed. Moreover, vessels not equipped with an AIS transponder are likely to be small and of little interest for the HFO fuel study.

3.5 Identifying the vessels within the Arctic

The AIS data from the AISSat-1 satellite has been collected from satellite launch in August 2010 to November 20th 2010. The data file received by the Norwegian Coastal Administration consisted of tens of thousands of ship registrations north of 52° N latitude. Using a GIS-tool (Geographic Information System) we reduced the data material covering only the Arctic region according to the specification presented in section 3.2. Based on this data set, which identified vessels submitting at least one position within the Arctic region, a complete list of vessels operating in the region for the given period was made.

The positions are generally logged with 6 hours intervals, but as the system has got no redundancy as per today, glitches in the data may occur due to reception problems or because the satellite has been "down" for maintenance. This may be seen as discontinued lines drawn on the map and/or lines crossing land. This has no practical relevance for the results as the main purpose is to map the relevant vessels in the region and only the main routes used.

The AIS data have several fields giving specific information on ship identification and ship particulars. However the ship particulars presented in the AIS source are limited and a link with a more comprehensive ship register is required for improving the data quality and for including additional information.

The link between the AIS data and the ship register are made through the fields "IMO number" and "Callsign". The "MMSI" field is unique for each ship and for that reason can be used as an additional source, hence this field is at the moment not included in the ship register.

DNV have a unique register of all DNV classified ships and in addition a register of all ships above 100 gross ton (Lloyds Fairplay). Both registers are consciously monitored and updated hence any changes of ship particulars will be captured. The ship registers contain several data fields which contain information that have been applied in this study.

The ship register contain among others information about ship type categories and ship size. For the purpose of sorting, aggregating and allocation of supporting data, the ships are categorised in 13 main ship categories and 7 gross tonne categories (13 x7 matrix). The main ship types and size categories are presented in Table 3-1. The appurtenant sub categories of ships are presented in Appendix II. It should be noted that all calculations are made on a single ship basis, and that the results are aggregated for the below ship types and size categories.

Table 3-1 Main ship type and size categories

Ship types	Size categories (gross ton)
Oil tankers	<1000 1000-4999 5000-9999 10000-24999 25000-49999
Chemical and product tankers*	
Gas tankers	
Bulk carries	
Container vessels	
General cargo	
Reefers	

Ro Ro vessels	50000-99999 >100000
Passenger	
Offshore supply vessels	
Other offshore vessels	
Other activities	
Fishing vessels	

* The majority of the vessels within this category are product tankers or combined chemical/products tanker. The actual type of cargo transported on these vessels does not appear from the data material; however different types of refined oil products will be common, as for the oil tankers.

The approach has been applied in a number DNV shipping assessment studies on behalf of Norwegian Authorities (see ref. /5/ and /6/).

3.6 Identifying the vessels using HFO as fuel

The identification of vessels operating on HFO in the Arctic is principally made through collection of AIS data and paring of the data set with databases for ship specific information and test results on supplied fuel qualities. In addition there are gather supplementary information and made assumptions. The analysis has been performed in a step-vice process as described below.

- The AIS data set for ship movements in the Arctic was paired with the ship register to incorporate ship specific information not found in the AIS data source. Additionally, the AIS data set was paired with the Veritas Petroleum Services (DNVPS) data base holding specific information on fuel qualities which are supplied to single ships operating in the region. The DNVPS undertakes fuel quality testing and holds a database with fuel test information for more than10,000 vessels world wide. Pairing of the datasets was done primarily by matching IMO number. If not successful, call sign, or finally ship names were applied for identification.
- The entire data set was then organized in a matrix as described in table 3-1. Based on the number of positive identifications of HFO within each ship type and size category, each vessel group where then evaluated for having a high likelihood of operating on HFO. Likewise for the most obvious non-HFO users, the ship types and size categories were excluded as HFO users. Based on this generalization the remaining vessels were organized as likely/unlikely HFO users.
- These two groups of vessels were then assessed with machinery data obtained through pairing the data with ship data base as well as searching for information in relevant databases (for example Russian vessels the fuel type is specified in the Russian Register which provided valuable input) for the purpose of confirming the assumptions made and for including additional information for the specific vessels. Based on this exercise the vessels were categorized as HFO/non-HFO vessels, all laid out as a matrix as shown in the **Table 6-1**.
- For a few vessels the undertaking was not conclusive and in these cases we made contact with the operators for a final confirmation.

The following assumptions have been made:

- All vessels having registered DNVPS samples of HFO are defined as a consumer of HFO.
- A vessel will chose to operate on HFO in the Arctic with the same considerations as for normal world wide operation.
- Vessels with large, long stroke and slow speed (< 200 RPM) machinery are assumed to operate on HFO.

Results from the analysis are found in section 6

4 TECHNICAL AND PRACTICAL ASPECTS OF USING HFO IN THE ARCTIC

Use of HFO in Arctic waters represents additional challenges related to temperature and ensuring a correct liquidity of the bunker oil, however it is not in general considered technically or practically inappropriate for use in cold climates. The below sections give a brief introduction to technical feasibility, classification rules and user-experiences regarding the use of HFO in cold climate shipping.

4.1 Technical feasibility

Utilising HFO requires, in any case, pre-heating of the fuel to a temperature to make the fuel sufficiently fluid for pumping, separation etc. The need for heating may typically be higher in cold climates, and the available time for restart of machinery during a black-out will be shorter due to faster cooling of the machinery spaces in cold climates. As an alternative to HFO, vessels may utilise distillate fuels (MDO/MGO) which is significantly less viscous than HFO, and requires less or none (MGO) pre-heating and processing before injection into the engine.

A typical heavy fuel oil quality known as IF380 will have a kinematic viscosity of 380 mm^2/s (cSt) at 50ºC, while MGO will have a kinematic viscosity of 6 mm^2/s at 40ºC. Furthermore, the pour point[1] of winter quality fuel will be 30ºC for HFO, while the equivalent for distillate fuels is 0ºC to -6ºC. This means that HFO is in a viscous state at room temperature while distillates generally are highly fluid. A typical HFO fuelled configuration requires pre-heating of fuel to 45ºC in the fuel tank before being pumped further into several heaters, increasing the temperature in two rounds upon delivery to the settling tank and service tank. The lower the temperature, the more energy is needed to heat the fuel and keep it at a sufficient temperature. Heating the fuel and keeping at a stable, high temperature during winter requires minimum two to three times the energy as opposed to summer.

Most marine engines running on HFO will have been designed for operation also on distillate fuels of marine diesel oil quality (ISO DMB quality), but not necessarily on marine gas oils (ISO DMX/DMA/DMZ quality). Pumping fuels with too low viscosity into machinery not designed for such may lead to technical problems.

[1] Pour point refers to the temperature at which the fuel transitions from a liquid to a solid state.

4.2 Classification rules

As a basis for being prepared for Arctic conditions, several classification rules pertaining to vessel preparedness for ice and colder climate need to be fulfilled. For cargo ships or other vessels in commercial operation, excluding ice breakers, the Polar Class notations PC-1 to PC-7 and WINTERIZED, according to the DNV Rules for Classification of Ships, is an example of such a rule set. The following section gives an overview of requirements under the winterization rules (using the DNV rules as an example) pertaining to the fuel and cargo system, where HFO, marine diesel- and gas oils could be present. Both Polar Class and WINTERIZATION are today voluntary notations specified by the owner.

The WINTERIZATION class rules are summarized in **Table 4-1** below.

Table 4-1 DNV Winterized Notation, ref DNV Rules for Classification of ships, Part 5, Chapter 1, Sec 6

WINTERIZED ARCTIC: ▪Built to higher ICE, Polar Class or ICEBREAKER class ▪Requirements to CP propeller, or diesel/electric ▪Propeller material (austenitic stainless steel or equiv.) ▪Two engine rooms for Power, AUX, and heating ▪**OPP-F** and Oil outflow index less than 0.01 according to MARPOL ▪Helicopter landing facilities ▪Life saving and navigation equip certified for low temperatures
WINTERIZED COLD ▪Built to BALTIC or ARCTIC ice class ▪Requirements to location of safety equipment ▪Requirements to steel grades, DAT(-xx) notation - Low temp. materials hull - Low temp. material equipment - Propeller material
WINTERIZED BASIC ▪Arrangements for anti-icing and de-icing ▪Heating of spaces with important equipment ▪Arrangements and location of generator capacity

WINTERIZED COLD notation gives requirements to documentation of heat balance calculations to ensure sufficient heating. Moreover, the notation is specific on requirements to the fuel and cargo systems:

- The fuel oil storage tanks shall be provided with sufficient heating enabling transfer of fuel and fuel oil transfer lines exposed to the low temperature environment shall have heat tracing. This means that vessels with this notation need to have heating of fuel tanks and heat tracing of oil transfer lines, regardless of fuel type.
- The cargo manifold and manifold valves on tankers shall be located in a semi-enclosed space. If protection by a semi-enclosure is impracticable alternative arrangements may be

considered, e.g. hot water for de-icing in combination with heat tracing of valves and portable covers with heating.
- The engine room and other spaces containing important equipment shall be fitted with heating unless the equipment and piping installations are so designed and/or heated that they can operate at the lowest indoor temperature that can be generated by the lowest outdoor temperature, t_2, defined in the notation, with realistic space ventilation. Insulation of these areas should also be considered in order to improve heating efficiency.
- All equipment exposed to the low temperature and being important for ship operations shall be made from materials suitable for the material design temperature specified in the class notation.

The WINTERIZED ARCTIC notation gives especially stringent requirements to fuel and cargo systems. In addition to the requirements in the WINTERIZED Basic and Cold, the cargo oil lines shall be located under deck or inside a deck trunk, except for the loading and unloading manifold. Furthermore, the bunker capacity shall be sufficient for at least 30 days operation of the ship's accommodation power, in addition to what is needed for the transit distance.

Icing of deck space and cargo structures (Eknes, 2004)

4.3 User experiences

In order to give a brief insight into actual operational experiences about the use of HFO in the Arctic, DNV has been in contact with selected cold climate shipping operators. The following chapter summarizes the views and discussions from communication with the operators on the topic.

4.3.1 Tschudi Arctic Transit (TAT)

TAT specialise in ship to ship transfer of distillates and naphtha (petroleum products) for clients transporting these products in high volumes from Northern Russia to the USA and Europe. The background for doing STS transfer is difficulties with quay limitations and ice class requirements for docking quayside. Although the STS operations are not conducted in the Arctic, but in Northern Norway, TAT have extensive experience in handling of petroleum products in cold climate. The feedback from TAT is that they have never experienced problems in the transfer operations they have conducted. Furthermore, all vessels that TAT have conducted STS for have been fuelled by HFO and TAT have never experienced a ship being late for scheduled operations. The vessels regularly arrive from cold regions as for example the White Sea, where the winter temperatures can reach -40 ºC. The conclusion TAT draws from this is that using HFO in the Arctic region does not pose much of a challenge for experienced operators.

Ship to ship transfer in winter conditions (Tschudi Arctic Transit, 2010)

4.3.2 Swedish Maritime Administration (SMA)

The SMA operate several ice breakers that provide ice breaking services in the Gulf of Bothnia, in addition to contributing to polar expeditions. The ice breaker *Oden* has undergone bunkering in the Arctic, but only during summer season. If *Oden* were to bunker in the Arctic during winter, this would be done in the same way the SMA bunker their ice breakers in the Gulf of Bothnia in the winter season. These fuelling operations are conducted while at sea, utilising ship to ship transfer of fuel from a tanker. The operation is done in a fjord or when situated still in the ice to ensure calm conditions. The SMA seeks to avoid bunkering while in the Arctic, and the fuel storage capacity of the *Oden* is designed to be sufficiently large to facilitate this.

The *Oden* is designed with two separate tanks and fuel systems to enable supply of fuel to the engine from independent systems. Steam is used for heating of HFO and the volume of steam needed for heating while in the Arctic is large, but does not surpass the volume needed when operating in the Gulf of Bothnia. Operation in the Arctic is not a special case as such, but the main issue is if the boilers were to fail when in the Arctic because of greater distances (wrg to repairs) and demanding ice conditions. Furthermore, the handling of sludge from the HFO separators is an issue since the sludge has to be stored onboard until the ship returns to shore. To avoid complications, *Oden* always carries some volumes of distillate fuel in case of boiler failure. Onboard Oden, the distillate fuel is also heated before being pumped to the separators. After pumping to the engine, excess fuel is returned to the service tank. In general, fuel that is returned to the service tank has to be cooled to avoid gas vaporisation from the fuel. On the *Oden* this is not an issue because the return fuel lines are sufficiently long for natural cooling.

The low price of HFO over marine distillate fuel is a strong driver for continued use of HFO, but a ban on use of HFO in Antarctic waters south of S 060º means that *Oden* will be refitted for solely distillate fuel from summer 2011.

4.3.3 Royal Arctic Line (RAL)

RAL operate a cargo liner service between Denmark and Greenland with a fleet of 10 vessels. All the vessels run on HFO after the Irena Arctica was converted from distillate fuel to HFO operation during spring 2010. Based on operational experience with both HFO and distillate in the Arctic, the feedback from RAL is that in general there are no differences in operating the vessels on distillates or HFO. For HFO operations there is an increased capacity on boilers due to the extra amount of heat needed for HFO handling, in addition to possibly higher heating capacity demands for separators, booster unit and heat tracing on pipes. RAL would ultimately like to run their vessels on MGO since it is a cleaner fuel than HFO, resulting in longer maintenance intervals. However, the significantly higher price of MGO means that this alternative is not considered profitable.

5 PATTERN OF SHIP TRAFFIC IN THE ARCTIC

This study bases its understanding of the marine traffic patterns and volumes solely on data received by the AISSat-1 satellite (see described methodology in Section 3). In general the data was found to be of good quality and provides a representative selection of vessels populating the region.

5.1 Type and number of vessels

Table 5-1 and Figure 5.1 show the number of unique AIS registered vessels in the Arctic from August through November 2010. The vessels operating in the Arctic region are dominated in number by the fishing vessels – followed by a diverse group of vessels within the category "Other activities" such as different service ships and research vessels, in addition to local community support vessels (cargo ships) and passenger vessels. The vast majority of the vessels are smaller ships (less than 5000 GT).

Table 5-1 AIS registered ships within the Arctic from August through November, 2010

Ship type and size category (gross ton)	< 1000	1000 - 4999	5000 - 9999	10000 - 24999	25000 - 49999	50000 - 99999	> 100000	All sizes
Oil tankers	0	19	9	8	7	1	0	44
Chemical and product	1	11	5	9	1	0	0	27
Gas tankers	0	0	0	0	0		1	1
Bulk carries	0	2	1	23	26	0	0	52
Container vessels	0	0	5	7	0	0	0	12
General cargo	6	69	19	11	1	0	0	106
Reefers	1	24	13	5	0	0	0	43
Ro Ro vessels	1	1	2	1	0	0	0	5
Passenger	3	13	6	9	8	4	1	44
Offshore supply vessels	6	18	6	0	0	0	0	30
Other offshore vessels	3	1	1	1	0	0	0	6
Other activities	110	58	12	19	1	0	0	200
Fishing vessels	159	211	13	1	0	0	0	384
Sum	290	427	92	94	44	5	2	954

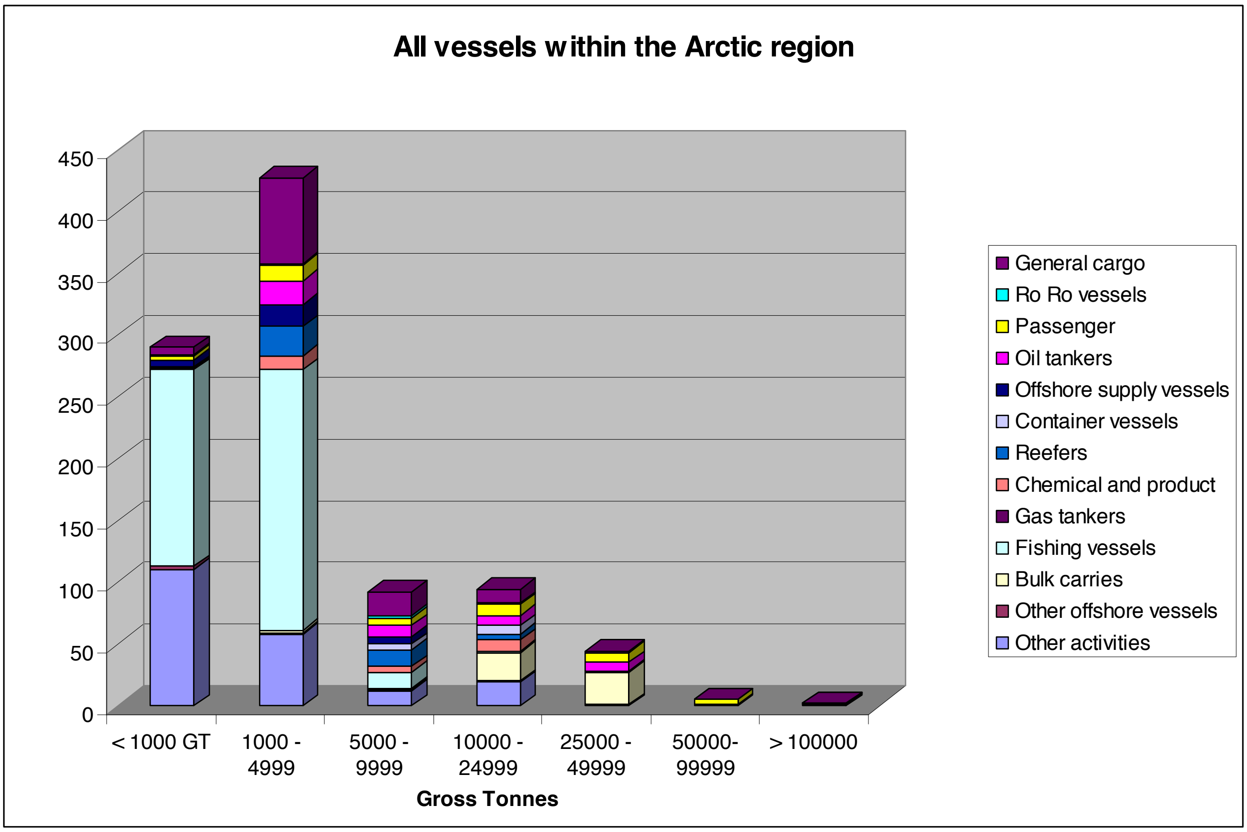


Figure 5.1 AIS registered ships within the Arctic from August through November, 2010

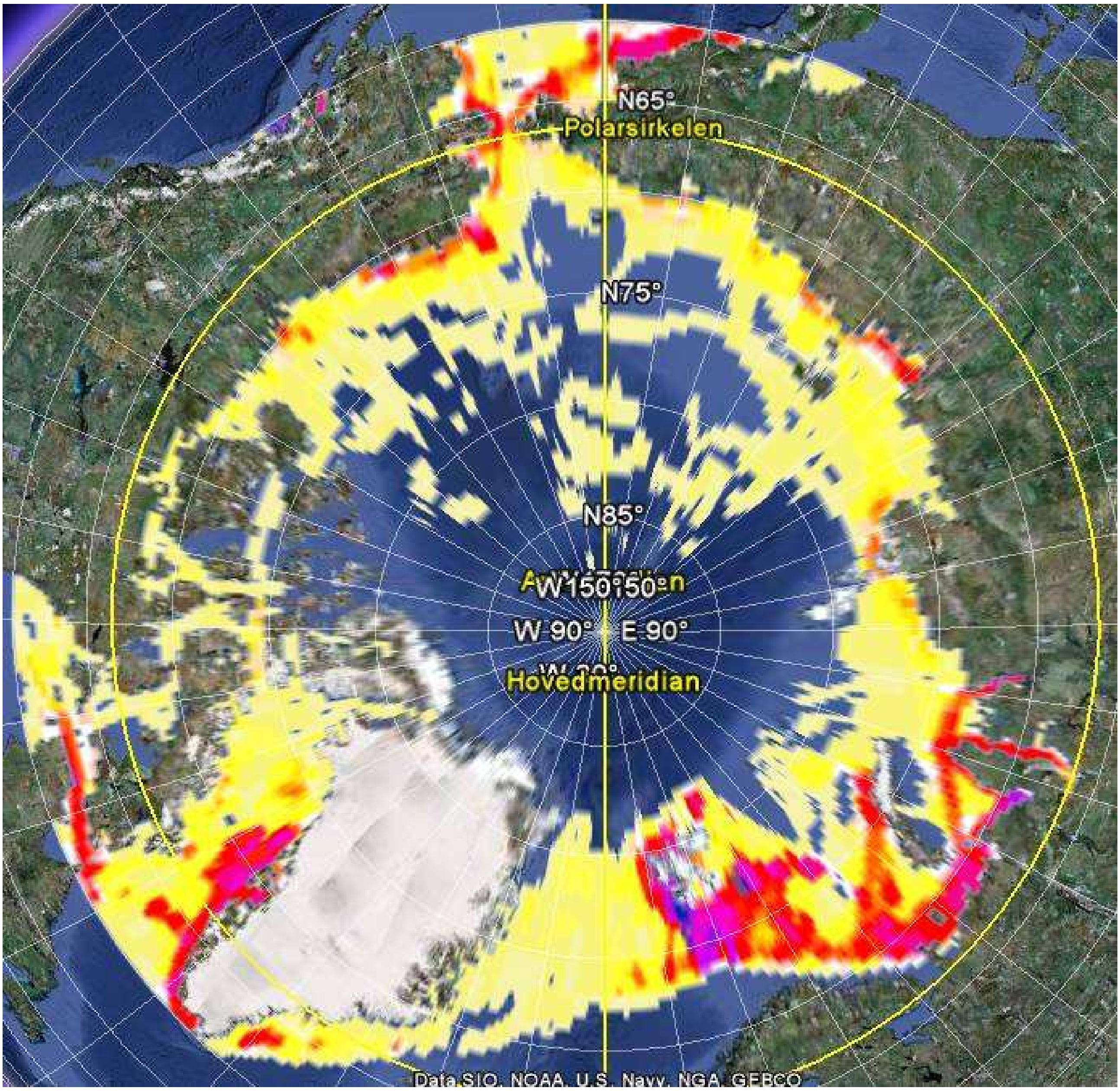
5.2 Traffic patterns in the Arctic

In addition to providing information for ship identification and particulars, the AIS data provides positions of any given vessel, updated with 6 hours intervals. This allows us to plot the traffic density and routes from all the individual vessels over the entire period. Section 5.2.1 illustrates the traffic density for the registered shipping activity, while Section 5.2.2 shows the ship tracks. Note that we have included on the density plots and ship track plots a couple of areas outside the defined zone (but north of 60° latitude), namely parts of the Gulf of Alaska and the Sea of Okhtotsk. Vessels appearing exclusively in these areas (about 150 vessels) are not included in the data material, neither the diagram shown above.

Section 5.2.3 shows the registered ship tracks from the different ship types separately.

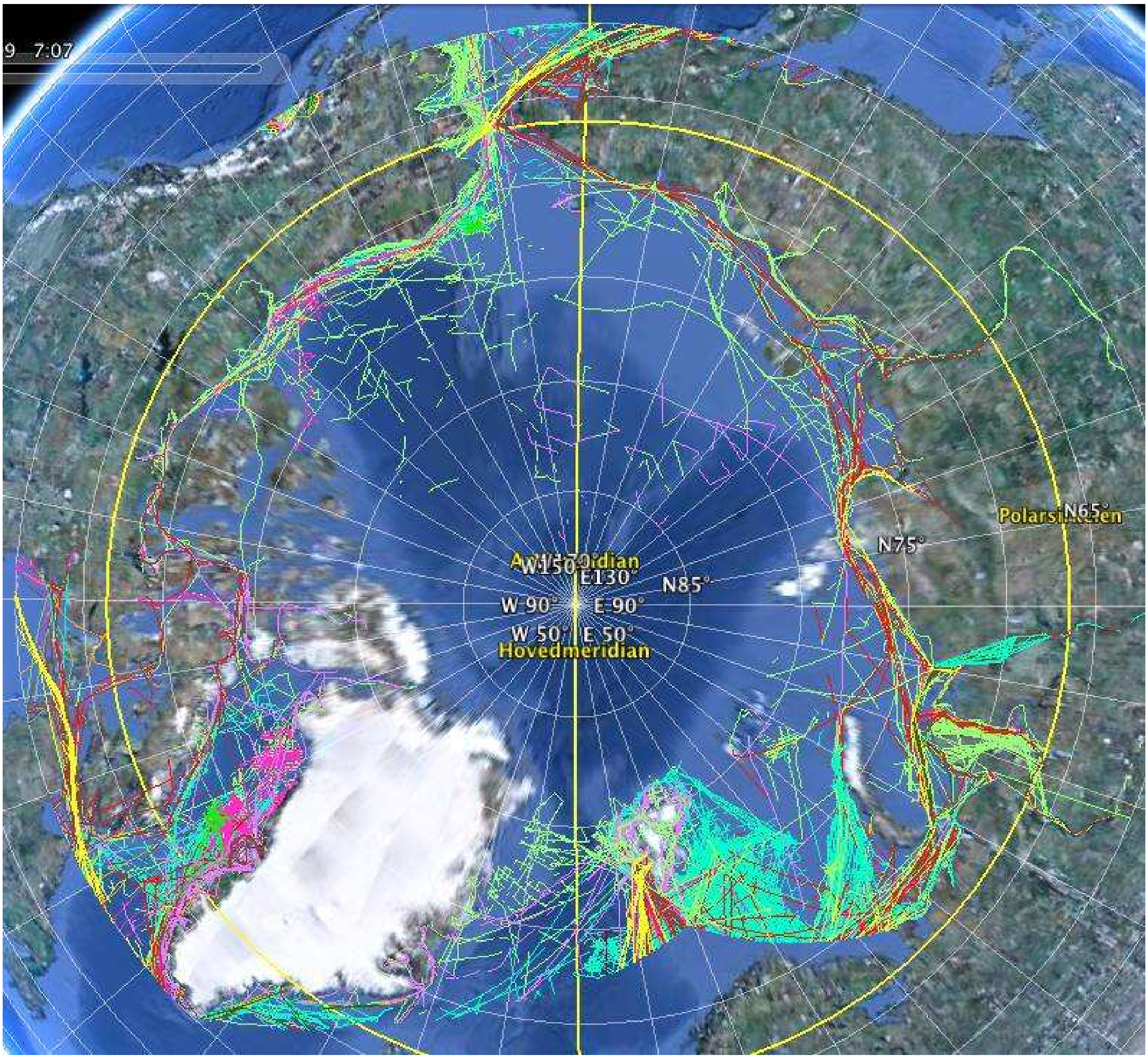
As described in Section 5.4, the below traffic plots are just snap shots from the digital map tool (Google Earth based), containing the dataset for identified ship activities and HFO use. To be able to study the actual patterns with greater sharpness and detail, it is referred to the digital tool.

5.2.1 All vessels in the Arctic – Density plot



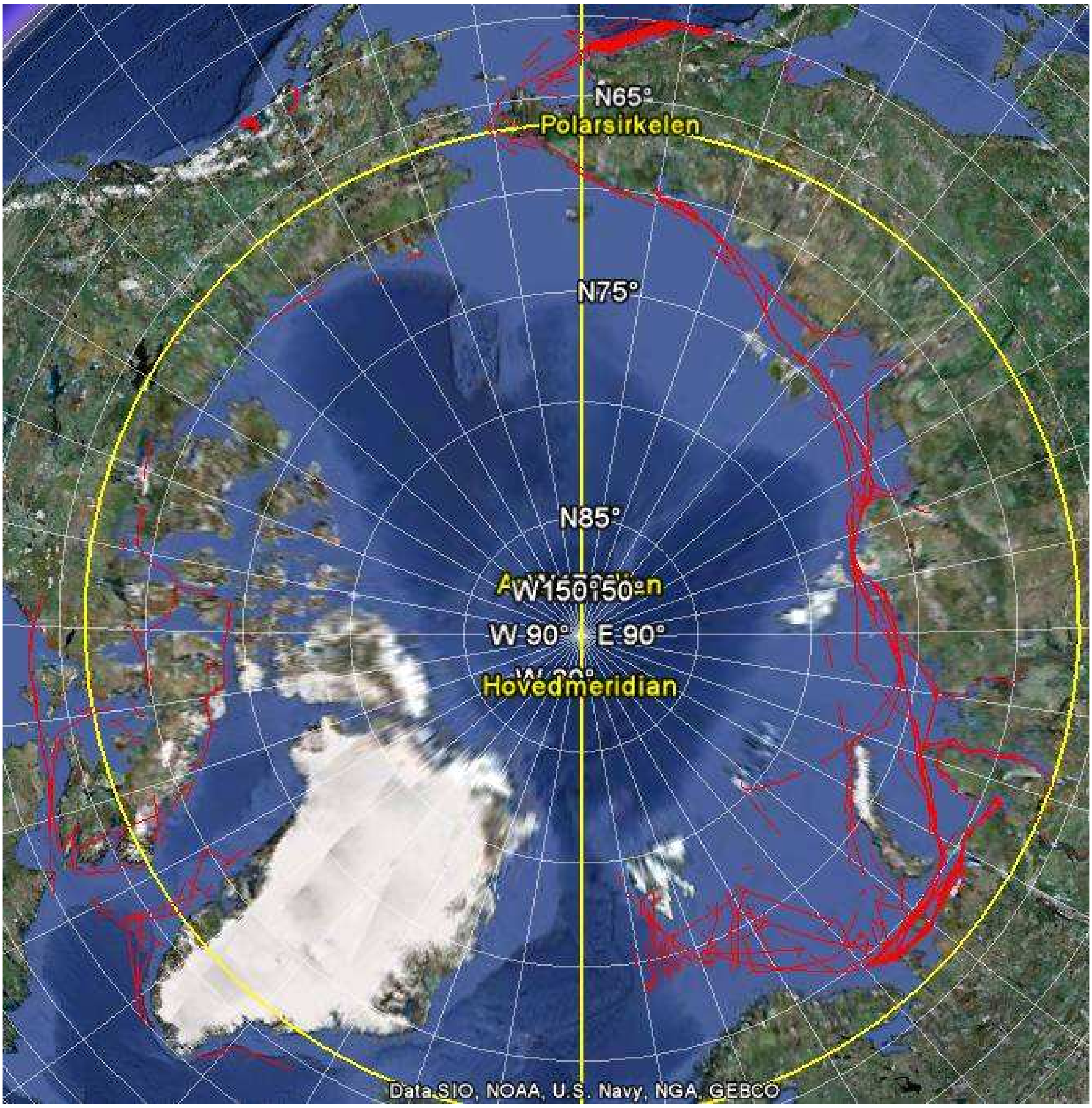
(Yellow colour: Low density, Red: Medium density, Blue: Highest density)

5.2.2 All vessels – ship tracks



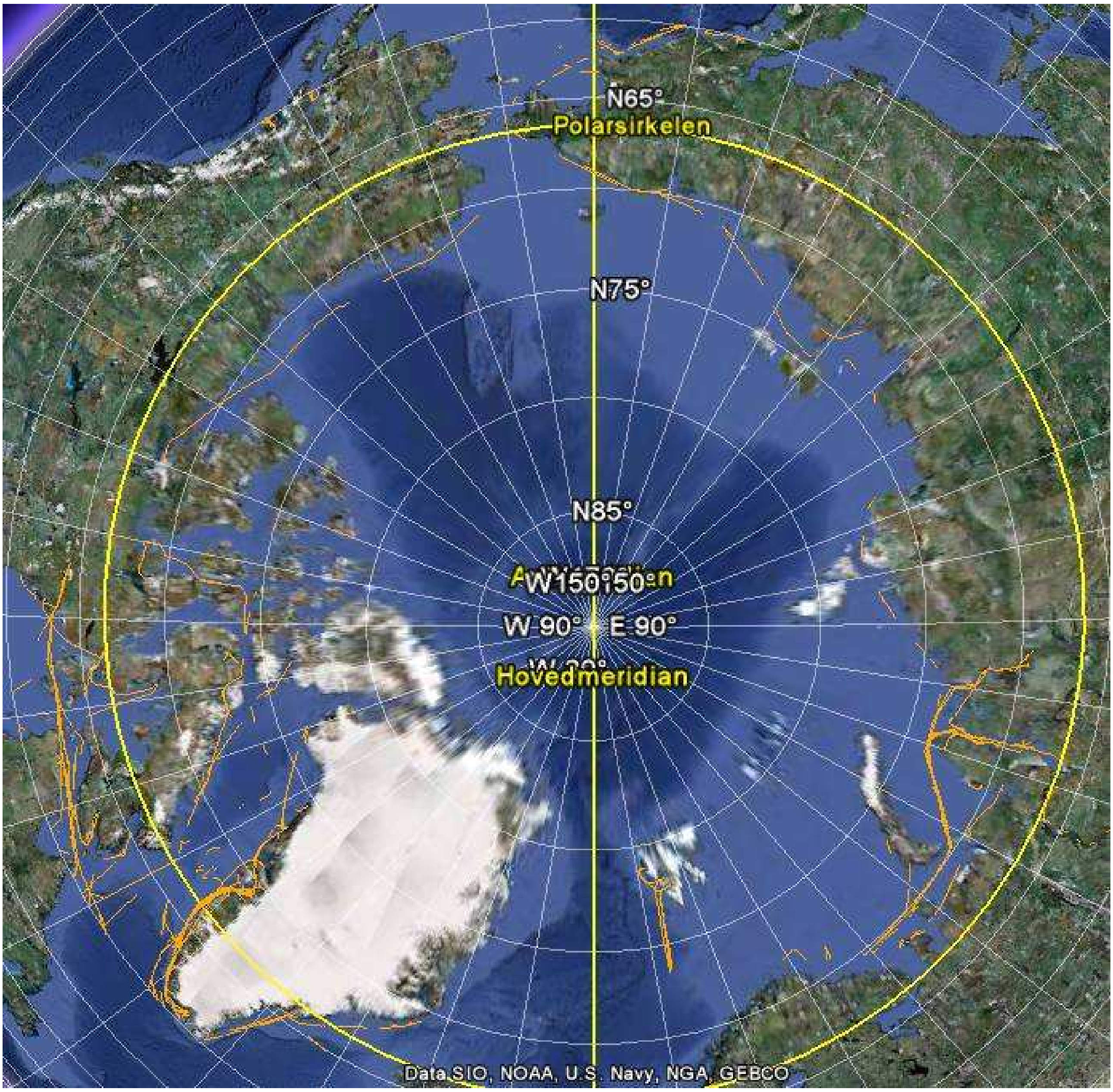
5.2.3 Individual vessel types

5.2.3.1 Oil tankers



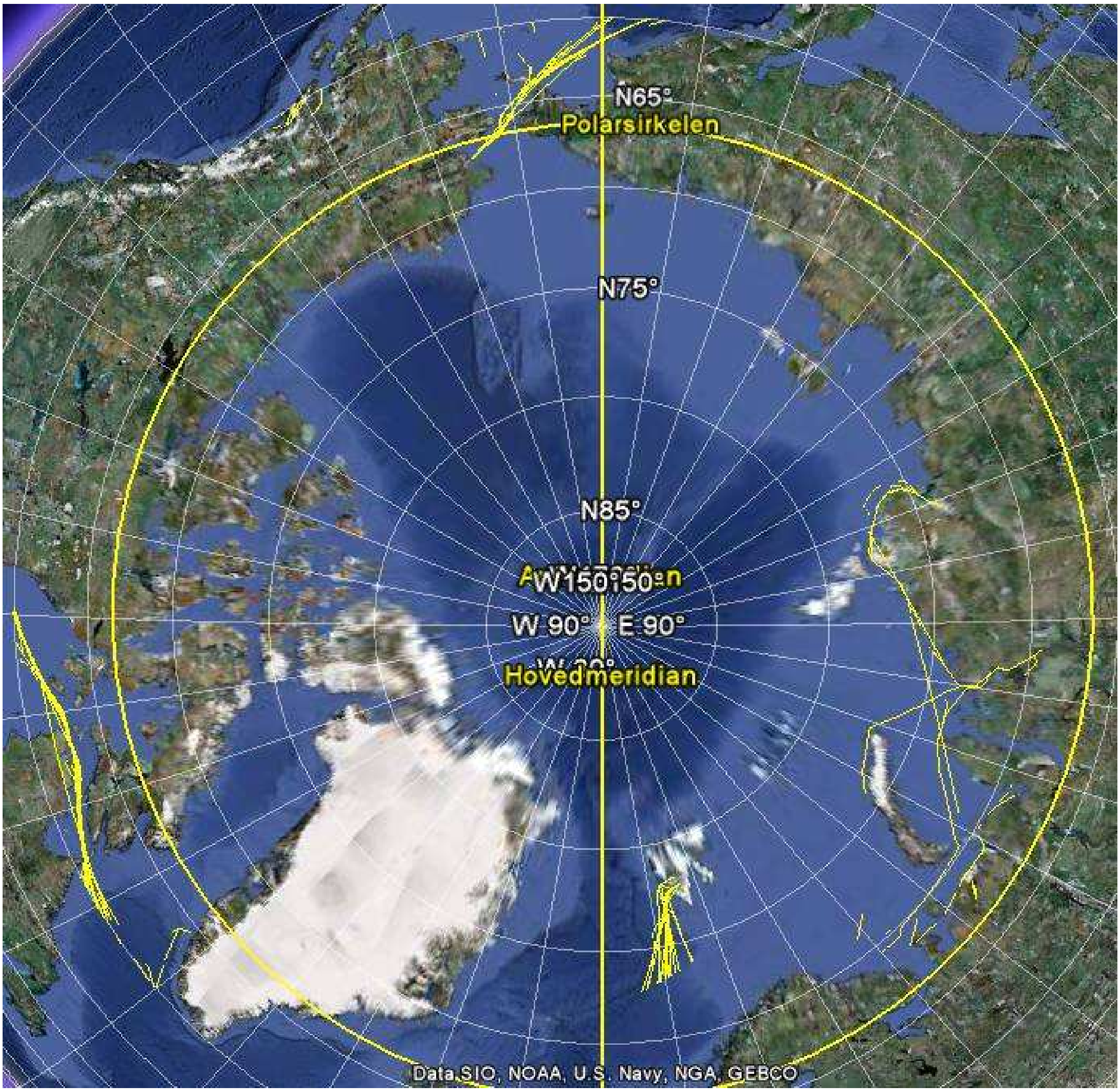
The oil tanker traffic is dominated by the traffic along the north coast of Russia and in addition activity on the Russian side of the Bering Sea.

5.2.3.2 Chemical/product Carriers



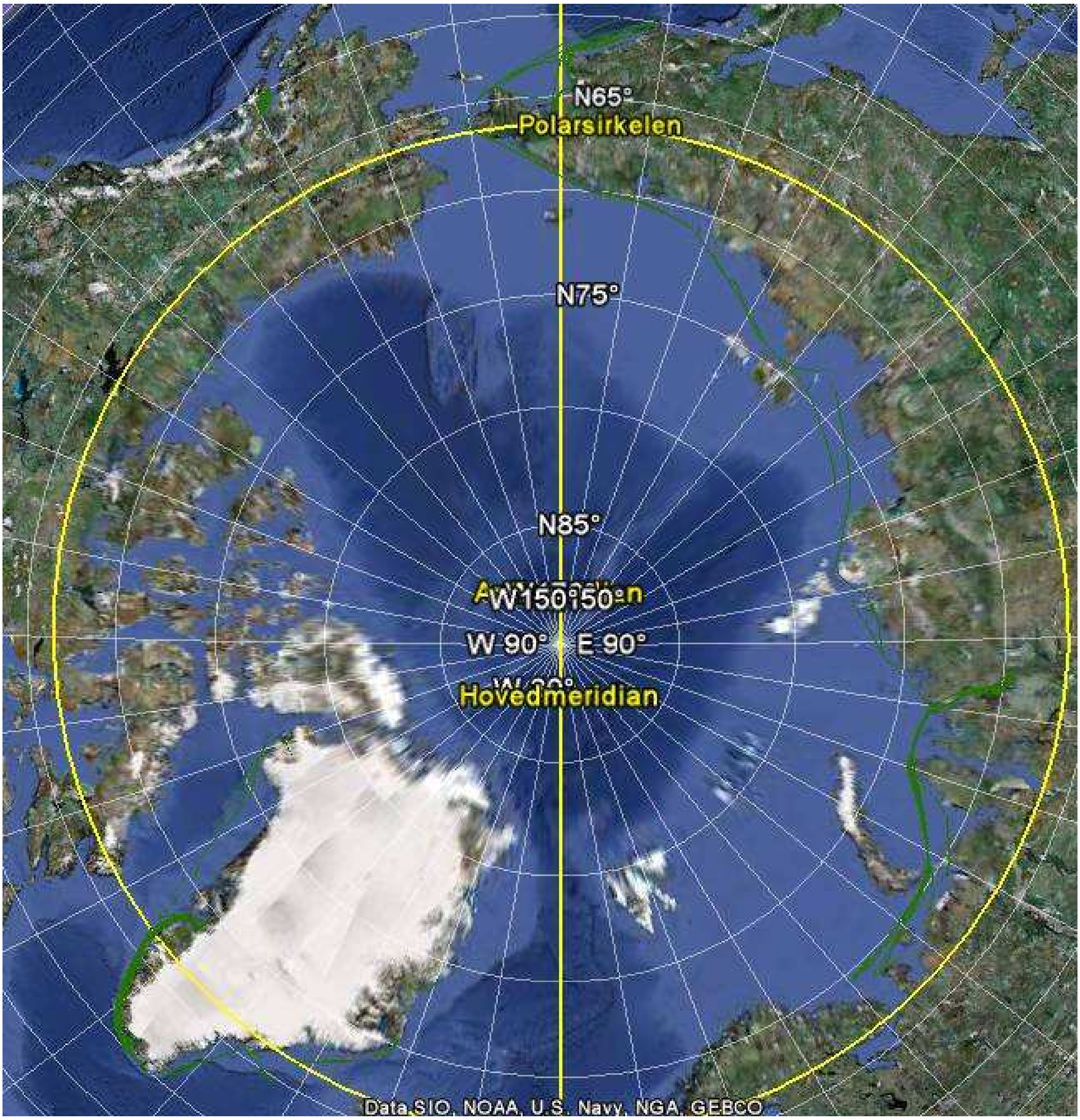
The chemical/product carriers follow much of the same routes as the oil tankers except considerably less traffic in the Russian Arctic.

5.2.3.3 Bulk Carriers



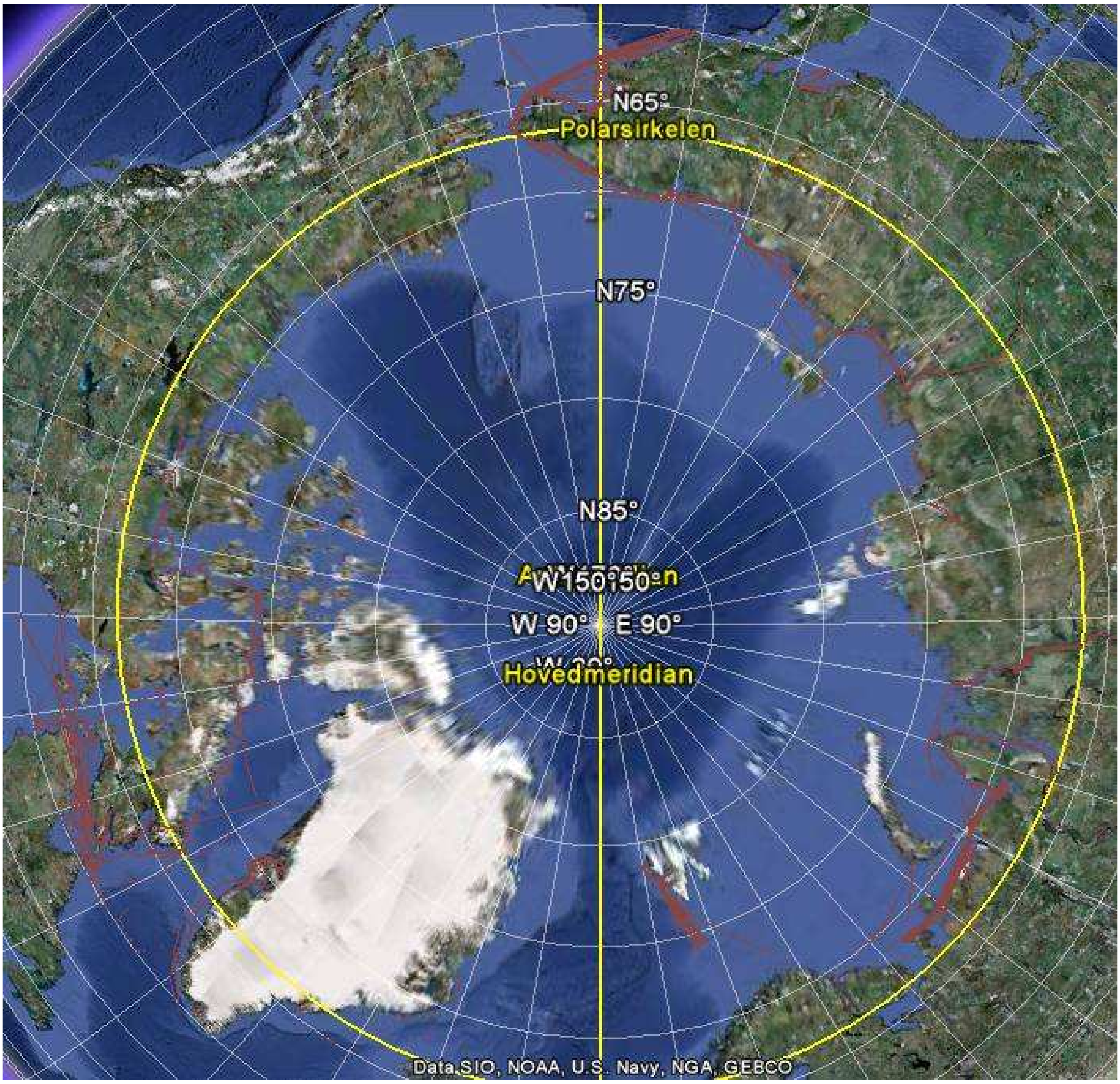
The bulk carriers dominate among the larger vessel size categories trafficking the Arctic. The trade is concentrated to 3 main ports; i.e. shipping of coal from the Svea Mine at Spitsbergen, Zink and lead export from the Red Dog mine in Alaska and finally traffic in to Churchill in the Hudson Bay in Canada.

5.2.3.4 Container vessels



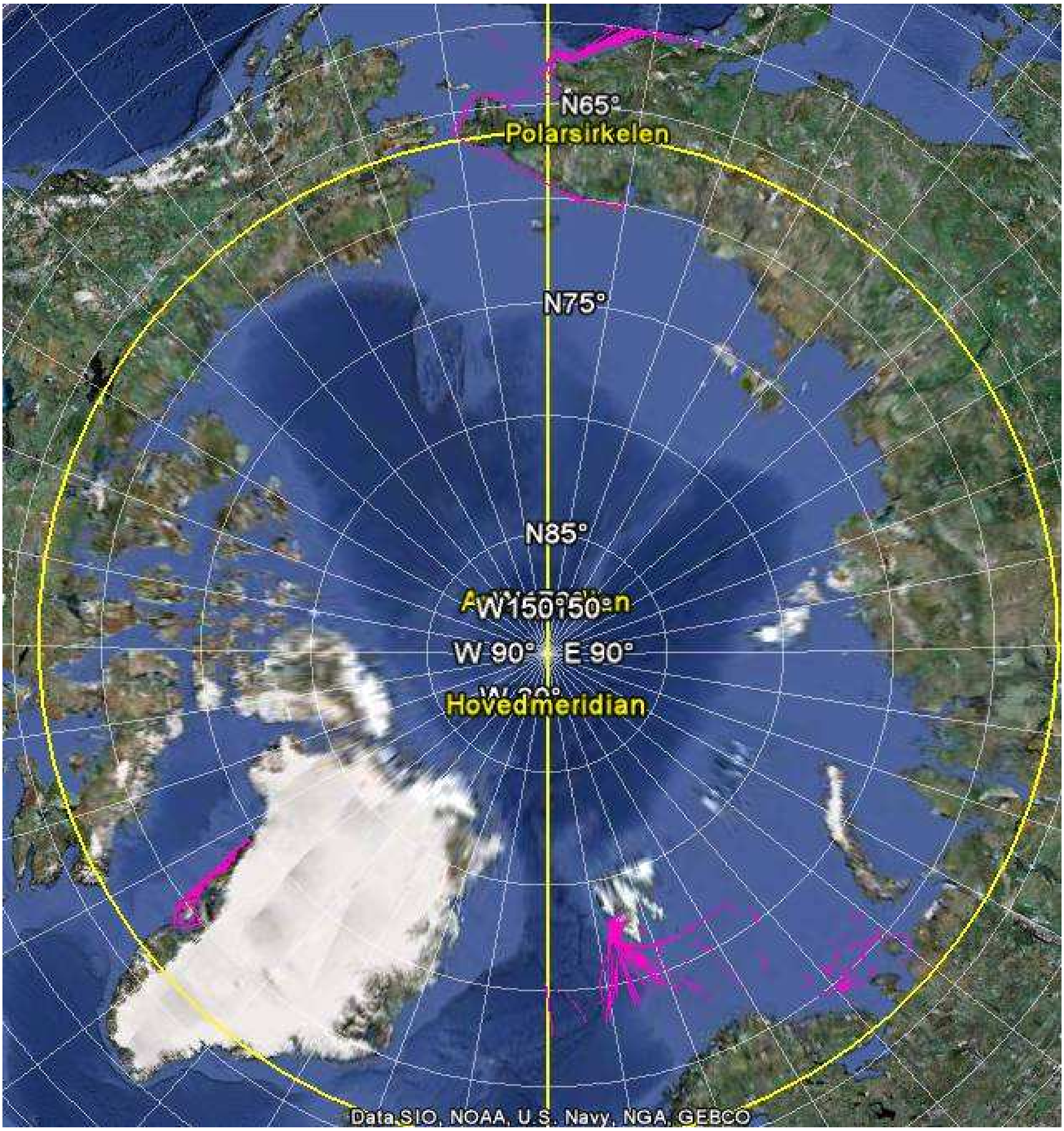
The container traffic is generally limited to a few ports, dominated by transport in and out of Greenland and a major shipping route along the northern coast of Russia in to the port of Dudinka in Siberia. In addition we see a couple of transits along the North East passage, and a number of ship movements along the North-East passage.

5.2.3.5 General cargo vessels



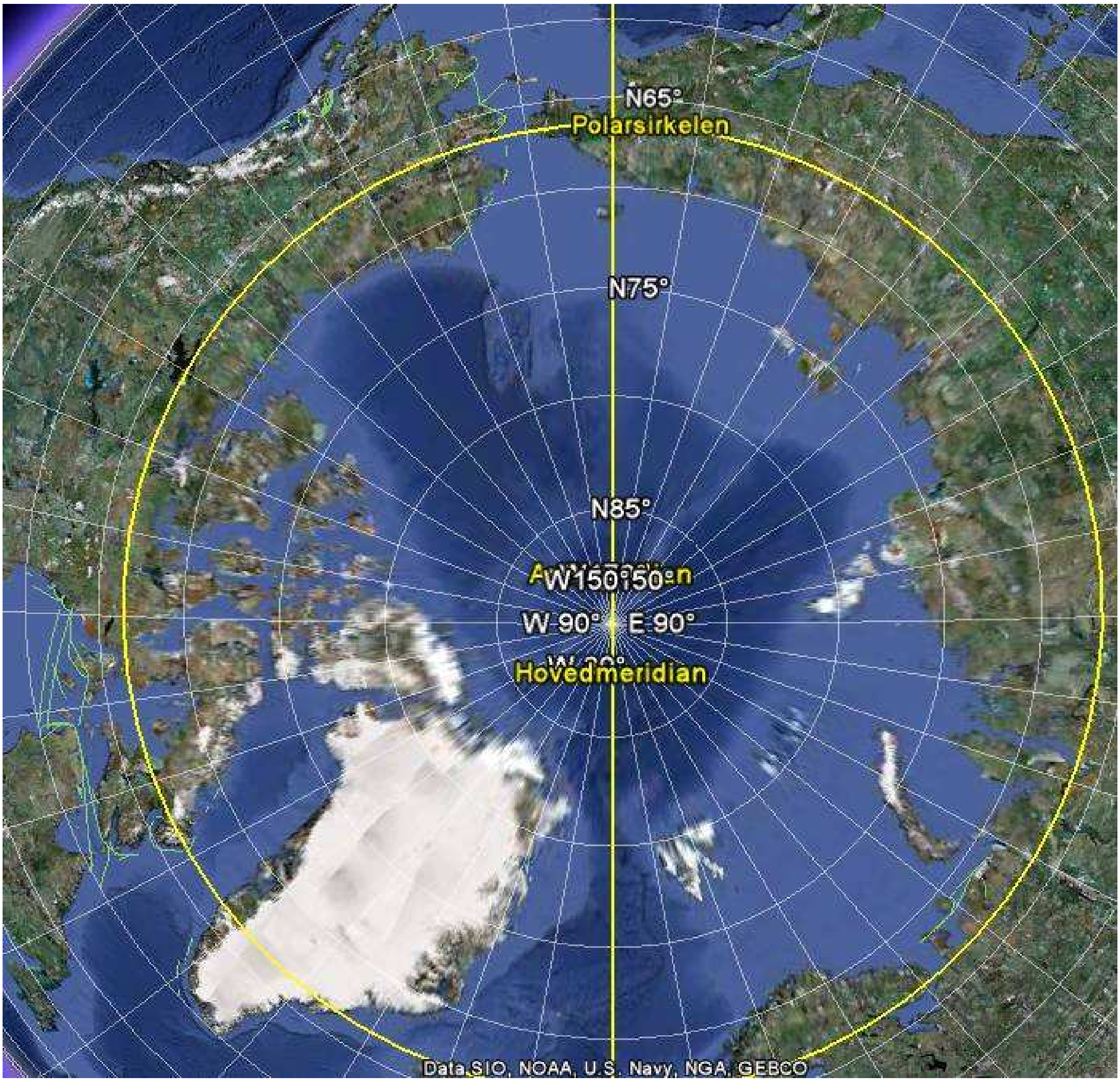
The general cargo vessels are numerous; serving the main part of the local settlement supply. The vessels are generally small.

5.2.3.6 Reefers



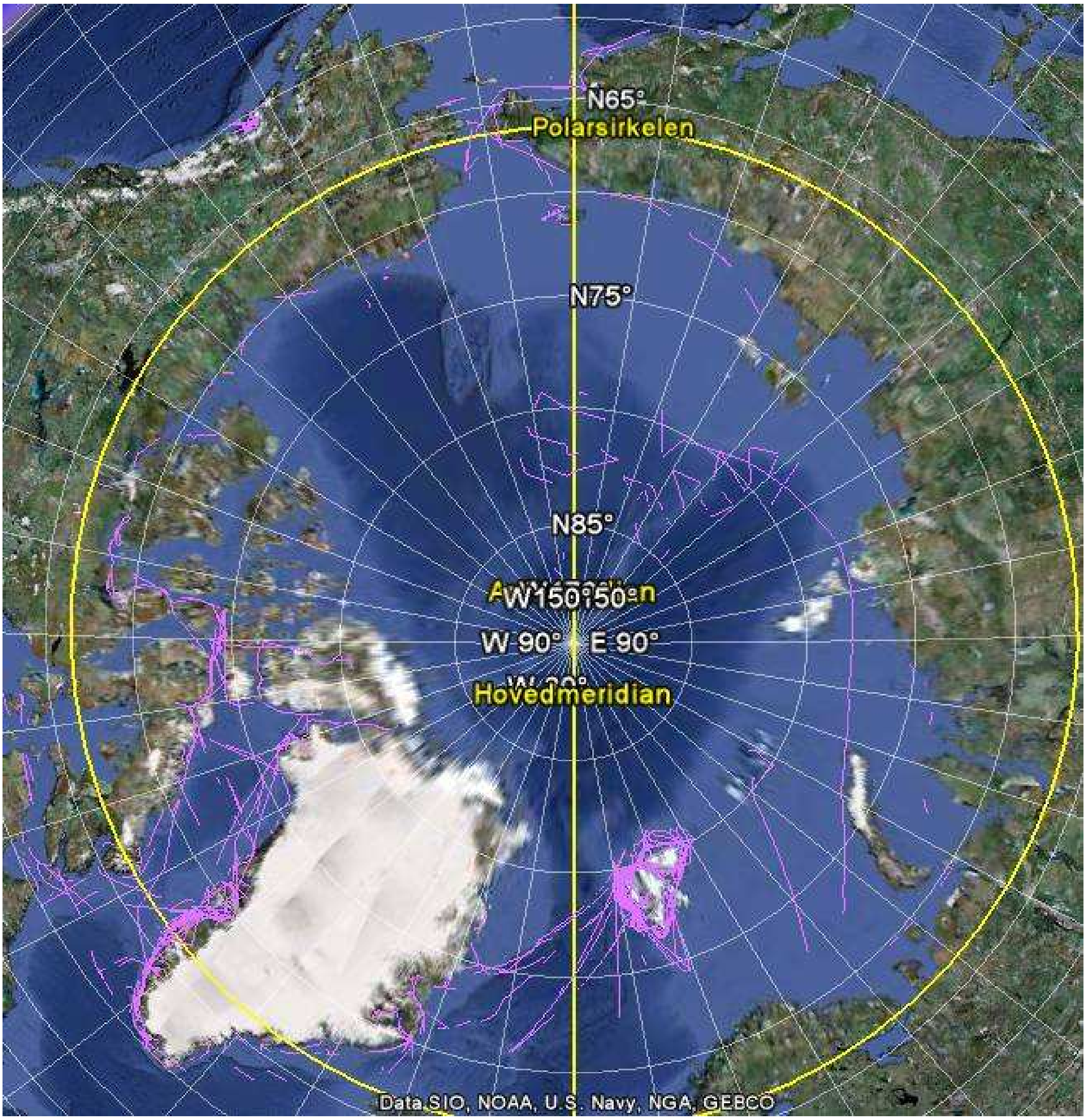
The reefer traffic in the region are concentrated to areas with fisheries and human settlements, with the major traffic along the west coast of Greenland, Svalbard and Russian coast towards the Bering Straight and the Bering Sea.

5.2.3.7 Ro-Ro vessels



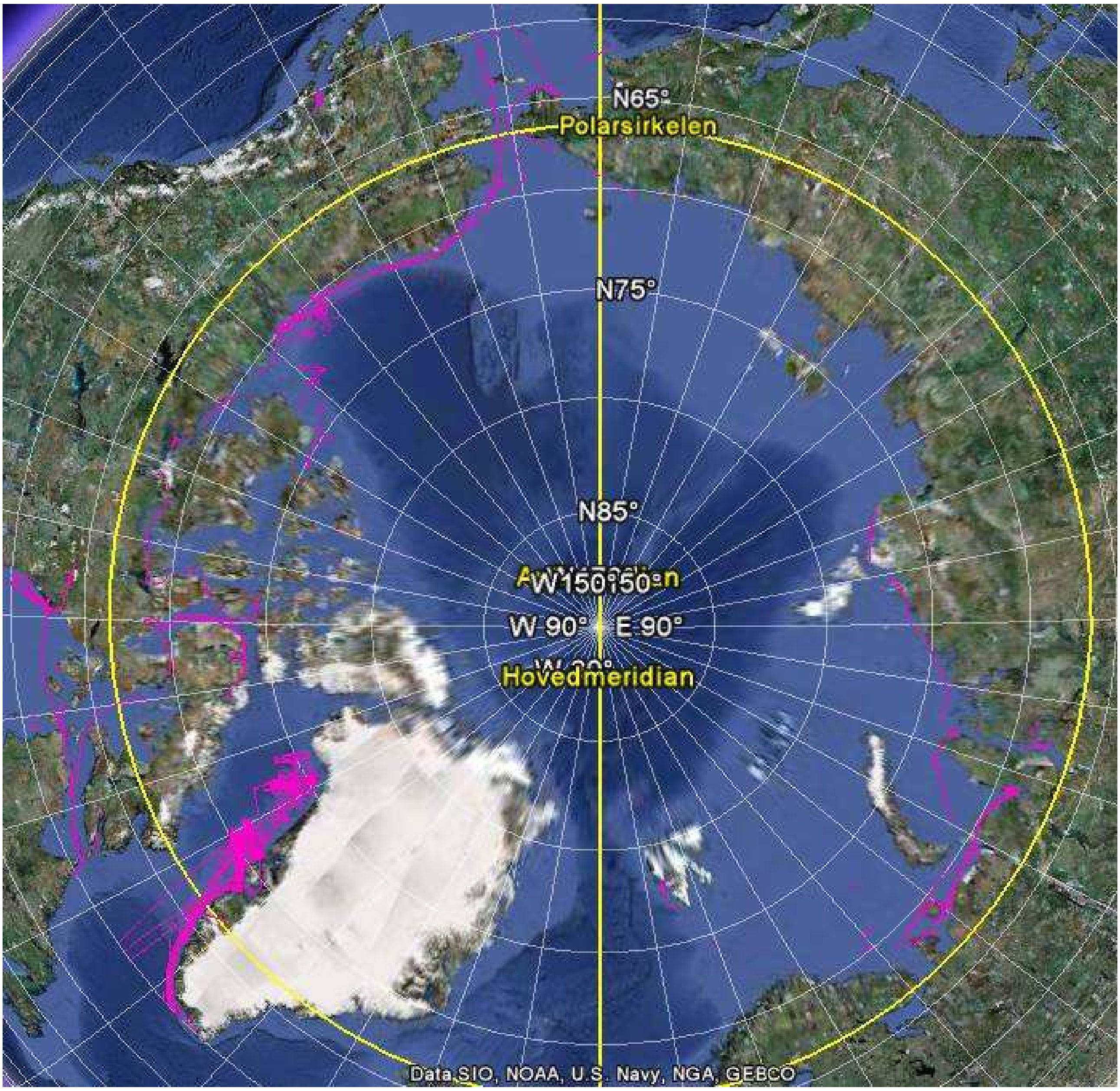
In general this is a very marginal group of vessels within the Arctic, consisting of smaller cargo vessels and landing vessels, typically part of the local community supply. Within our sample period we observed a few ship movements from south in to Hudson Bay as well as some scattered activity south of Novaya Zemlya and along the north coast of Alaska.

5.2.3.8 Passenger vessels



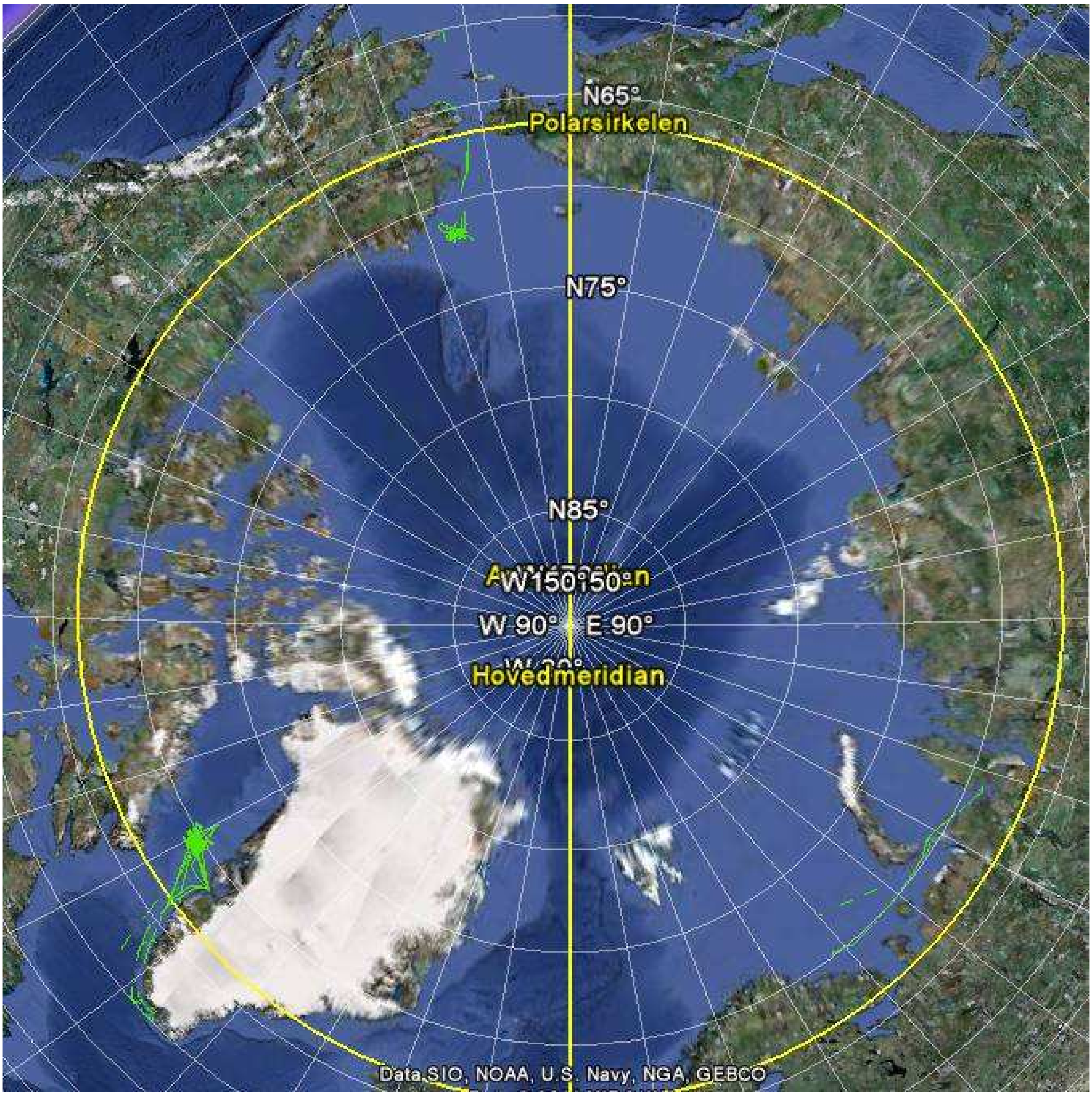
The passenger ships (mainly cruise and tourism related traffic) concentrate around two areas – Spitsbergen and the vest coast of Greenland.

5.2.3.9 Offshore supply vessels



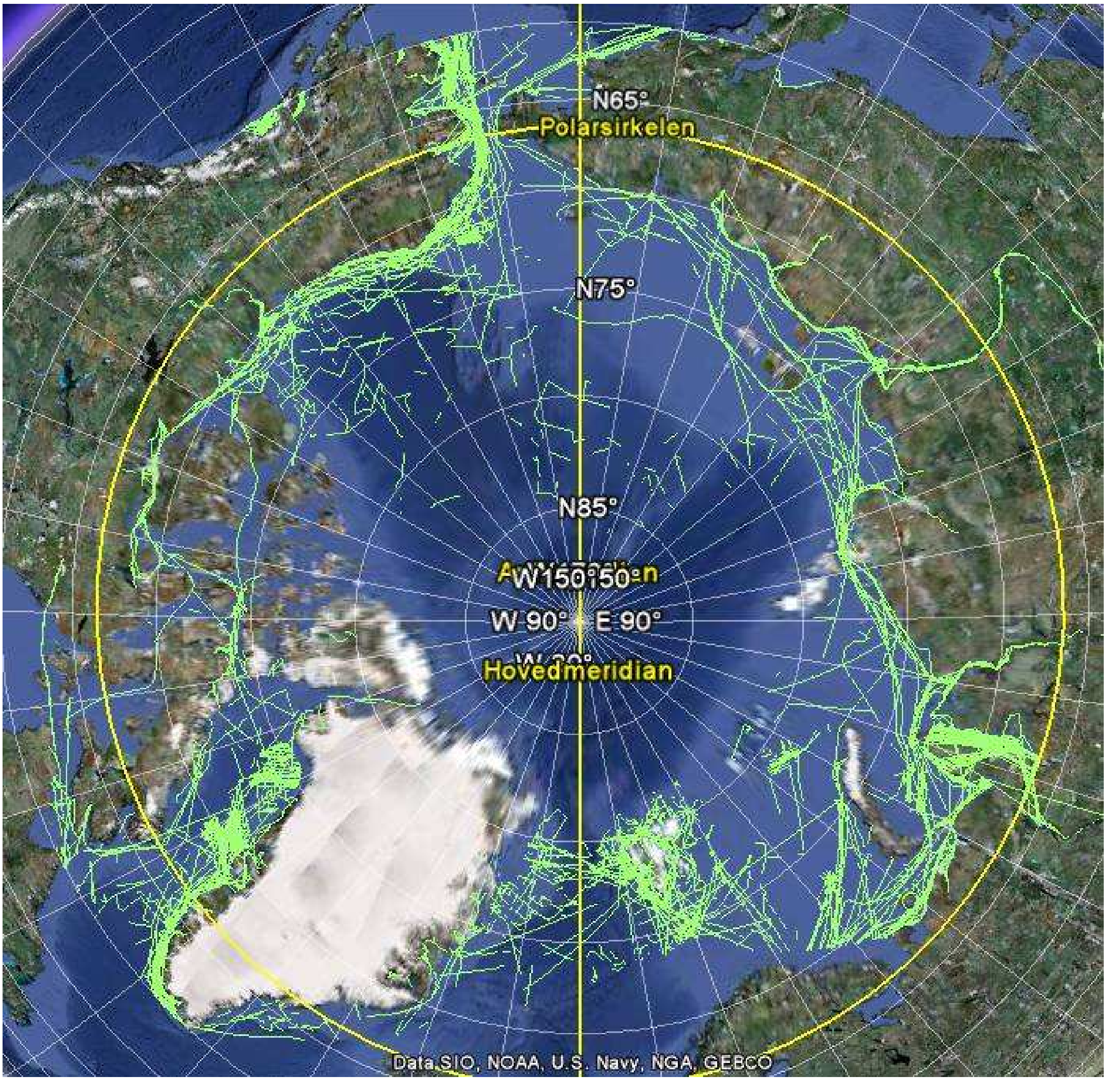
This group consists of offshore supply vessels and offshore tugs, operating mainly off the vest coast of Greenland plus activity in the Canadian Basin and in the Kara Sea. The remaining activity seems to mainly be transit to and from these areas.

5.2.3.10 Other offshore vessels



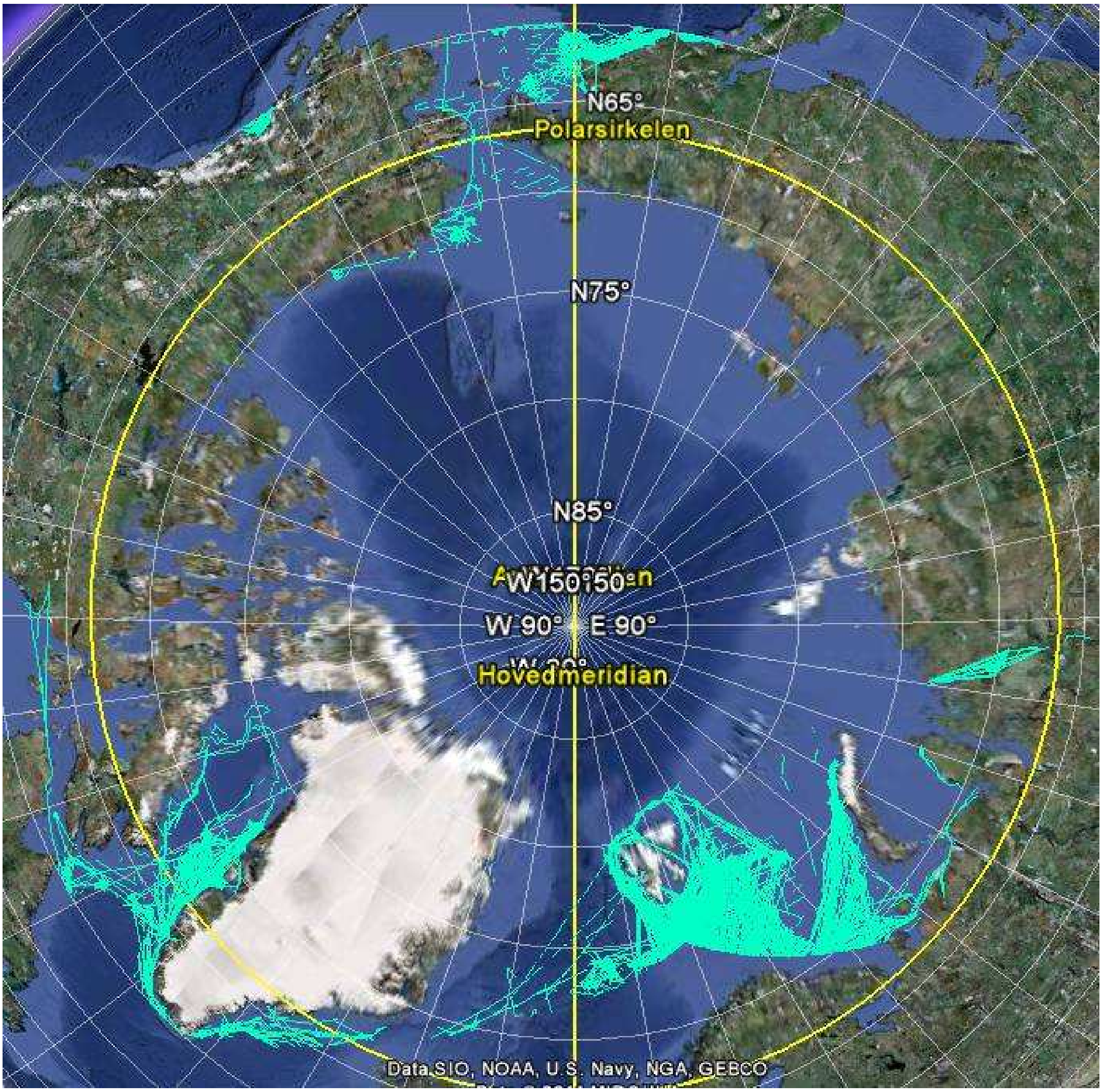
The vessels in this category may comprise a variety of offshore service and exploration vessels (see Appendix II), however the few vessels identified are registered as Safety and Rescue vessels (SAR) and tugs. This vessel group's activity is dominated by two locations – off the west coast of Greenland and off the north coast of Alaska.

5.2.3.11 Other activities



Other activities is a large and complex group of vessels in the Arctic region consisting of vessels like pilot vessels, ice breakers, tugs, research vessels, salvage and rescue vessels, dredgers etc (see Appendix II). Ships that fall within this category may typically have overlapping activities with many of the other vessel categories, such as offshore supply/service vessels, passenger ships and to a certain degree cargo transport. Thus, as seen from the above plot, activity from this heterogeneous group is widely distributed in the areas of the Arctic where shipping occurs.

5.2.3.12 Fishing vessels



The fishing fleet constitute the largest group if vessels in the Arctic. The major fishing areas are to be found in the Barents Sea/northern part of the Norwegian Sea, around Greenland and in the Chukchi Sea/Berings Sea. It is worth noting that the fisheries are seasonal, thus the picture may change considerably through the year.

5.3 Seasonal variations

In this study we have only been able to cover the months August thought to November, thus the seasonal variation outside this has not been covered. With a full year of data available from August 2011 however, we are in the position to track sailed distances, estimate emissions and calculate risks with a new level of confidence as compared to before the availability of the AIS data.

5.4 Presentation of the results

On should note that the very comprehensive set of data generated from this study is only to a limited degree possible to present properly in way of plots as shown in this report. Therefore we also issue with the report a data file allowing the reader to present the data in Google Earth and thus drill down in to the data as required. Google Earth is a free software and may be downloaded via the following link; http://www.google.com/intl/us/earth/index.html

5.5 Establishing trends and likely scenarios for the future

Several studies during recent years have discussed the future scenarios of Arctic shipping (see for example ref /1/, /7/, /8/ and /9/). The scenarios commonly discuss the potential increased use of the northern sea routes (mainly the North East Passage) for international transit shipping operations to Asia, in light of potential changes in ice patterns. However, the predictions for regular commercial cargo shipment via the Arctic are highly uncertain. In addition, increased shipping activity is expected in connection with the oil-and gas activities in the Barents Sea and Russian Arctic, although much of this shipping will occur in the outskirts of or outside the Arctic as defined in this report. An increase in LNG transport from the current very limited level up to several hundreds of shipments by large LNG tankers is for instance forecasted in some of the scenarios for the Barents Sea/Shtokman. In addition a considerable increase of oil transport by larger oil tankers may also be expected (see for example ref /7/, /10/ and /11/.

This study does not elaborate further on the scenarios for future Arctic shipping; however the forecasted changes may influence the pattern of HFO utilization in the Arctic. The Arctic shipping today is dominated by fishing vessels and relatively small vessels involved in a variety of activities within the Arctic, such as local community supply and passenger transport, research activities, tourism, authoritative tasks and other. As discussed by this study, the majority of these vessels are of types and sizes that can be expected to run on distillate fuels rather than HFO.

However, a potential increase in global commercial transit shipping via the northern sea routes, in addition to a increased Arctic petroleum activity related traffic, will add to the larger cargo ships and oil/LNG tankers in the Arctic region; ships which traditionally and as shown by this study are HFO users. The HFO use is fully possible from the practical/technical perspective and under the current legislation. However, the future picture of HFO use versus distillates will also be governed by how the global and regional environmental legislation influence the fuel markets in general, especially due to the coming and stricter sulphur requirements (see also discussed in Section 9.1.1). The effects from these mechanisms on the HFO use in the Arctic are not yet known and have not been possible to forecast within the scope of this study.

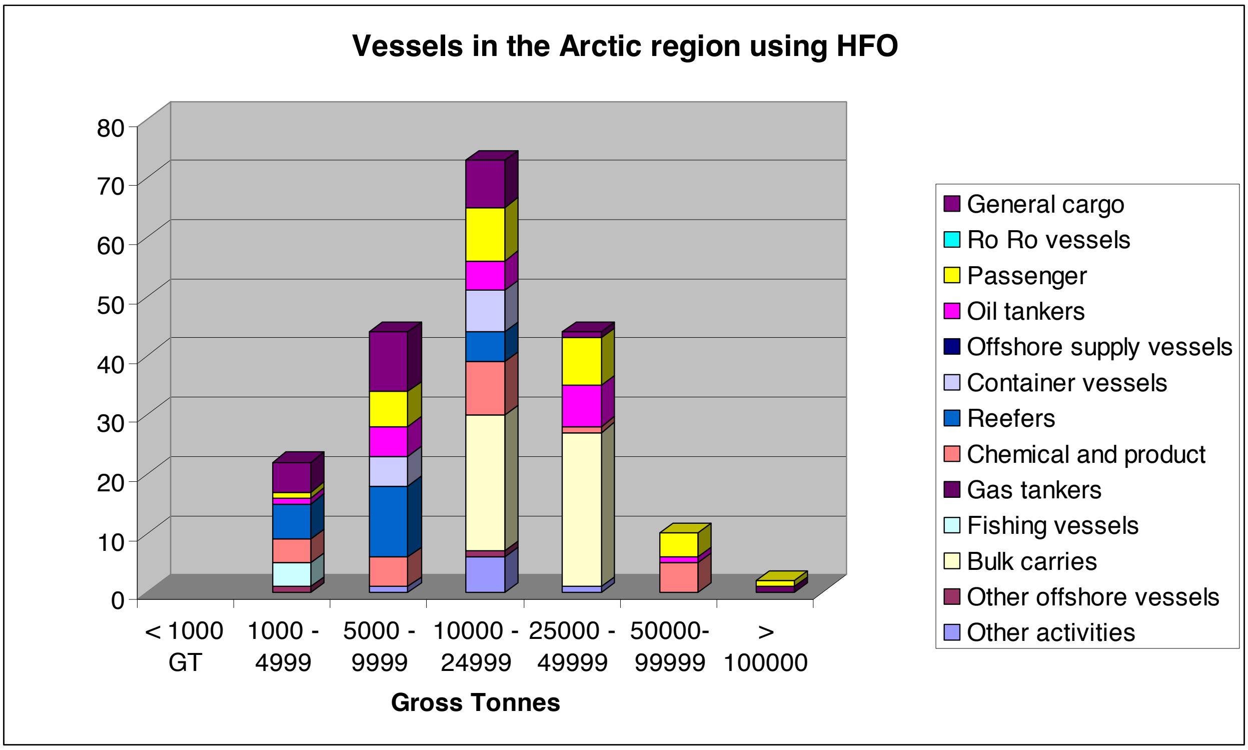
6 VESSELS OPERATING ON HFO IN THE ARCTIC

Having established an overview of the vessels operating in the Arctic region, another major part of this undertaking is to identify the vessels which are – or may use fuel oil classified as Heavy Fuel Oil (HFO). The AIS data, nor most of the available ship data bases, contain any information regarding the fuel types a vessel is using. However, by combining data from different sources of information and carefully processing it, (as explained in Section 3.6) we are able to draw a picture of the proportion of vessels capable of operating on HFO with a high degree of confidence.

Based on the above mentioned exercise we were able to identify a total of 189 vessels operating within the Arctic region through the period August – November 2010 and capable of operating on HFO.

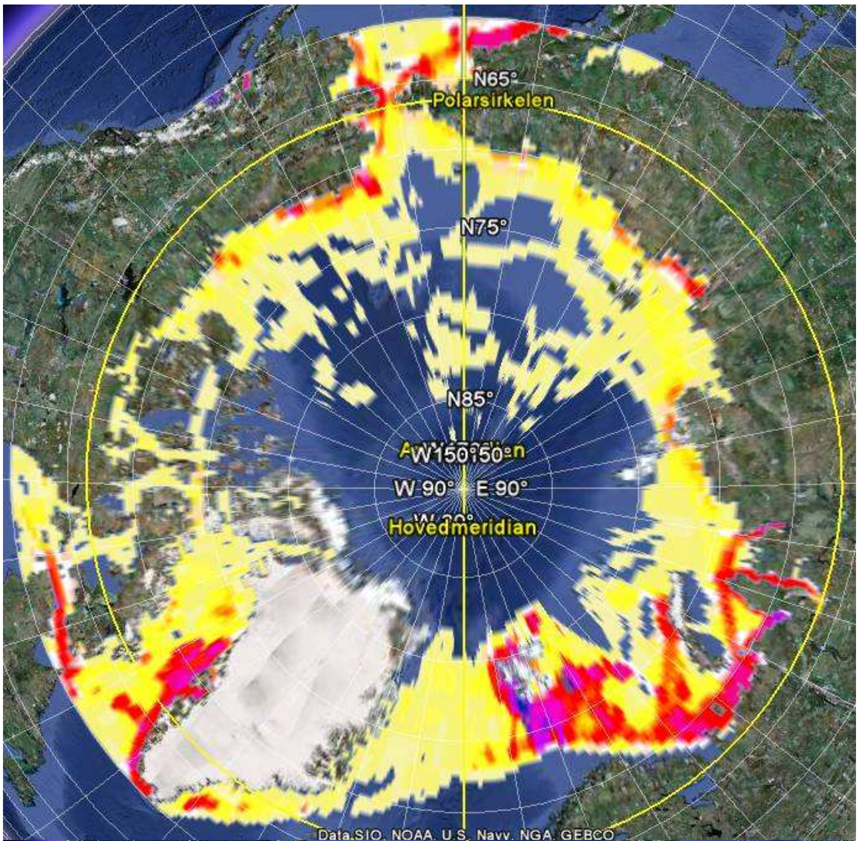
Table 6-1 All vessels vessels identified within the region and period with the vessels operating on HFO in brackets

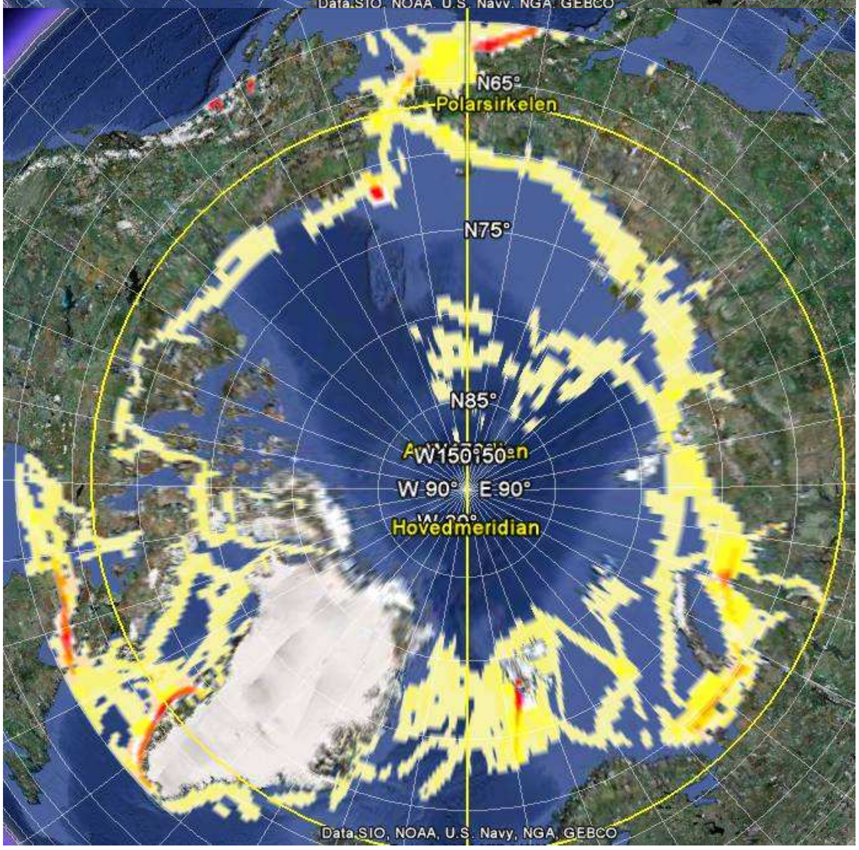
Ship type and size category (gross ton)	< 1000	1000 - 4999	5000 - 9999	10000 - 24999	25000 - 49999	50000 - 99999	> 100000	All sizes
Oil tankers	0	19(1)	9(5)	8(5)	7(7)	1(1)	0	44(19)
Chemical and product	1	11(4)	5(5)	9(9)	1(1)	0	0	27(19)
Gas tankers	0	0	0	0	0		1(1)	1(1)
Bulk carries	0	2	1	23(23)	26(26)	0	0	52(49)
Container vessels	0	0	5(5)	7(7)	0	0	0	12(12)
General cargo	6	69(5)	19(10)	11(8)	1(1)	0	0	106(24)
Reefers	1	24(6)	13(12)	5(5)	0	0	0	43(23)
Ro Ro vessels	1	1	2	1	0	0	0	5(0)
Passenger	3	13(1)	6(6)	9(8)	8(8)	4(4)	1(1)	44(28)
Offshore supply vessels	3	1(1)	1	1(1)	0	0	0	6(2)
Other offshore vessels	6	18	6	0	0	0	0	30(0)
Other activities	110	58	12(1)	19(6)	1(1)	0	0	200(8)
Fishing vessels	159	211(4)	13	1	0	0	0	384(4)
Sum	290(0)	427(22)	92(44)	94(72)	44(44)	5(5)	2(2)	954(189)



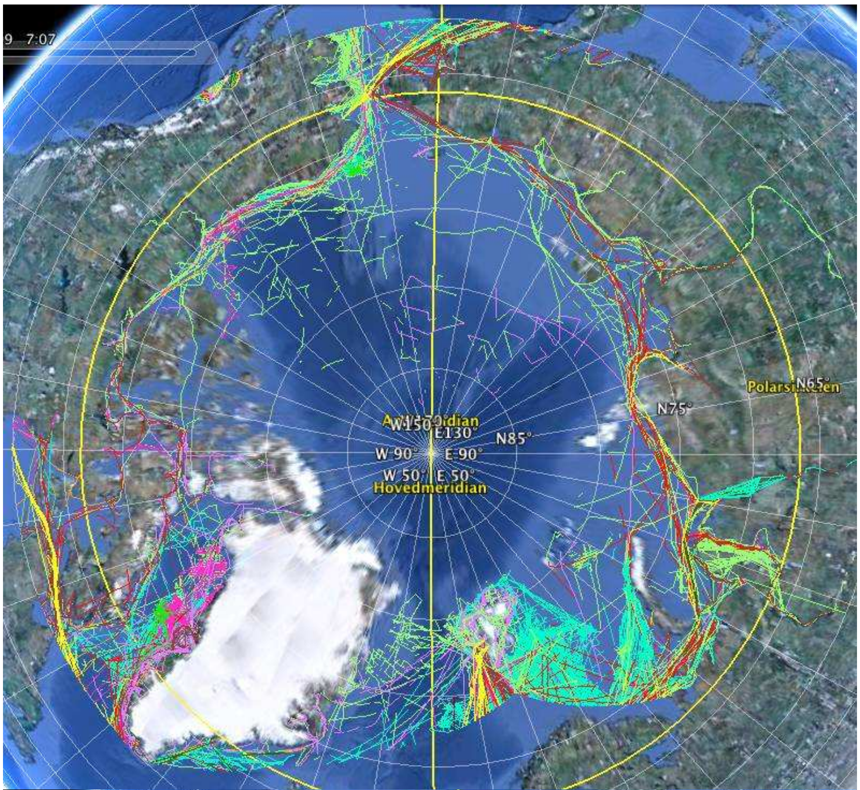
Not surprisingly the vessels using HFO are to be found among the larger size vessels operating over larger distances. Ie, the fleet of HFO users is radically different to the general fleet in the Arctic Region. With the high volume traffic within the fishery and governmental vessels more or less removed from the selection the differences in the traffic are clearly demonstrated in the figures in section 6.1.1. Also the traffic patterns of the HFO vessels differ from the general non-HFO vessels (fishing vessels and other activities). The HFO traffic is dominated by a relatively few fixed routes and generally over large distances whereas non-HFO traffic is much more scattered over smaller distances.

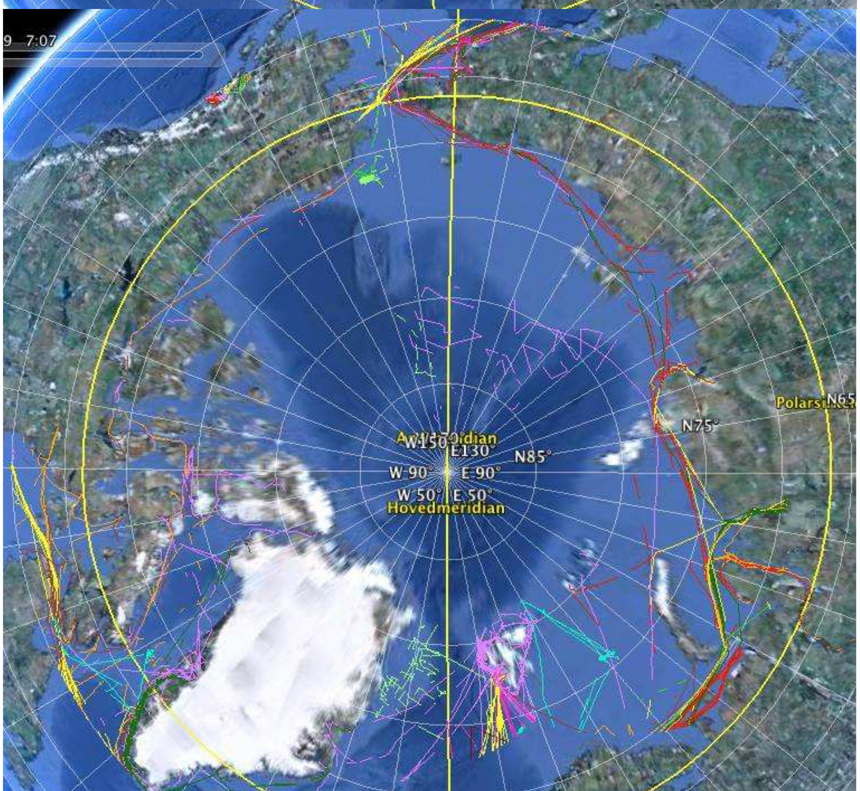
6.1.1 Density plot – All vessels versus vessels using HFO





6.1.2 Line plots – All vessels versus vessels using HFO





7 VESSELS CARRYING HFO IN THE ARCTIC

Determining the carriage of HFO has been difficult as no data is available for actual cargo type carried onboard the identified ships operating in the Arctic region. However, the potential of HFO carriers have been identified from the AIS data based on identification of ship types capable of carrying HFO, as well as HFO bunkering operations in the Arctic from the DNVPS data.

7.1 Ships potentially transporting HFO

According to the categorization of vessels used for this study (see Table 3-1 and Appendix II), both the oil tankers and the chemical/product tankers may potentially carry HFO as well as other oil products. The AIS registered oil and chemical/product tankers are shown in **Table 7-1**, and Figure 7.1.

Table 7-1 All tankers identified to operate in the Arctic region, August – November 2010

Ship type and size category (gross ton)	< 1000	1000 - 4999	5000 - 9999	10000 - 24999	25000 - 49999	50000 - 99999	> 100000	All sizes
Oil tankers	1	11	5	9	1	0	0	27
Chemical and product	0	19	9	8	7	1	0	44
Sum	1	30	14	17	8	1	0	81

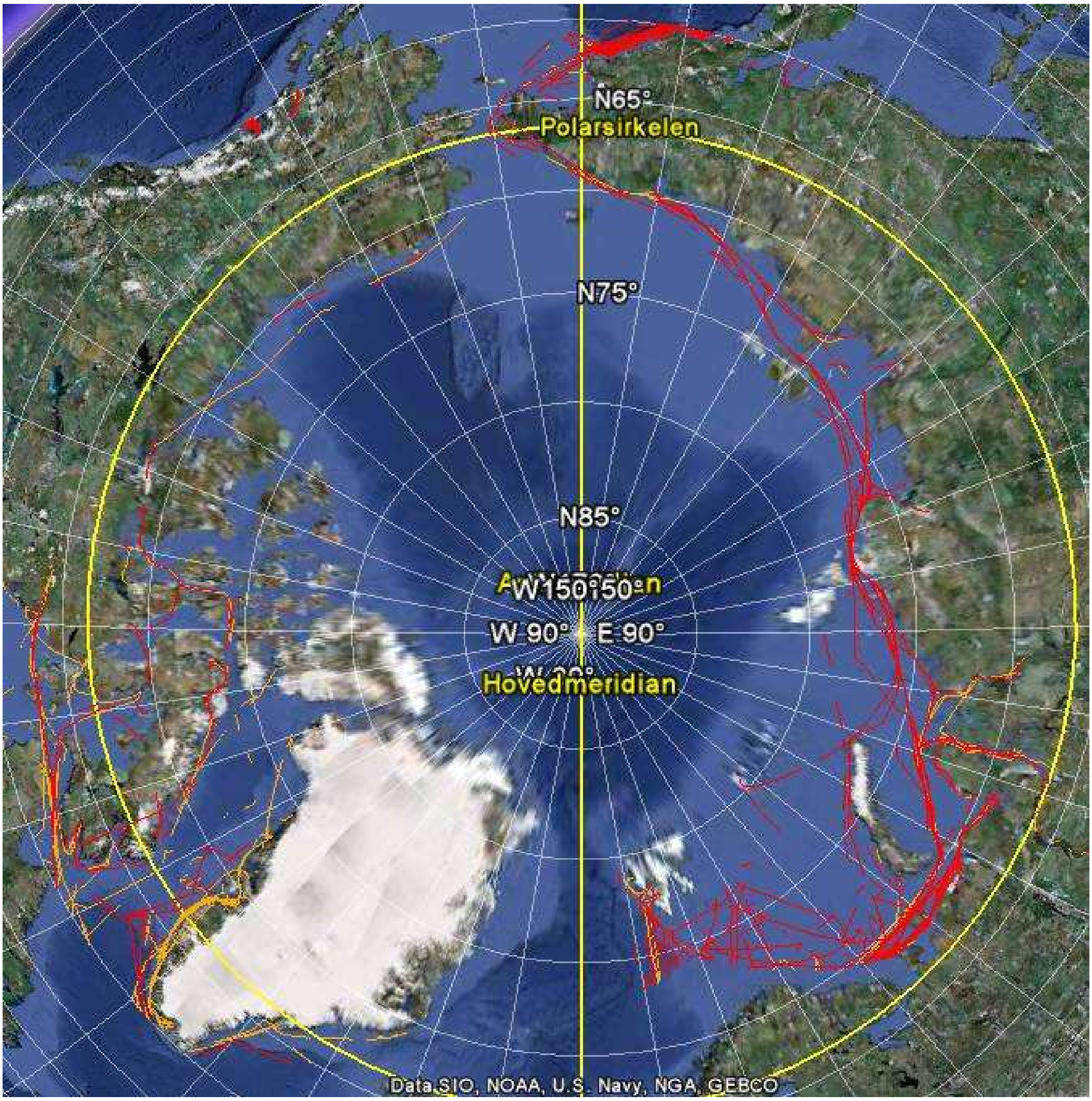


Figure 7.1 Routes of all oil tankers and chemical/product carriers in the Arctic, from August – November 2010. The red lines are registered as oil tankers whereas the orange lines represent chemical/product tankers.

7.2 Bunkering samples taken within the Arctic

Several bunkering samples from the Arctic were identified among the samples registered in the DNVPS data base over the last 3 years, see table Table 7-2 and Figure 7.2. Note that for the ports situated within the Arctic region as defined in this report, there are only a limited number of ports we have registered samples in the DNVPS data base. Thus some of the important ports in the close proximity of the Arctic have been included as well.

Table 7-2 DNVPS samples taken in Arctic ports

Port	HFO sampl.	Non-HFO sampl
AASIAAT	0	2
AKUREYRI	3	0
ARKHANGELSK *	49	25
BAYDARATSKAYA	3	0
HAFNARFJORDUR	8	2
HAMMERFEST *	0	37
ILULISSAT	0	3
KANDALAKSHA	2	1
KENAI *	2	2
LONGYEARBYEN	1	5
MURMANSK *	447	63
NIKISKI *	31	21
NJARDHVIK	1	0
NUUK	0	17
SISIMIUT	0	12
STAPLETON ANC *	230	41
VARANDEY	1	0

**indicates ports in the Arctic vicinity, but strictly outside the definition of the Arctic.*

The table clearly shows that HFO is being bunkered and used by ships in the Arctic region. Naturally, this HFO has to be transported to the respective ports, and likely by ships. However, the table clearly shows that the major bunkering ports are found in the outskirts of the Arctic region, all accessible by land and sea without having to cross Arctic waters. Thus, the HFO bunkered in these ports may have been transported by other means than ships, or by ships not operating within the definition of the Arctic as applied in this study.

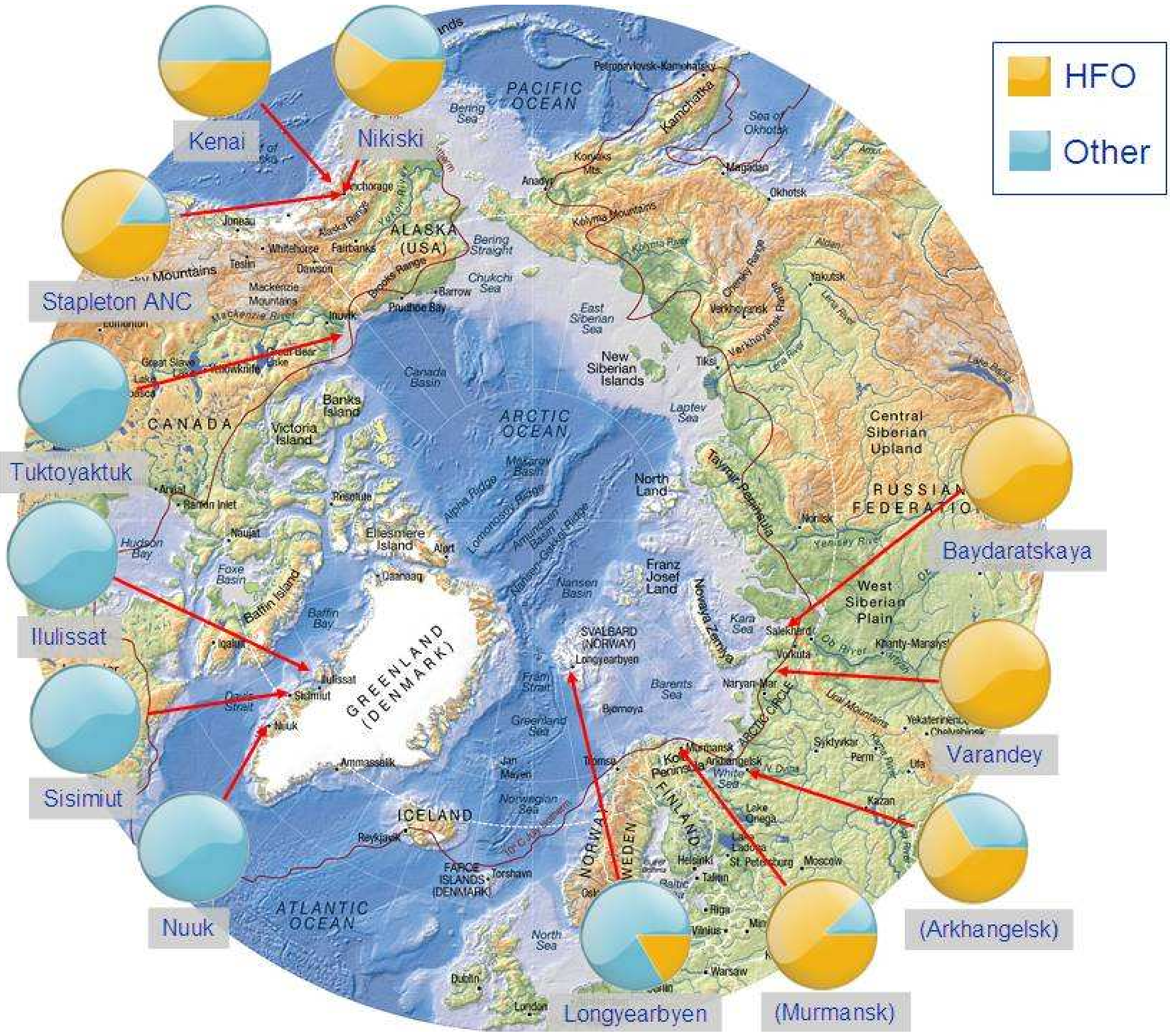


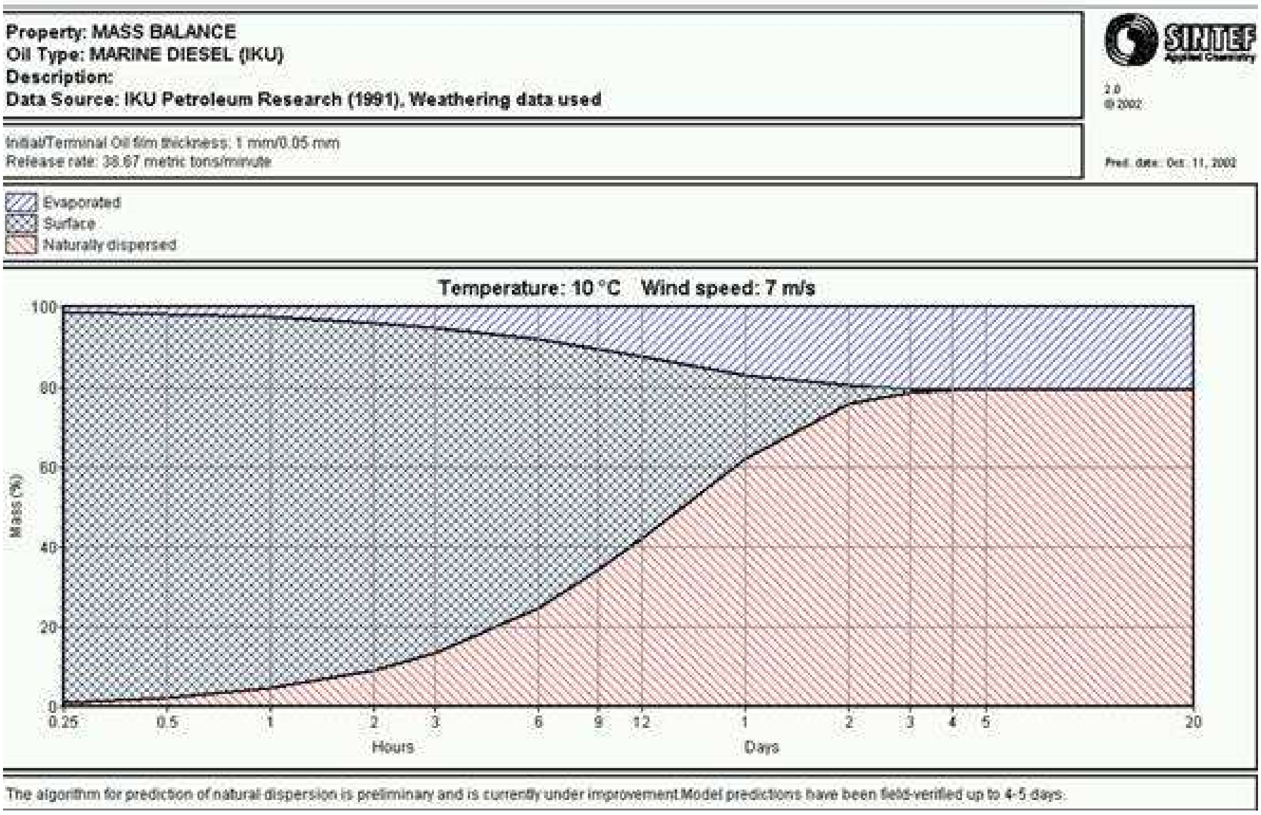
Figure 7.2; The proportion of HFO samples versus other product samples tested by DNVPS for the different ports in the Arctic region (note that Baydaratskaya and Varandey together only represent 4 samples and only 6 samples are issued from Longyearbyen of which only 1 from 2008 is HFO).

8 PARTICULAR ENVIRONMENTAL RISKS FROM HFO IN THE ARCTIC

This chapter explains the different behaviour of HFO spills versus spills of marine distillate fuels. It further addresses the particular aspects of arctic vulnerability with regards to the consequences of oil spills, as well as the particular challenges with regard to risk mitigation strategies. Aspects such as arctic haze and deposition of soot/black carbon on ice from of the emissions to air from engine combustion are also briefly discussed.

8.1 Properties specific to HFO regarding oil spills in the Arctic

The consequences and hazards of an oil spill depend, among others, largely on the properties of the specific oil. When discharged into water, the weathering processes such as evaporation, dissolving, dispersion and water uptake/emulsification will start. The lighter components evaporate and the water-soluble parts dissolve and disperse into the water column. Most marine distillate fuels do not emulsify in contrast to the HFO. The duration of these processes varies with temperature, waves, wind and most of all the properties of the oil. Figure 8.1 shows a comparison of the amount of distillate fuel and typical HFO on the water surface over time after a spill. As shown; where the diesel oil has fully disappeared from the surface after 3 days, nearly all the HFO is still present after 20 days. In addition, after 3- 5 days most HFO's have emulsified to the maximum water content (40 – 80%). This results in a significant increase in the volume to be handled by an oil spill recovery operation. Hence the consequences of HFO spills are likely to be more severe than spills of marine diesels.



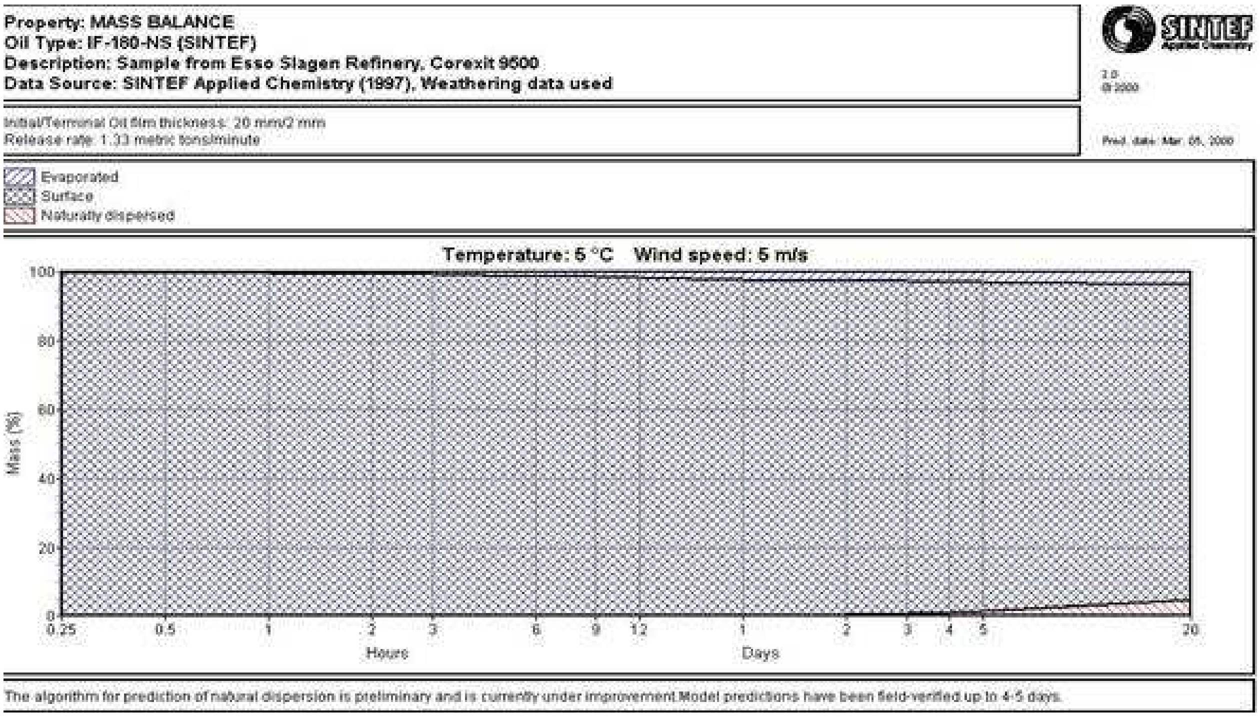


Figure 8.1 Mass balance of marine diesel oil (top) and HFO (IF-180-NS) (bottom) on water.

8.2 Particular aspects of Arctic environmental conditions and vulnerability from spills

When discussing the environmental vulnerability of the polar waters, it is important to acknowledge that the areas are not uniform with respect to ecosystem composition and physical conditions (ref /12/). There are large spatial and temporal variations between and within different areas and sub-areas. Polar waters have its sensitive and less sensitive areas and periods, as one will find in other regions. The normal ecosystem situation is constant natural variation; however different components may in varying degree be sensitive to different man-induced changes. Thus, vulnerability evaluations cannot be performed universally for the Arctic but need to be addressed for particular activities and areas at a more limited and focused scale.

The issue of environmental vulnerability of the polar areas is high on both the political and the scientific agenda. The polar areas are frequently referred to as a fragile and vulnerable environments, however there is insufficient scientific information available to give a general and unified judgement on whether and in which way it is any more or less fragile than other parts of the world. The environmental risks associated with human activities will depend on how the ecosystem responds and on its capacity to adapt. Better information on the responses of individuals, populations and communities to stressors is in general required for ecological risk assessments as the basis determining whether provisions developed primarily with a view to other areas can be used in the polar areas with confidence.

Still, based on a review of selected assessments of polar environmental issues, certain common particular polar conditions can be summarized of relevance for the risks from pollution from shipping, such as oil spills.

8.2.1 Temperature and light

Temperature and light conditions are at the extreme in Polar waters, and they are important issues especially with regard to accidents and oil spill preparedness and response during winter time. Generally and maybe of particular relevance to littoral components is that oil have a slower degradation rate in cold climates indicating longer recovery time than in warmer climates. Emulsified HFO will be challenging to collect and pump due to low temperatures and high viscosity.

Light conditions are favourable in the summer time allowing 24 hours of operations. In the winter there are practically no operational light at all and operational success are dependent on monitoring equipment as detecting radars, satellite, monitoring aircrafts with oil detecting equipment and further on.

An important issue with regard to ecosystem vulnerability on a general level is that ecosystem compounds which are already under stress for some reason, for instance due to extreme or marginal environmental conditions may have a higher vulnerability to additional stress or change.

8.2.2 Remoteness

Remoteness of major parts of the polar areas with regard to relevant resources and infrastructure (or lack of such) can be seen as one of the more important *particular* conditions in the areas with regard to environmental regulation and control measures, compared to other areas. This is of special importance with regard to accidents and spill preparedness and response. Long response time for oil spill recovery startup allows a spill to potentially influence a wider area. In addition, it will more or less exclude chemical dispersion techniques due to the short time window of opportunities of chemical dispersion of spills (HFO).

8.2.3 Natural recourses

Organisms in the polar seas are used to extreme conditions with significant natural variations in the short and longer term. Important physical factors include low temperatures in some areas, seasonal variation in light conditions, ice coverage and ice melting, and ocean fronts between warmer and colder water.

The polar ecosystems may be characterised as a relatively simple food-web system with short food-chains and few species (but with many sub species) that are high in abundance, compared with other ecosystem areas (sub-arctic, temporal, etc.). Many species tend to grow slower, live longer, have low reproduction rate, and are essential for the energy transfer in the system – compared to other ecosystem-regions (with higher diversity). For certain key species, large natural fluctuations in number of individuals over time are observed, but also caused by humans (due to direct and indirect harvesting, etc), making the populations more vulnerable when already in a reduced state. Such systems are normally considered *sensitive* (ref /13/).

The large number of individuals within each species is often considered as robustness rather than a vulnerability, as no single "normal" incident may affect a large part of the population. An important characteristic with the Polar ecosystem is however the seasonal variation in abundance (as well as many physical, chemical environmental parameters). A high number of individuals of many species tend to migrate and concentrate in limited areas at certain parts of the year to feed and/or reproduce. Such "biomass" accumulation may highly influence on the evaluation of vulnerability, and many of these areas are regarded as having international importance. During the periods when polar species migrates and gather in and around concentrated areas, they may be more vulnerable to potential environmental stresses.

Areas with ice have different ecosystem communities than open sea areas. Various ice algae and ice fauna occur, in/under ice or adjacent to ice. Along the ice edge, the gradients between open sea and ice create life conditions for particular ice edge communities, linked to the continuous "new" growth associated with the edge of retreating ice.

Arctic species, which are reliant on feathers and fur to insulate against the cold, are especially vulnerable to contamination from oil that will compromise their insulating layers, leaving them exposed and at risk of hypothermia and death. Animals can also ingest oil while preening their feathers or licking their fur, leading to death or other biological effects for both short and long-term. Even if fish may metabolise hydrocarbons relatively quickly, they may retain enough to affect their quality as food (ref /14/).

Long-term consequences of an oil spill on Arctic wildlife is a complex matter and the effects of chronic diffuse oil pollution are still uncertain (ref /14/). Based on experience from the Exxon Valdez oil spill in 1989, long term effects were identified due to the fact that oil persisted in the environment beyond a decade and was sufficiently available to cause long-term impacts on the environment. Three major pathways of induction was identified: (i) chronic persistence of oil, biological exposure, and population impacts to species closely associated with shallow sediments, (ii) delayed population impacts by sub lethal doses (comprising health, growth and reproduction), (iii) indirect effects of trophic and interaction cascades, all of which transmit impacts well beyond the acute phase mortality (ref /15/).

8.2.4 Ice and snow

Ice and snow is of particular importance in terms of influencing the probability for - and consequences from - accidental oil spills, and our abilities for effective spill mitigation and clean up measures (see Section 8.3). Trapping of oil in ice makes the pollution longer-lasting, and make it possible for the oil to be transported over long distances (see Figure 8.2). Ice that contains oil from spills may melt and release the trapped oil in the spring. Some northern fish species such as polar cod, arctic cod, saffron cod and navaga spawn under the sea ice in winter. The eggs hatch when the ice begins to melt in spring, a time when plankton blooms occur and their larvae will have food to eat. An oil spill or released oil in such spawning areas could severely reduce that year's recruitment to the population (ref /14/)

Ice conditions in the Arctic are changing, and it is believed to be highly affected by global warming processes. According to PAME (ref /1/), it is projected that the main change in sea ice will be decreasing ice coverage in the summer along the coastal Arctic seas with the formation of first-year ice occurring later in the fall. Even with a warmer climate, the Arctic Ocean will still remain ice-covered for most of the year. As climate and sea ice conditions continue to change, the timing and movements of the animals' activity will also be modified, making predictions of the potential interactions between shipping and animals increasingly complex.

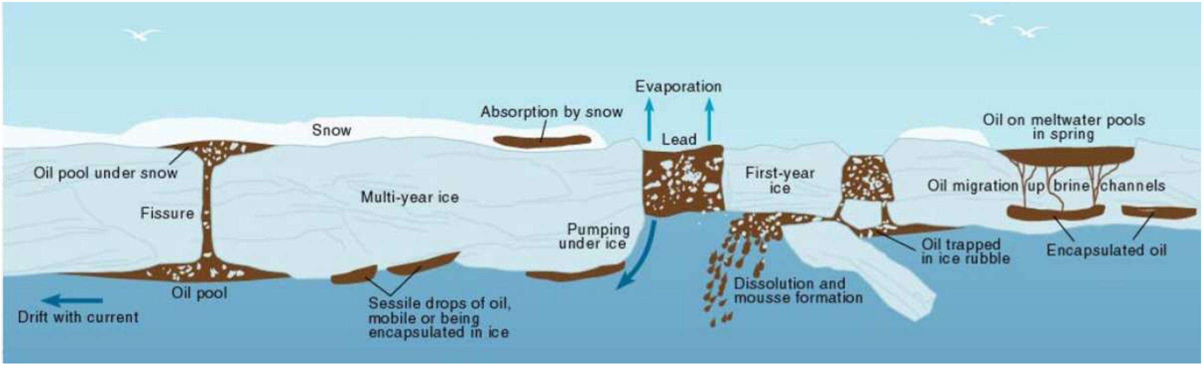


Figure 8.2 Schematic diagram of oil in ice covered water (ref /14/)

8.3 Risk mitigation measures

Typical conditions in the arctic includes cold sea waters, remote areas without infrastructure, the formation and movement of sea ice, extreme and unpredictable weather conditions, and long periods of darkness. All of these conditions are known to negatively influence the efficiency of an oil spill recovery operation, and might even exceed the operating limits of existing response technologies and preparedness. For instance today's skimmer technologies are performing poorly in terms of collecting oil emulations in ice, and the movement of sea ice and extreme and unpredictable weather conditions complicates an oil spill operation significantly. In situ burning of oil is an alternative technique that has been applied in some cases.

The limited ability to effectively clean up is a critical component of the risk equation and should be emphasized in the further discussion on the use of HFO in arctic waters. In addition, to build and maintain an effective oil spill emergency preparedness based on seasonal ship traffic will most likely not be cost effective. Relevant risk mitigating strategies therefore should be focused on preventing accidents and any spill of oil, particularly of HFO and other emulsifying oils. In light of the environmental conditions described in Section 8.2 and with reference to the particular HFO properties as described in Section 8.1, significant risk reduction will be achieved if the onboard oil type possible for spill is of distillate type rather than HFO. In other words, what an effective oil response operation could achieve of risk reduction by collecting and/or dispersing HFO, would to a certain extent already be achieved in case of distillates, due to the physical properties of lighter products.

8.4 Exhaust emissions/Black Carbon

Even though this study primarily focuses on HFO in the perspective of spills to sea, aspects of air pollution from combustion is also of relevance when discussing the use of HFO. An overview of the basis for the below considerations can be found in ref /1/, /7/, /8/, /16/, /17/, /18/ and /19/.

Deposition of soot and black carbon (BC) from ship exhaust may potentially play a role in accelerated melting of ice, because such light absorbing aerosols can decrease the surface albedo (reflectivity) of ice and snow; especially evident in proximity to high traffic areas/corridors. In polar areas where the ice cover and dynamics currently is believed to be highly affected by global warming processes, this additional aspect of accelerated melting by deposition of air pollutants on ice has got special attention.

- Ship exhaust emissions are also likely to contribute to phenomena like *Arctic haze*, where sulphate and other aerosols; BC/soot and other particulate matter from ship exhaust may affect *local/regional climate forcing* processes by influencing solar radiation in air masses and on snow/ice. Tropospheric ozone formed by ship generated NOx is also of relevance for such processes. Even though the effects in terms of regional warming/cooling are complicated with feedbacks between aerosols, clouds, radiation, snow and ice cover, and vertical and horizontal transport processes; the contribution from shipping, especially taking into account the most optimistic scenarios for traffic development, should be considered as significant and of special importance in polar areas which are otherwise highly affected by global warming processes. Note however that the environmental and climate effects of these mechanisms in the Arctic are only beginning to be understood, and that the main source for phenomena like arctic haze is air pollutants transported to the Arctic from other sources (industry and forest fires) further south.
- Certain arctic areas experiencing high levels of air pollution and acidification effects from land based industry, such as on the Kola Peninsula and in limited areas of northern Norway, Finland and around Norilsk in the Taymir region of Russia, may be vulnerable for additive emissions of sulphur and nitrogen from shipping. Even though today's SO_2 emissions from shipping are only marginal compared to the emissions from the Russian smelters, the contribution to NOx emissions from shipping is quite much higher. Moreover, considering the highest estimates for increases in emissions in connection with the oil and gas activity and increased use of the Northern Sea Route, shipping may contribute to extended periods where the critical loads for acidification and pollution in coastal areas are exceeded. Note that this study has not found support for considering this aspect as a general polar particular challenge, but rather a local Arctic problem in certain areas with high background concentrations and vulnerability to increased nitrogen/sulphur load.

The above emission aspects cannot be uniformly differentiated between HFO and other fuel types, and the correlation between fuel types and the different types of particulate matter emissions and secondary formation are complex (ref /19/). However, the burning of HFO clearly leads to higher emissions of many of the particle fractions, including those that may deposite as black pollutants on ice.

9 INTERNATIONAL REGULATION REGARDING THE USE OR CARRIAGE OF HEAVY FUEL OILS

9.1 Use of heavy fuel oils

Marine fuel property standards are reported from standardization organisations such as ASTM (American Society for Testing and Materials) and ISO (International Standards Organization), and others. The fuel property criteria includes parameters such as kinematic viscosity and density, which are of direct relevance for the classification of fuels on a heavy fuel oil gradient such as in the amendment to MARPOL regarding the ban on the use and carriage of heavy grade oils in the Antarctic area (see below)

Except from in a few areas (see below), international legislation does not specifically regulate when and where to use heavy fuel oils versus lighter products. Marine engines are however required to run on suitable fuel ensuring a safe and reliable operation, which practically enables for use of a range of fuel types from light distillate marine gas oils and diesel oils to the heavier intermediate fuels and residual fuels. Heavy fuel oil can in principle be applied under any conditions; as long as the engine is designed for doing so and adequate fuel heating capabilities are in place.

IMO adopted in March 2006 an amendment to MARPOL Annex I to include a new regulation 12A on oil fuel tank protection. The regulation applies to all ships delivered on or after 1 August 2010 with an aggregate oil fuel capacity of 600 m3 and above. It includes requirements for the protected location of the fuel tanks and performance standards for accidental oil fuel outflow. A maximum capacity limit of 2,500m3 per oil fuel tank is included in the regulation, which also requires Administrations to consider general safety aspects, including the need for maintenance and inspection of wing and double-bottom tanks or spaces, when approving the design and construction of ships in accordance with the regulation. However, the fuel tank regulation does not address heavy fuel oils versus lighter products.

The following sections describe special regulations of direct or indirect relevance for the use of heavy fuel oils:

9.1.1 IMO requirements under revised MARPOL Annex VI

The revised MARPOL Annex VI opens for designating certain areas as Emission Control Areas (ECA) where stricter requirements shall apply for emissions to air of SOx, NOx and PM. SOx emissions is regulated by a requirement for maximum sulphur content in fuels. Today's maximum allowed sulphur content of 1 % will be reduced to maximum 0,5 % from 1 January 2015 in ECAs. In other areas, the requirements imply a gradual reduction from today's 4,5 % to 0,5 % towards 2020/2025). Currently the Baltic Sea , the North Sea and US/Canadian waters are designated as Emission control areas.

The sulphur regulation does not imply a requirement on *type of fuel*, such as residual fuels versus distillates or along any heavy fuel oil gradient of density or viscosity. Thus any fuel type meeting the sulphur limits, including heavier fuel qualities, will be compliant. In addition, the alternative of using exhaust gas cleaning methods (scrubbers) to remove the sulphur while running on sulphur rich fuels will be accepted, although the technologies are still immature.

Although the coming sulphur requirements does not principally rule out the use of heavy fuel oils, they will likely lead to higher share of lighter products and distillates, particularly in ECAs. However the full effect of future sulphur requirements on fuel type demand and availability is still unknown.

9.1.2 Additional IMO requirements in the Antarctic area

From 1 August 2011, a new MARPOL regulation to protect the Antarctic from pollution by heavy grade oils enters into force. The amendments to MARPOL includes a new chapter 9 with a new regulation 43, which would prohibit the carriage, in bulk as cargo, *or carriage and use as fuel*, of:

- crude oils having a density, at 15°C, higher than 900 kg/m3;
- oils, other than crude oils, having a density, at 15°C, higher than 900 kg/m3 or a kinematic viscosity, at 50°C, higher than 180 mm2/s; or
- bitumen, tar and their emulsions.

An exception is envisaged for vessels engaged in securing the safety of ships or in a search-and-rescue operation.

9.1.3 Additional US/Californian regulations on fuel types

In California (US), additional fuel requirements are adopted for ocean-going vessel main (propulsion) diesel engines, auxiliary diesel engines, and auxiliary boilers when operating within 24 nautical miles of the California Coastline. Vessel owners/operators would be required to use the marine distillate fuels shown in Table 1. In contrast to IMO and EU legislation, these requirements do actually set a requirement for type of fuel to be used (distillate fuels), not only sulphur content.

Table 1: Fuels Complying with the Requirements

Effective Date	Fuel**
July 1, 2009 (except auxiliary engines)*	Phase I Fuel Requirement Marine gas oil (DMA) at or below 1.5% sulfur; or Marine diesel oil (DMB) at or below 0.5% sulfur
January 1, 2012	Phase II Fuel Requirement Marine gas oil (DMA) or marine diesel oil (DMB) at or below 0.1% sulfur

* The fuel requirements for auxiliary engines will become effective when the regulation becomes legally effective, which is expected to occur early in 2009.

** DMA and DMB are marine grades of fuel as defined in Table I of International Standard ISO 8217.

9.1.4 Additional EU legislation

The EU legislation basically reflects that of IMO MARPOL Annex VI, however there are some additional requirements:

- From January 1st 2010, all vessels at EU/EEA berth and inland waterways were required to use fuel with no more than 0,1% sulphur.
- Marine gas oils in all EU/EEA waters shall not contain more than 0,1% sulphur. Marine gas oils with more than 0,1% sulphur is not allowed for sale.

- Marine diesel oils and heavy fuel oils for passenger ships in scheduled traffic to and/or from EU/EEA portes shall use fuel with no more than 1,5% sulphur. Marine diesel oils with more than 1,5 % sulphur is not allowed for sale.

As for the IMO requirements, the EU legislation does not set requirements for the type of fuel to be used, only the sulphur content in different fuels.

9.1.5 Additional national legislation within the Svalbard archipelago (Norway)

To avoid major pollution from heavy fuel oil in the event of an accident, ships sailing in the three largest national parks of Svalbard are from 1.1.2010 not allowed to use or carry heavy fuel oil. In these areas, the fuel shall be within the DMA quality (marine gas oil) according to the ISO 8217 fuel standard.

An exemption applies for the shortest, most secure route via:

- The north-west part of South Spitsbergen national park, for sailings to and from Svea mine.
- The northern part of Forlandet national park and the southern part of North-West Spitsbergen national park for sailings to and from Ny-Ålesund up to 01.01.2015.
- North-West Spitsbergen national park for sailings to Magdalenefjorden up to 01.01. 2015

9.2 Carriage of heavy grade oils

Prevention of pollution from carriage of oil (including heavy grade oils) as cargo is regulated by IMO MARPOL Annex I with provisions for the construction of oil tankers, requirements for equipment and operational discharge control, and more. The essential part of the regulations is the requirements for segregated ballast and double hull for the cargo areas of tankers carrying heavy grade oils. It is not within the scope of this report to elaborate on the full extent of MARPOL Annex I oil carriage requirements.

Basically the MARPOL carriage requirements for oil and oil products applies in all areas, however there are certain area-specific regulations, described below.

9.2.1 Operational discharges

Regulation 34 of MARPOL Annex 1 prohibits the operational discharge of oil and oily mixtures from the cargo areas of oil tankers, such as oil and oily water from tank washing operations (slop), while in a Special Areas (as defined in regulation 1 of Annex 1). Outside special areas, such discharge is allowed when all the following conditions are satisfied:

- the tanker is more than 50 nautical miles from nearest land;
- the tanker is proceeding *en route;*
- the total quantity of oil discharged to sea does not exceed 1/30000 of the total quantity of the particular cargo of which the residue formed a part
- the tanker has in operation a compliant oil discharge monitoring and control system and slop tank arrangement.

9.2.2 Additional IMO requirements in the Antarctic areas

The carriage of heavy grade oils is prohibited in Antarctic waters, see details in Section 9.1.2

9.2.3 Additional national legislation within the Svalbard archipelago (Norway)

The carriage of heavy grade oils is prohibited in certain areas of the Svalbard archipelago, see details in Section 9.1.5.

9.2.4 Additional requirements in certain Particularly Sensitive Sea Areas (PSSAs)

Particularly Sensitive Sea Areas (PSSA) are areas that need special protection through action by IMO because of its significance for recognized ecological or socio-economic or scientific reasons and which may be vulnerable to damage by international maritime activities. When designated as a PSSA, specific measures can be used to control the maritime activities in that area, such as routeing measures, strict application of MARPOL discharge and equipment requirements for ships, such as oil tankers; and installation of Vessel Traffic Services (VTS). Thus, in contrast to Special Areas, where MARPOL has pre-defined the measures, PSSA status opens for more tailor-made application of measures.

Currently 12 PSSAs has been designated, where special requirements apply to the carriage of heavy grade oils in two areas, as follows:

- PSSA Paracas National Reserve (Peru) is an area to be avoided for ships > 200 gt carrying hydrocarbons and hazardous liquids in bulk.
- PSSA Western European Waters (Belgium, France, Ireland, Portugal, Spain, United Kingdom) has mandatory reporting for single hull tankers carrying heavy grades of fuel oil

10 FUTURE WORK

DNV propose to make a revision of the AIS-study after August 2011 when the first complete year of AIS data has been recorded. In this revision DNV may also do a detailed study of how different geographical delimitations affect the total traffic picture in the Arctic. DNV has also built a comprehensive model which has been used successfully for several AIS based (activity based) emission inventories for the Norwegian coast. This model could be applied for the Arctic AIS data, estimating emissions to air, the sea as well as for assessing the risks of HFO spills for any given location.

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APPENDIX 1

ANNEX

DRAFT AMENDMENTS TO MARPOL ANNEX I

Addition of new chapter 9

Chapter 9 – Special requirements for the use or carriage of oils in the Antarctic area

Regulation 43
Special requirements for the use or carriage of oils in the Antarctic area

1 With the exception of vessels engaged in securing the safety of ships or in a search and rescue operation, the carriage in bulk as cargo or carriage and use as fuel [in tanks not protected by the provisions of regulation 12A of this Annex] of the following:

.1 crude oils having a density at 15°C higher than 900 kg/m^3;

.2 oils, other than crude oils, having a density at 15°C higher than 900 kg/m^3 or a kinematic viscosity at 50°C higher than 180 mm^2/s; or

.3 bitumen, tar and their emulsions,

shall be prohibited in the Antarctic area.

2 When prior operations have included the carriage or use of oils listed in paragraphs 1.1 to 1.3 of this regulation, the cleaning or flushing of tanks or pipelines shall not be required.

APPENDIX II

Ship type (as used in this study	Lloyds category 3	Lloyds category 4	Lloyds category 5
Oil tankers	Oil	Bitumen Tanker	Asphalt/Bitumen Tanker
Oil tankers	Oil	Crude Oil Tanker	Crude Oil Tanker
Oil tankers	Oil	Oil Products Tanker	Products Tanker
Oil tankers	Oil	Oil Products Tanker	Products Tanker Barge, propelled
Chemical/Product Carriers	Chemical	Chemical Tanker	Chemical Tanker
Chemical/Product Carriers	Chemical	Chemical Tanker	Molten Sulphur Tanker
Chemical/Product Carriers	Chemical	Chemical Tanker	Parcels Tanker
Chemical/Product Carriers	Chemical	Chemical/Oil Products Tanker	Chemical/Products Tanker
Chemical/Product Carriers	Chemical	Edible Oil Tanker	Edible Oil Tanker
Chemical/Product Carriers	Chemical	Fruit Juice Tanker	Fruit Juice Tanker
Chemical/Product Carriers	Chemical	Vegetable Oil Tanker	Vegetable Oil Tanker
Chemical/Product Carriers	Chemical	Wine Tanker	Wine Tanker
Chemical/Product Carriers	Other Liquids	Edible Oil Tanker	Alcohol Tanker
Chemical/Product Carriers	Other Liquids	Molasses Tanker	Molasses Tanker
Chemical/Product Carriers	Other Liquids	Water Tanker	Water Tanker
Gasstankere (LGT)	Liquefied Gas	LNG Tanker	LNG Tanker
Gasstankere (LGT)	Liquefied Gas	LPG Tanker	LPG Tanker
Gasstankere (LGT)	Liquefied Gas	LPG Tanker	LPG/Chemical Tanker
Bulk Carriers	Bulk Dry	Bulk Carrier	Bulk Carrier
Bulk Carriers	Bulk Dry	Bulk Carrier	Bulk Carrier (with Vehicle Decks)
Bulk Carriers	Bulk Dry	Bulk Carrier	General Cargo/Tanker (Container/oil/bulk - COB ship)
Bulk Carriers	Bulk Dry / Oil	Bulk/Oil Carrier	Bulk/Oil Carrier (OBO)
Bulk Carriers	Bulk Dry / Oil	Bulk/Oil Carrier	Ore/Bulk/Products Carrier
Bulk Carriers	Bulk Dry / Oil	Ore/Oil Carrier	Ore/Bulk/Products Carrier
Bulk Carriers	Bulk Dry / Oil	Ore/Oil Carrier	Ore/Oil Carrier
Bulk Carriers	General Cargo	General Cargo Ship	General Cargo/Tanker (Container/oil/bulk - COB ship)
Bulk Carriers	Other Bulk Dry	Aggregates Carrier	Aggregates Carrier
Bulk Carriers	Other Bulk Dry	Cement Carrier	Cement Carrier
Bulk Carriers	Other Bulk Dry	Limestone Carrier	Limestone Carrier
Bulk Carriers	Other Bulk Dry	Refined Sugar Carrier	Refined Sugar Carrier
Bulk Carriers	Other Bulk Dry	Urea Carrier	Urea Carrier
Bulk Carriers	Other Bulk Dry	Wood Chips Carrier	Wood Chips Carrier, self unloading
Bulk Carriers	Self Discharging Bulk Dry	Self-Discharging Bulk Carrier	Bulk Cargo Barge, self discharging, propelled
Bulk Carriers	Self Discharging Bulk Dry	Self-Discharging Bulk Carrier	Bulk Cargo Carrier, self discharging
General Cargo	General Cargo	Deck Cargo Ship	Deck Cargo Ship

General Cargo	General Cargo	General Cargo Ship	General Cargo Barge, propelled
General Cargo	General Cargo	General Cargo Ship	General Cargo Ship
General Cargo	General Cargo	General Cargo Ship	General Cargo Ship (with Ro-Ro facility)
General Cargo	General Cargo	General Cargo Ship	General Cargo/Tanker
General Cargo	General Cargo	General Cargo Ship	General Cargo/Tanker (Container/oil/bulk - COB ship)
General Cargo	General Cargo	General Cargo Ship	Open Hatch Cargo Ship
General Cargo	General Cargo	Palletised Cargo Ship	Palletised Cargo Ship
General Cargo	Other Dry Cargo	Barge Carrier	Barge Carrier
General Cargo	Other Dry Cargo	Heavy Load Carrier	Submersible
General Cargo	Other Dry Cargo	Livestock Carrier	Livestock Carrier
General Cargo	Other Dry Cargo	Pulp Carrier	Pulp Carrier
Container vessel	Container	Container Ship	Container Ship (Fully Cellular)
Container vessel	Container	Passenger/Container Ship	Passenger/Container Ship
RORO lasteskip	Ro-Ro Cargo	Landing Craft	Landing Craft
RORO lasteskip	Ro-Ro Cargo	Ro-Ro Cargo Ship	Rail Vehicles Carrier
RORO lasteskip	Ro-Ro Cargo	Ro-Ro Cargo Ship	Ro-Ro Cargo Ship
RORO lasteskip	Ro-Ro Cargo	Vehicles Carrier	Vehicles Carrier
Reefers	Refrigerated Cargo	Refrigerated Cargo Ship	Refrigerated Cargo Ship
Passenger	Passenger	Passenger Ship	Car Carrier
Passenger	Passenger	Passenger Ship	Passenger Ship
Passenger	Passenger	Passenger Ship	Undefined Lloyds Type Level 5
Passenger	Passenger	Passenger Ship	Wing In Ground Effect Vessel
Passenger	Passenger / General Cargo	Passenger/General Cargo Ship	General Cargo/Passenger Ship
Passenger	Passenger/Ro-Ro Cargo	Passenger/Landing Craft	Passenger/Landing Craft
Passenger	Passenger/Ro-Ro Cargo	Passenger/Ro-Ro Cargo Ship	Passenger/Ro-Ro Ship (Vehicles)
Passenger	Passenger/Ro-Ro Cargo	Passenger/Ro-Ro Cargo Ship	Rail Vehicles Carrier
Offshore supply vessels	Offshore Supply	Offshore Supply Ship	Anchor Handling Tug Supply
Offshore supply vessels	Offshore Supply	Offshore Supply Ship	Offshore Support Vessel
Offshore supply vessels	Offshore Supply	Offshore Supply Ship	Platform Supply Ship
Offshore supply vessels	Offshore Supply	Offshore Tug/Supply Ship	Anchor Handling Tug Supply
Offshore supply vessels	Offshore Supply	Offshore Tug/Supply Ship	Offshore Tug/Supply Ship
Other Offshore vessels	Other Offshore	Drilling Ship	Drilling Ship
Other Offshore vessels	Other Offshore	FSO (Floating, Storage, Offloading)	FSO, Oil
Other Offshore vessels	Other Offshore	Offshore Processing Ship	FPSO, Gas
Other Offshore vessels	Other Offshore	Offshore Processing Ship	FPSO, Oil
Other Offshore vessels	Other Offshore	Offshore Processing Ship	Undefined Lloyds Type Level 5
Other Offshore vessels	Other Offshore	Offshore Support Vessel	Accommodation Ship
Other Offshore vessels	Other Offshore	Offshore Support Vessel	Diving Support Vessel

Other Offshore vessels	Other Offshore	Offshore Support Vessel	Offshore Support Vessel
Other Offshore vessels	Other Offshore	Pipe Burying Vessel	Pipe Burying Vessel
Other Offshore vessels	Other Offshore	Pipe-Layer	Pipe Layer
Other Offshore vessels	Other Offshore	Standby-Safety Vessel	Offshore Support Vessel
Other Offshore vessels	Other Offshore	Standby-Safety Vessel	Standby Safety Vessel
Other Activities	Dredging	Dredger	Dredger (unspecified)
Other Activities	Dredging	Dredger	Suction Dredger
Other Activities	Dredging	Hopper Dredger	Hopper/Dredger (unspecified)
Other Activities	Dredging	Hopper Dredger	Hopper/Suction Dredger
Other Activities	Other Activities	Buoy/Lighthouse Vessel	Buoy & Lighthouse Tender
Other Activities	Other Activities	Cable-Layer	Cable Layer
Other Activities	Other Activities	Crane Ship	Crane Ship
Other Activities	Other Activities	Crane Ship	Pipe Layer Crane Vessel
Other Activities	Other Activities	Crane Ship	Undefined Lloyds Type Level 5
Other Activities	Other Activities	Crewboat	Crew Boat
Other Activities	Other Activities	Fire-Fighting Vessel	Fire Fighting Vessel
Other Activities	Other Activities	Hospital Vessel	Hospital Vessel
Other Activities	Other Activities	Icebreaker	Icebreaker
Other Activities	Other Activities	Patrol Vessel	Patrol Vessel
Other Activities	Other Activities	Pilot Vessel	Pilot Vessel
Other Activities	Other Activities	Pollution Control Vessel	Pollution Control Vessel
Other Activities	Other Activities	Pollution Control Vessel	Research Survey Vessel
Other Activities	Other Activities	Salvage Ship	Icebreaker
Other Activities	Other Activities	Salvage Ship	Salvage Ship
Other Activities	Other Activities	Search & Rescue Vessel	Search & Rescue Vessel
Other Activities	Other Activities	Tank-Cleaning Vessel	Tank Cleaning Vessel
Other Activities	Other Activities	Tender (Unspecified)	Supply Tender
Other Activities	Other Activities	Training Ship	Training Ship
Other Activities	Other Activities	Utility Vessel	Tank Cleaning Vessel
Other Activities	Other Activities	Utility Vessel	Undefined Lloyds Type Level 5
Other Activities	Other Activities	Work/Repair Vessel	Work/Repair Vessel
Other Activities	Other Activities cont./	Dry Storage	Bulk Cement Storage Ship
Other Activities	Research	Research Vessel	Research Survey Vessel
Other Activities	Towing / Pushing	Pusher Tug	Pusher Tug
Other Activities	Towing / Pushing	Tug	Icebreaker
Other Activities	Towing / Pushing	Tug	Tug

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