APP4SEA

ARCTIC PREPAREDNESS PLATFORM

FOR OIL SPILL AND OTHER ENVIRONMENTAL ACCIDENTS

Report on oil tanker marine routes and tracking systems

Report T.2.2.1

Jorma Rytkönen & Markus Santasalo

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The 21st century has brought unprecedented interest in Arctic resources, transforming the region from the world's unknown periphery into a centre of global attention.

Within the next 50 years, local coastal communities, their living environment and traditional lifestyle will undergo major changes, starting from climatic perturbations and ending with petroleum industrial intervention and increased shipping presence.

The APP4SEA project, financed by the Northern Periphery and Arctic Programme, will contribute to the environmental protection of Arctic waters and preserving the traditional lifestyle of the local communities. It will improve the oil spill preparedness of local authorities and public awareness about potential oil tanker accidents at sea.

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Summary

This report is one outcome of the project APP4SEA, the Arctic Preparedness Platform for Oil Spill and other Environmental Accidents, funded by the EU Northern Periphery and the Arctic Programme. The aim of the report is to describe factors affecting shipping traffic in the Arctic. Maritime activities are expected to increase significantly over the coming decades. Recent studies estimate that the increase in maritime traffic in the Arctic will be more than 50 % between 2012 and 2050. Depending on international demands for transit voyages through the North West Passage and the Northern Sea Route, the growth of maritime transport may be even more significant.

This report highlights some of the most important factors affecting maritime transport scenarios in the future. Global warming and decrease of the extent and thickness of the ice cover in the Arctic is perhaps the most important factor allowing more and more ice strength vessels to enter the area and ensuring year-round navigation with the assistance of the ice breaker fleet. Here the new demands of the International Maritime Organization, the Polar Code and the novel tracking systems and services under development have been recognised to enhance both environmental and safety requirements.

Finally, the lack of Arctic infrastructure is discussed, along with the recently developed weather and ice information systems, wave prognoses and novel tools of Aids to Navigation (ATON).

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- Share knowledge on oil behaviour at sea, oil spill response methods, experience with tools and models;
- Introduce cutting edge technologies;
- Provide local authorities and the general public with access to the knowledge bank.

Contents

Introduction

The increase in human activities in the sensitive and unique ecosystem of the Arctic will predictably cause an increase of harmful emissions; the Arctic region is already warming twice as rapidly as the rest of the planet and this trend is expected to accelerate as global warming intensifies. Ships operating in the Arctic and Antarctic environments are exposed to a number of unique risks. Poor weather conditions and the relative lack of good charts, communication systems and other navigational aids pose challenges for mariners. The remoteness of the areas makes rescue or clean-up operations difficult and costly (IMO 2017).

There is a general lack of marine infrastructure in the Arctic, except for areas along the Norwegian coast and northwest Russia, compared with other marine regions of the world with high concentrations of ship traffic. Gaps in hydro-graphic data exist for significant portions of primary shipping routes important for the support of safe navigation (AMSA 2009). Ice data and data on the existence of icebergs are examples of the vital information needed onboard ships sailing in the area. In the case of emergency situations, the lack of infrastructure causes severe problems for any salvage or rescue operations. Radio and communication support systems are also scarce, with many limitations on coverage. Monitoring of ships in ice-covered waters with moving ice is also a challenge, where new technology is needed to ensure the safety and survivability patterns.

Thus, the international community decided in 2008 to adopt specific regulations for ships sailing in polar waters through the development of a mandatory code for ships operating in polar waters, i.e. The Polar Code. The Polar Code covers the full range of design, construction, equipment, operational, training, search-and-rescue and environmental protection matters relevant to ships operating in the inhospitable waters surrounding the two poles. The Polar Code entered into force on 1 January 2017.
https://www.imo.org/en/MediaCentre/HotTopics/Pages/Polar-default.aspx

Climate change, with rapid warming, has had several impacts both on local and global levels in the Arctic. The rapid decline of the sea ice will also increase the possibilities for shipping and the utilization of the Arctic area's sea routes. Over the past decades the Arctic has warmed up twice as fast as the rest of the world (Dings, J. 2012). The decline in the thickness and extent of the sea ice in the Arctic is predicted to continue, with the possibility of mainly ice-free conditions during the summer season in the next 30 – 40 years, see Figure 1 (AMAP, 2011).

And it is not only the extent of sea ice which is decreasing. The extent of multi-year ice is also decreasing rapidly: in the early 1980s, multi-annual ice represented approximately 50 % of the Arctic Sea ice, whereas by 2010 the percentage was close to 30 % of the total ice cover http://nsidc.org . Simultaneously with the decrease of the ice extent, the ice cover is getting younger and thinner.

This development will offer new possibilities for the industry and for other human activities in the Arctic. It has been estimated that by 2050 the Arctic sea routes (Figure 2) will cover approximately 10 % of the container trade between Europe and Asia. This means 850 transit voyages carrying approximately 2.5 million TEU. The opening of the Northern Sea Route alone could shorten the sailing time between Europe and Asia by one third. For the Canadian Arctic, the Northwest Passage is not expected to become a viable trans-Arctic route during the 2020s, but maritime shipping is anticipated to increase. Marine transportation of oil from the Pechora Sea to Europe is considered technically and economically feasible, and the use of the Northern Sea Route (NSR) has growing importance (AMSA 2009).

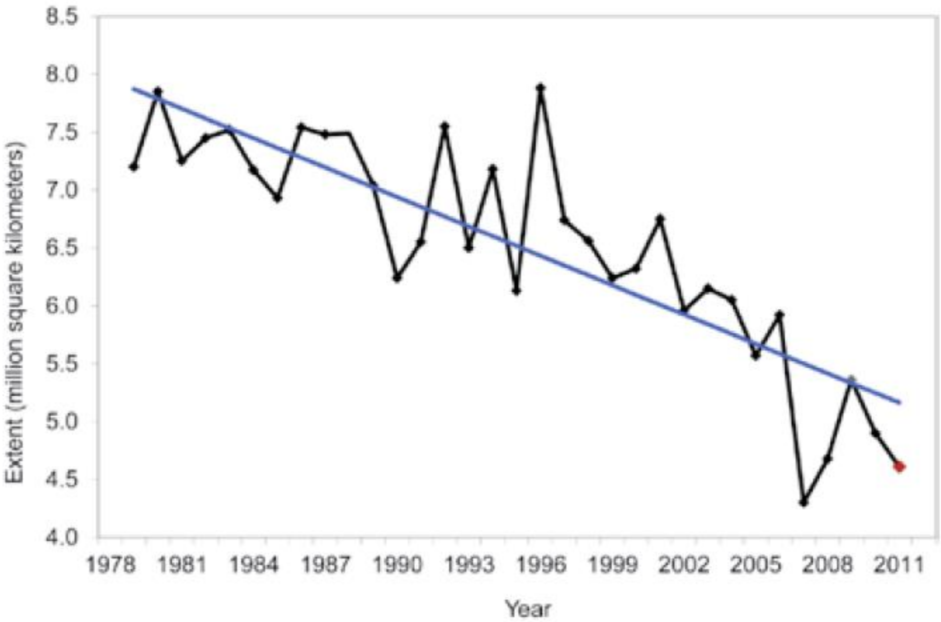

Figure 1. Average monthly sea ice extent in September, 1979 to 2011 (NSDCI 2011).

There was a slight decline in maritime traffic in many areas of the Arctic after 2014, but traffic is anticipated to increase in future years. By 2025, vessel traffic through the Bering Strait is projected to increase from 100% to 500% relative to the 2013 traffic level (Ocean Conservancy 2017). Table 1 shows the share of the different vessel types and sizes sailing in the Polar Code region in 2014 (Ocean Conservancy 2017). Vessel tracks recorded in the same area in 2014 are presented in Figure 2. By the end of the century, some experts predict ice-free passage through the Northern Sea Route for three to six months of the year and via the Northwest Passage for two to four months of the year (Khon, V. et al 2010). Figure 3 shows monthly variations in the location of vessels in the Polar Code region in 2014.

Table 1. Number of vessels operating in the Polar Code area in 2014. Ocean Conservancy 2017).

Gross Tonnage (GT)									
	<1000	1000-5000	5000 – 10,000	10,000 - 25,000	25,000-50,000	50,000-100,000	≥100,000	Not known	Total
Bulk carriers		4	3	40	84	5			136
Cargo – General	11	112	64	31	8				226
Cargo – Refrigerated	1	49	38	8					96
Cargo – Roll on/ Roll off (Ro-Ro)	5	2	2	1		2			12
Container ships			5	3	3				11
Fishing vessels	305	387	29						721
Liquid gas carriers							1		1
Offshore supply vessels	7	42	18						67
Other offshore activities	17	2	2	1					22
Other activities	166	118	46	33	5				368
Passenger	12	17	11	20	20	9	3		92
Tankers – Chemical and other	2	24	13	18	9				66
Tankers – Oil	1	53	8	11	21	5			99
Unknown	1							382	383
Total	**528**	**810**	**239**	**166**	**150**	**21**	**4**	**382**	**2,300**

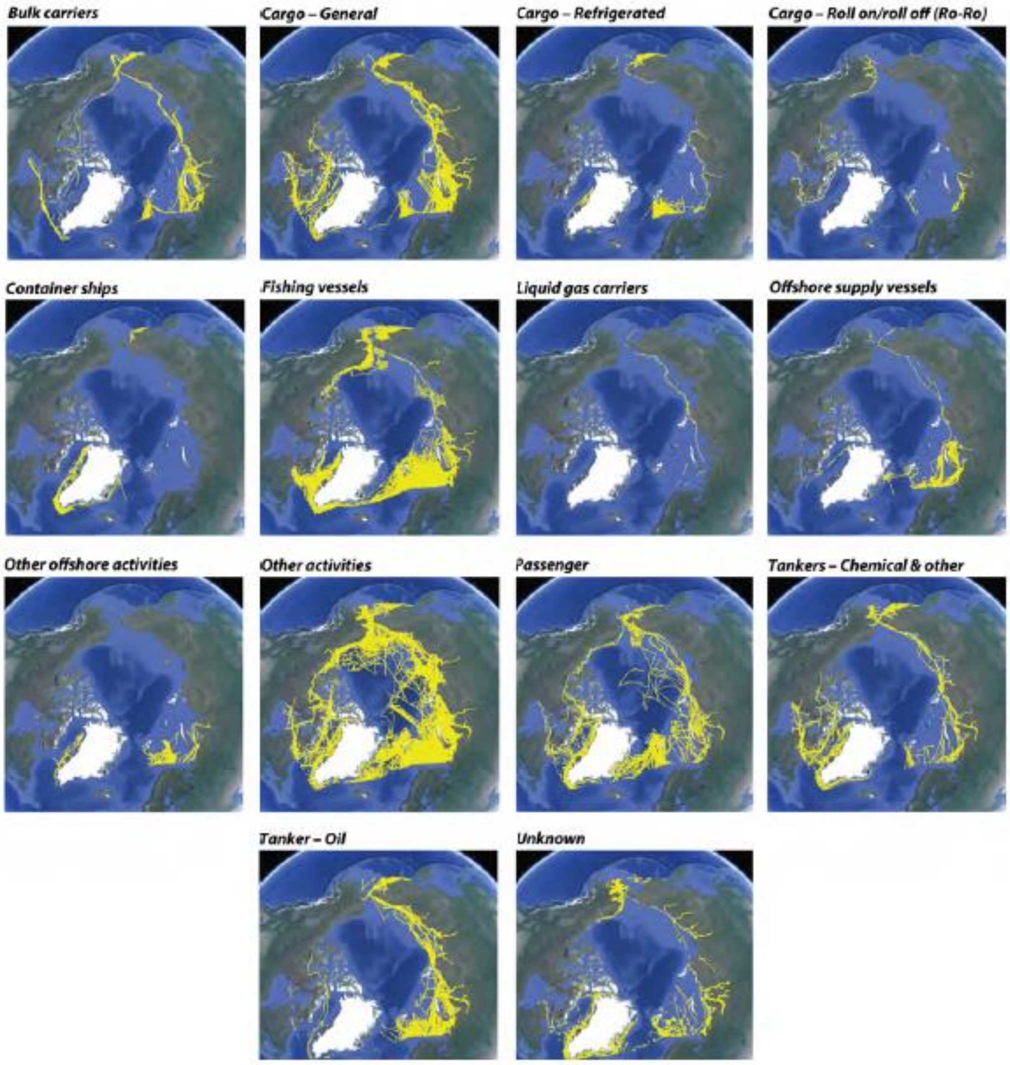

Figure 2. Vessel tracks recorded in 2014 in the Polar Code area. Yellow colour indicates the tracks of vessels of the specified type (Ocean Conservancy 2017).

Sea ice is a key driver of vessel location, with stark differences between winter and summer months. Most Arctic traffic consists of vessels with light or no ice strengthening. Vessel operators avoid ice-covered waters, since ice slows forward progress. In addition, snow and ice can adversely affect propulsion by clogging or blocking machinery air- and seawater intakes for cooling or firefighting systems (Ocean Conservancy 2017). Similar analyses using the AIS data of 2015 -2017 were presented in (Silber, G & Adams, J. 2019) and also provided an idea about the short-term variation of the operations during the three-year period.

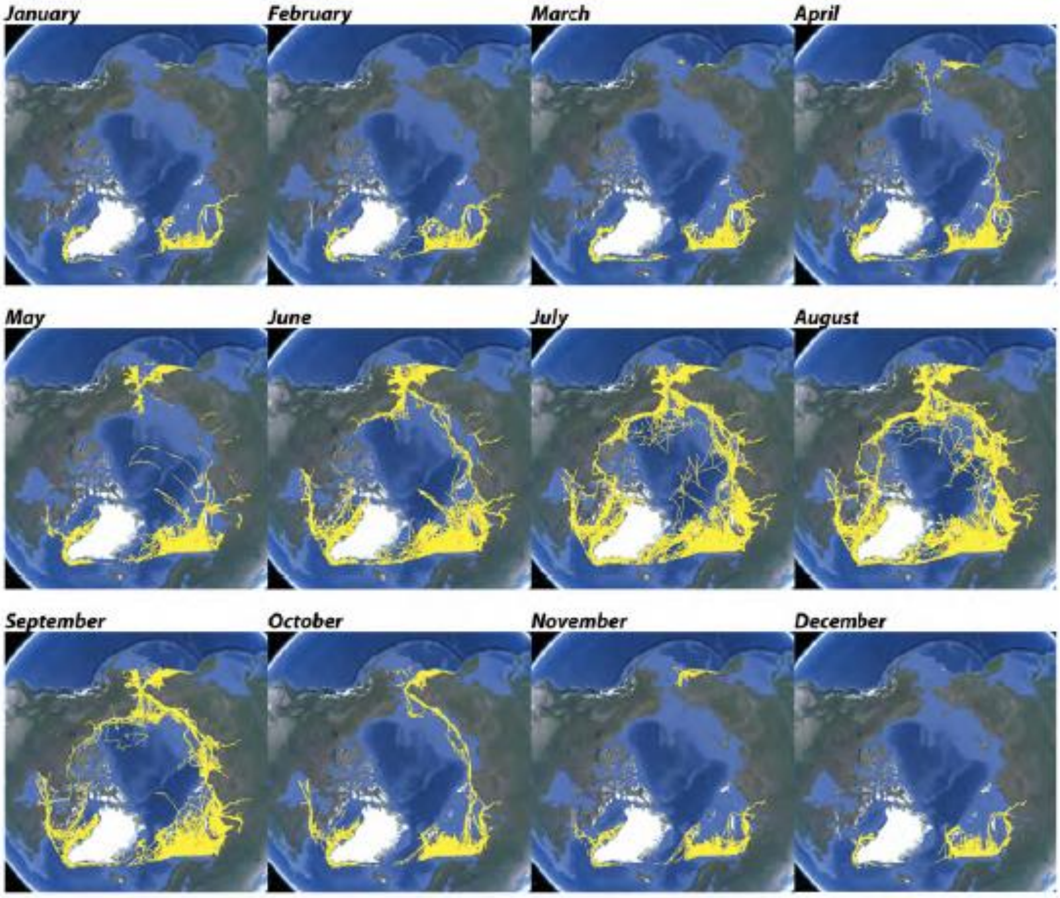

Figure 3. Vessel tracks by month, recorded in 2014. (Oceans Conservancy 2017).

The increasing maritime traffic may also increase the risks for accidents. Even with the current low shipping activity in the Arctic, nearly 300 accidents and incidents occurred in the region during the period 1995 – 2004. Without environmental policies, environmental accidents may increase with the increasing traffic. Three major types of environmental risks can be defined (Dings, J. 2021):

- First, typical shipping accidents such as collisions, groundings and sinking of ships. Due to the long distances and remoteness, any counteraction for salvage or environmental protection will take too much time, and the impacts may be serious;
- Second, impact sources will be various releases from the ships, even if they are legally permissible. Typical releases such as sewage, sludge, garbage and grey water will threaten the vulnerable environment, and
- Third, one mode of impact will be the diverse impacts on the Arctic ecosystem due to subjecting marine mammals to noise, due to ice channels created through the ice and due to emissions. Emissions represent a significant booster for Arctic warming, and the growth in Arctic shipping could result in a twenty-fold increase of black carbon emissions in the area.

The possible impact of black carbon releases could be particularly significant in conjunction with the increase in shipping. Carbon emissions will accelerate the ice melting due to the impact of the solar radiation on the dark-coloured carbon particles. Melting ice and open water do not reflect radiation as well as white snow and ice. Larger open water areas will cause warmer water, which in turn will increase the melting, etc. There are studies available which indicate that the black carbon releases may account for up to half of the overall Arctic warming (Corbett, et. al 2010). Thus, all measures to reduce carbon emissions caused by shipping will have significant effects in future Arctic shipping. Typical options are the use of LNG, a ban of heavy fuel oils and the use of scrubbers, low-sulphur marine diesel, water in-fuel emulsion, and diesel particulate filters etc.

This report presents part of the work carried out within the project “Arctic Preparedness Platform for Oil Spill and Other Environmental Damages (APP4SEA)”, funded by the EU Northern Periphery and Arctic (NPA) Programme. The main goal of APP4SEA was to improve oil spill response (OSR) preparedness in the NPA region.

The report is one of the outcomes of the project describing the main routes of vessels in the Arctic and highlighting briefly the main parameters affecting the future of Arctic shipping. The report is part of the APP4SEA’s Activity T.2.2 .”Tracking System for Oil Carriers”. Other outcomes of this research activity included preparatory phases to construct additional layers in the Interactive Smart Map designed in the APP4SEA projects, and to illustrate the weather zones and areas having high risks for ecological damage in the case of environmental impacts and oil spills. The project’s web-page is https://app4sea.interreg-npa.eu/outputs-and-results/
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Ship routing in the Arctic

There is a long history of Arctic marine transport conducted primarily around the ice-free periphery of the Arctic Ocean. Year-round navigation has been maintained since 1978-79 in the ice-covered western regions of the Northern Sea Route (between the port of Dudinka on the Yenisei River and Murmansk) (AMSA 2009).

The IMO's Maritime Safety Committee (MSC), at its 99th session in May 2018, adopted new and amended ship routing measures in the Bering Sea and Bering Strait, aimed at reducing the risks of incidents - the first measures adopted by IMO for the Arctic region where the Polar Code applies.

The measures include six two-way routes and six precautionary areas, to be voluntary for all ships of 400 gross tonnage and above, in the Bering Sea and Bering Strait off the coast of the Chukotskiy Peninsula and Alaska, proposed by the Russian Federation and the United States. These waters are expected to see increased traffic due to growing economic activity in the Arctic.

In addition, the MSC established three areas to be avoided in the Bering Sea, proposed by the United States, to improve the safety of navigation and protect the fragile and unique environment. These measures entered into force on 1 December 2018.

Routing measures are widely used to enhance navigational safety. By steering vessels into a defined traffic lane or away from particular locations, the predictability of vessel movement is improved. The lanes can also help ensure that vessels remain in well-charted waters, thus avoiding groundings and other potential accidents. Routing measures such as traffic lanes and areas to be avoided (ATBAs) are also used to protect vulnerable and valuable habitats from vessel impacts such as marine mammal strikes and noise disturbance. For example, as part of a shipping study of the Bering Strait region, the United States Coast Guard (USCG) recommended a designated route for vessel traffic and a series of ATBAs to ensure that vessels steer clear of dangerous or sensitive areas, including areas where subsistence hunting occurs (US Coast Guard 2016).

Northern Sea Route

The Northern Sea Route (NSR) runs through the Kara Sea, Laptev, East Siberian and Chukchi Seas. From the west the starting point is the Straits Yukorsgiy Shar and Karskiye Vorota or passing north of the Novaja Zemlya island. From the east the NSR can be reached through the Bering Strait (see Figure 4). The literature also defines the North-Eastern Route NEP, which is defined as the set of sea routes from north-west Europe around North Cape (Norway) and along the north coast of Eurasia and Siberia through the Bering Strait to the Pacific (AMSA 2009).

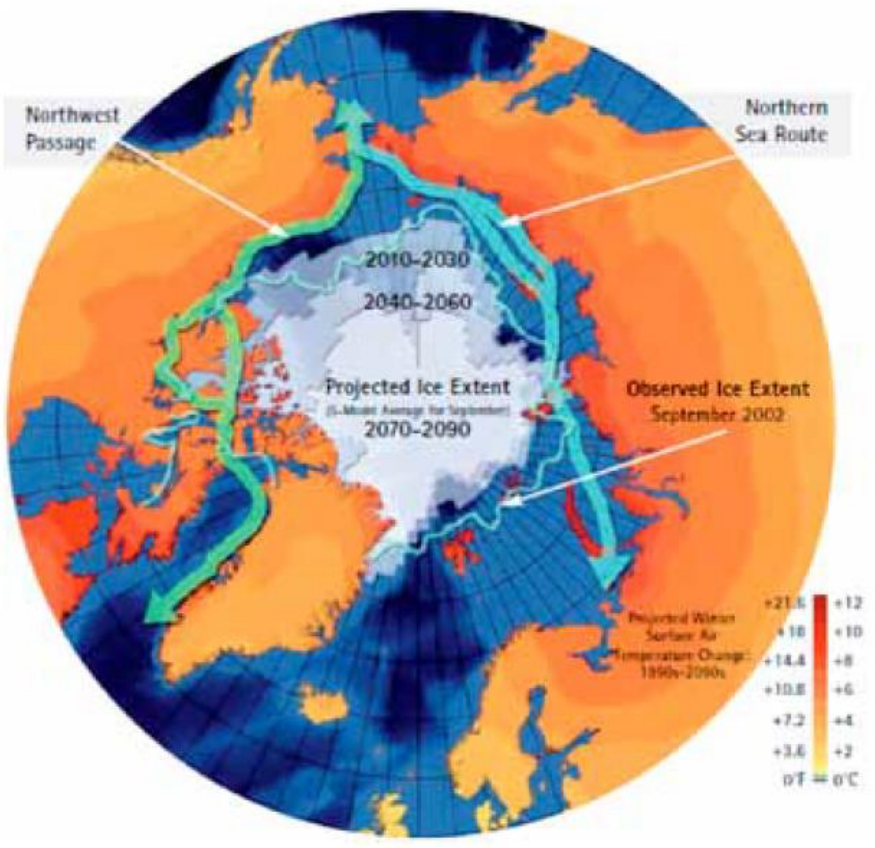

Figure 4. The main sea routes in the Arctic with the projected ice extent (ACIA 2004).

Navigation through the NSR is influenced by the presence of ice. Ice conditions will normally vary considerably, both annually and seasonally. The navigation season for transit starts typically at the beginning of July and continues to the second half of November. In the western parts it is possible to navigate year-round with the help of ice breakers, or by using ice-going vessels having an adequate ice class. The NSR extends for about 3000 nautical miles. The length of the route with icebreaker assistance in each case depends on ice conditions, and on the choice of particular variants of passage or different stretches of the route.

Since the winter of 1978 – 79, one of the most advanced marine transit routes in the Arctic has been the year-round route between Dudinka and Murmansk. The cargo flow along this route has for some years been close to one million tons per year. Other year-round targets in the area have been the Varandey terminal and the Prirazlomnaya oil terminal. Sabetta's LNG plant is one of the newest targets, with an oil loading terminal in the Ob Bay (Cape Kamenny). The transportation rates from these destinations were expected to be close to 16.5 million tons already in 2019 (AKER 2017).

Since 2010, high-capacity tankers of appropriate ice classes have carried out transit cargo operations during the summer – autumn period. These ships sail under the escort of Russian nuclear-powered ice breakers. For the first time an Aframax type tanker, SCF Baltica (Figure 5), used the NCR route and sailed from Murmansk to China in August 2010, and the even larger tanker Vladimir (Figure 6) of the Suezmax size sailed the route carrying 160 000 tons of oil. The Baltica's voyage was well recorded and documented, and it was noted that the sailing time compared to the Suez Canal was 40% shorter and resulted in 800 mt fuel savings and a reduction in CO emissions of 3000 metric tons.

Figure 5. SCF Baltica assisted by the nuclear ice breaker Rossiya.

Figure 6. During 2011 a new route north of the New Siberian Islands was established, where the water is deep enough to accommodate tankers with draughts of over 12 metres, and for the first time in history the route was navigated by the Sovcomflot tanker Vladimir Tikhonov, a Suezmax ice class 1A vessel with a dead weight of over 160 000 tons (AKER 2012) (Photo: D. Sands).

In November 2012, for the first time ever, transportation of LNG via the NSR was carried out. The transportation was performed by the LNG carrier Ob River (Figure 7), with a capacity of 150 000 m^3, which was escorted by two nuclear icebreakers during the period of intensive ice formation. Depending on the winter and seasonal variations, however, the transit cargo flows along the NSR may vary considerably, and cargo can easily be redirected along other routes.

The safety aspects and environmental protection of the NSR are based on the Federal Law "On amendments to certain legislative acts of the Russian Federation regarding the state regulation of commercial navigation in the water area of the NSR, in 2012". The activities are supervised by the Northern Sea Route Administration, which has the following key focus areas in its work (AKER 2017):

- Obtaining and considering the submitted applications and issuing permits for navigation through the NSR;
- Issuing certificates of the ice conventional pilotage through the NSR;
- Researching weather, ice, navigational and other conditions in the NSR;

- Coordination of installation of navigational aids and harmonization of regions to carry out hydrographical survey operations in the NSR;
- Assistance in the organization of search and rescue operations in the water area of the NSR;
- Assistance in eliminating the consequences of pollution from vessels due to release of harmful substances, sewage or garbage;
- Rendering the information services in relation to the water area of the NSR, for example concerning the organisation of navigation, requirements of safe navigation and other factors;
- Making recommendations about the development of navigation routes and using ice-breaking fleets in the water area of the NSR, and ice and navigational conditions there;
- Timely data retrieval from the Russian hydro meteorological service about hydro meteorological forecasts and ice analysis.

On the Northern Sea Route, SAR coverage is provided by the Marine Rescue Service (Morspassluzhba), with assistance from several other Russian agencies. The Marine Rescue Service has created a coordination centre in Dikson (Taimyr peninsula) that operates year-round, along with two sub-centres in Tiski and Pevek (central and eastern sections of the Northern Sea Route), and an eastern site in Provideniya (Figure 8). All of these locations have SAR and oil spill response equipment, but these resources are limited (Adm. of the NSR 2016).

The Marine Rescue Service currently has 12 multifunctional and supply vessels in Arctic and sub-Arctic areas, including specialized ice-breaking vessels. Direct involvement of icebreakers is seen as crucial to SAR, incident prevention and response in this region. Most Marine Rescue Service vessels are located in the less icy western and eastern regions, such as Murmansk, Sakhalin and Vladivostok.

Figure 7. The LNG tanker Ob River, IMO 9315692. (Photo: G Cailler)

Figure 8. Marine rescue and emergency centres along the Russian Arctic coastline (Smirnov, V. 2016).

The new “Rules of the navigation in the water area of the Northern Sea Route”, approved in 2013, state that icebreaker escort on the NSR is carried out only by icebreakers navigating under the flag of the Russian Federation. These rules also contain a list of documents which ship owners must attach to the application for permission to navigate in the water area of the NSR.

Northwest Passage (NWP)

The Northwest Passage (NWP) is the name given to the various marine routes between the Atlantic and Pacific oceans along the northern coast of North America that span the Canadian Arctic Archipelago (Table 2). The Canadian Arctic Archipelago stretches longitudinally about 1,900 km from mainland Canada to the northern tip of Ellesmere Island. From west to east, it covers a distance of about 2,400 km from Banks Island (west side) to Baffin Island (east side). There are five recognized routes or passages, with variations, through the Archipelago, which are presented in Table 2 below.

All passages have common eastern and western approaches. In the east, ships must proceed through the Labrador Sea, Davis Strait and Baffin Bay - the exception is for Route 5, which requires a transit through Hudson Strait. In the western approaches, ships proceed through the Bering Sea, Bering Strait, the Chukchi Sea and the Beaufort Sea before deciding which route to follow. In general, the operating season is short - from late July to mid-October - depending on the route and year (AMSA 2009).

The types of commercial shipping activity currently taking place in the Canadian Arctic consist of community re-supply; bulk shipments of raw materials, supplies and exploration activity for resource development operations; and tourism. Expectations for the improved use of the NWP route have been as follows (ASMA 2009):

- Dry bulk carriage stimulated by resource development: definitive forecasts of substantive marine transportation projects are, for the moment, the Mary River and High Lake developments.
- Liquid bulk carriage stimulated by resource development: minimal forecasts due to expectations that any substantive products in the Beaufort Sea will move out by pipeline.
- Supply/resupply: some important but manageable expansion in shipping activity is forecast, related to growing populations and to the movement of supplies and equipment in support of exploration projects.
- Cruise shipping: projections of modest but largely unpredictable growth.
- Container, bulk transit traffic: no substantive activity seen in this sector in the timeframe under examination.
- Other: unknown activity for fishing, seismic, etc.

Table 2. Water routes of the NWP (AMSA 2009).

Route	Routing (East to West)	Physical Description	Of Note
1	Lancaster Sound – Barrow Strait – Viscount Melville Sound – Prince of Wales Strait – Amundsen Gulf.	**Lancaster Sound:** 80 km wide, 250 km long, deep at over 500 m. **Barrow Strait:** 50 km wide, 180 km long, deep, string of islands west of Resolute disrupts clear navigation. **Viscount Melville Sound:** 100 km wide, 350 km long, experiences multi-year ice from M'Clure Strait. **Prince of Wales Strait:** minimum width of less than 10 km about half way through the Strait, 230 km long, limiting depth of 32 m. **Amundsen Gulf:** irregular shape, 90 km wide entrance, approximately 300 km long.	Suitable for deep draft navigation; the route followed by *St. Roch* in 1944 on westerly transit and the *SS Manhattan* in 1969.
2	Same as 1 but substitute M'Clure Strait for Prince of Wales Strait and Amundsen Gulf. Collectively Lancaster Sound – Barrow Strait – Viscount Melville Sound is known as Parry Channel.	**M'Clure Strait:** 120 km wide at east end, 275 km long to Beaufort Sea, deep at over 400 m, experiences multi-year ice from Arctic Ocean.	*SS Manhattan* attempted this route in 1969 but was turned back. Russian icebreaker *Kapitan Klebnikov* succeeded in a passage in 2001. In September 2007 was clear of Arctic pack ice for a limited time since satellite photos have been available; there was more ice in 2008.
3A	Lancaster Sound – Barrow Strait – Peel Sound – Franklin Strait – Larsen Sound – Victoria Strait – Queen Maud Gulf – Dease Strait – Coronation Gulf – Dolphin and Union Strait – Amundsen Gulf.	**Lancaster Sound and Barrow Strait:** see Route 1. **Peel Sound:** 25 km wide, deep at over 400 m at south end. **Franklin Strait:** 30 km wide. **Larsen Sound:** depths vary between 30 and 200 meters. **Victoria Strait:** 120 km wide, at southern end is blocked by Royal Geographical Society Islands, worst ice conditions along the mainland coast of Canada. **Queen Maud Gulf:** eastern entrance 14 km wide, but widens into an irregular area with width of up to 280 km before narrowing to 14 km at entrance to Dease Strait; numerous islands, reefs and shoals. **Dease Strait:** 14 – 60 km wide, 160 km long. **Coronation Gulf:** over 160 km long, many islands. **Dolphin and Union Strait:** 80 km wide at Amundsen Gulf, 150 km long, caution should be exercised in passage, several soundings of less than 10 m have been recorded. **Amundsen Gulf:** see Route 1.	Of the 3A, 3B and 4 routes, this is considered the best option but with a draft limit of 10 m.
3B	A variation of 3A. Rather than following Victoria Strait on the west side of King William Island, the route passes to the east of the island following James Ross Strait – Rae Strait – Simpson Strait.	**James Ross Strait:** 50 km wide, but restricted by islands, extensive shoaling. **Rae Strait:** 20 km wide, with limiting depths of between 5-18 m in mid channel. **Simpson Strait:** about 3 km wide at narrowest point, most hazardous navigation area in 3B route.	The route of Roald Amundsen. Also route of the *MS Explorer*, in 1984, the first cruise ship to navigate the Northwest Passage.
4	Similar to 3A. Rather than following Peel Sound on the west side of Somerset Island, the route passes to the east of the island through Prince Regent Inlet and Bellot Strait.	**Prince Regent Inlet:** 80 km wide, free of islands, deep. **Bellot Strait:** short and very narrow, strong currents, limiting depth of 22 m.	Route of *St. Roch* in 1940-42 on easterly transit.
5	Hudson Strait – Foxe Channel – Foxe Basin – Fury and Hecla Strait – Gulf of Boothia – Bellot Strait – remainder via routes 3A, 3B or 4.	**Hudson Strait:** 100 km wide, 650 km long, deep, also serves as entrance to Hudson Bay and Churchill port. **Foxe Channel:** 130 km wide, deep, with limiting shoal in the middle that can be avoided. **Foxe Basin:** very large, many islands in northern end. **Fury and Hecla Strait:** 160 km long, very narrow with fast current. **Gulf of Boothia:** very large waterway connecting to Prince Regent Inlet to the north (see route 4). No problems for navigation except at exit of Fury and Hecla Strait where Crown Prince Frederick Island is to be avoided.	Not generally considered a viable commercial passage for moderate to deep draft ships.

The Northwest Passage is not expected to become a viable trans-Arctic route during the 2020s due to seasonality, ice conditions, the complex archipelago, draft restrictions, chokepoints, lack of adequate charts, insurance limitations and other costs, which diminish the likelihood of regularly scheduled services from the Pacific to the Atlantic. It is estimated that the destination traffic may increase, but due to the high operational costs in the ice-infested waters, it is likely that viable year-round operations will still be very scarce.

Ship reporting updates

The MSC, at its 91st session in November 2012, adopted a new mandatory ship reporting system "In the Barents Area (Barents SRS)" (proposed by Norway and the Russian Federation). The new mandatory ship reporting system entered into force at 0000 hours UTC on 1 June 2013. The following categories of ships passing through or proceeding to and from ports and anchorages in the Barents SRS area are required to participate in the ship reporting system, by reporting to either Vardø VTS centre or Murmansk VTS centre: all ships with a gross tonnage of 5,000 and above; all tankers; all ships carrying hazardous cargoes; any towing vessel when the length of the tow exceeds 200 metres; and any ship not under command, restricted in their ability to manoeuvre or having defective navigational aids.

The Polar Code

The Polar Code includes mandatory measures covering a safety part and a pollution prevention part, and recommendatory provisions for both parts. Here the focus is on the requirements having a relevant effect on the safety issues, with a positive impact on the decreased risk of an oil spill.

All ships having the aim to sail through Arctic (or Antarctic) waters need to have a Polar Ship Certificate describing their capability to meet certain ice conditions:
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- Category A ship - ships designed for operation in polar waters at least in medium first-year ice, which may include old ice inclusions;
- Category B ship - a ship not included in category A, designed for operation in polar waters in at least thin first-year ice, which may include old ice inclusions;
- Category C ship - a ship designed to operate in open water or in ice conditions less severe than those included in Categories A and B.

Ships need to carry a Polar Water Operational Manual, to provide the Owner, Operator, Master and crew with sufficient information regarding the ship's operational capabilities and limitations in order to support their decision-making process (IMO, 2016).

The IMO's Maritime Safety Committee and related sub-committees are looking at the application of the Polar Code to ships not currently covered by SOLAS. The Polar Code is mandatory for certain ships under the SOLAS and MARPOL Conventions. While SOLAS Chapter V (Safety of navigation) applies to all ships on all voyages (with some specific exceptions), the other chapters of the Convention do not apply to some categories of ships (IMO 2020). Figures 9 and 10 describe the safety and environmental requirements of the Polar Code.

The Polar Code applies to ships differently, depending on how a ship is constructed and how it will be operated in polar waters. The Polar Code's requirements take into account the capabilities a ship will need in order to carry out its intended operations safely and responsibly. These capabilities may include operation in ice, low air temperature, high latitude, extended periods of darkness, icing, etc. These conditions are highly dependent on where, when and how a ship will operate in the polar regions and what environmental conditions it will probably encounter while there (Ocean Conservancy 2017). Not all ships traveling in the Arctic are subject to all provisions of the Polar Code. For example, non-SOLAS vessels (i.e., fishing vessels, cargo ships of less than 500 GT, ships of war, pleasure yachts not engaged in trade) are not subject to these provisions.

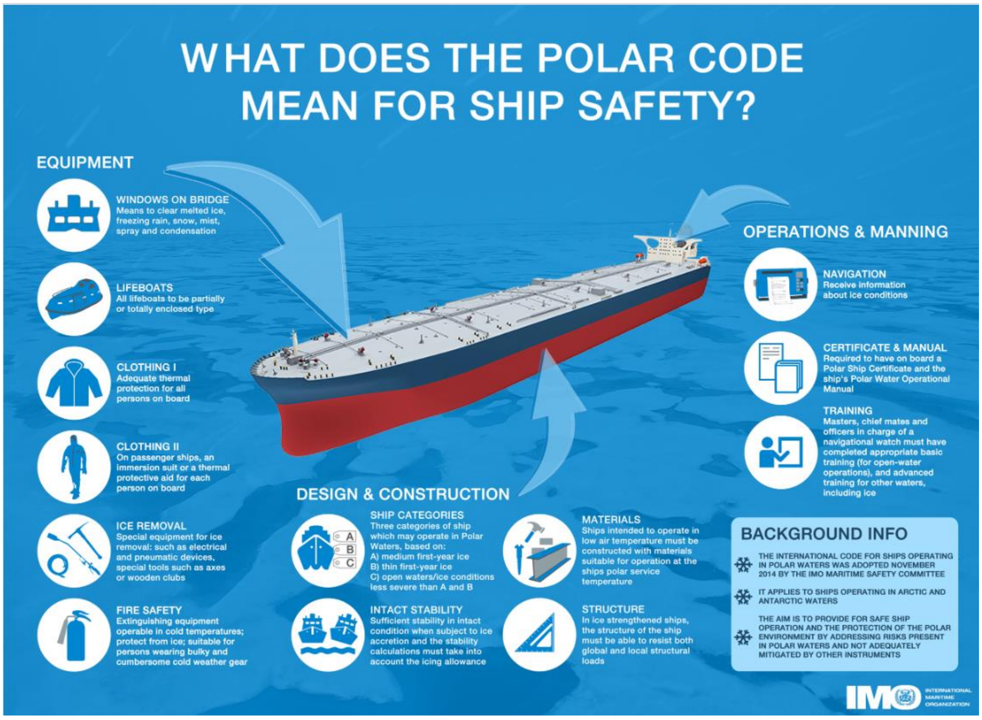

Figure 9. Illustration of the safety requirements based on the Polar Code (www.imo.org)

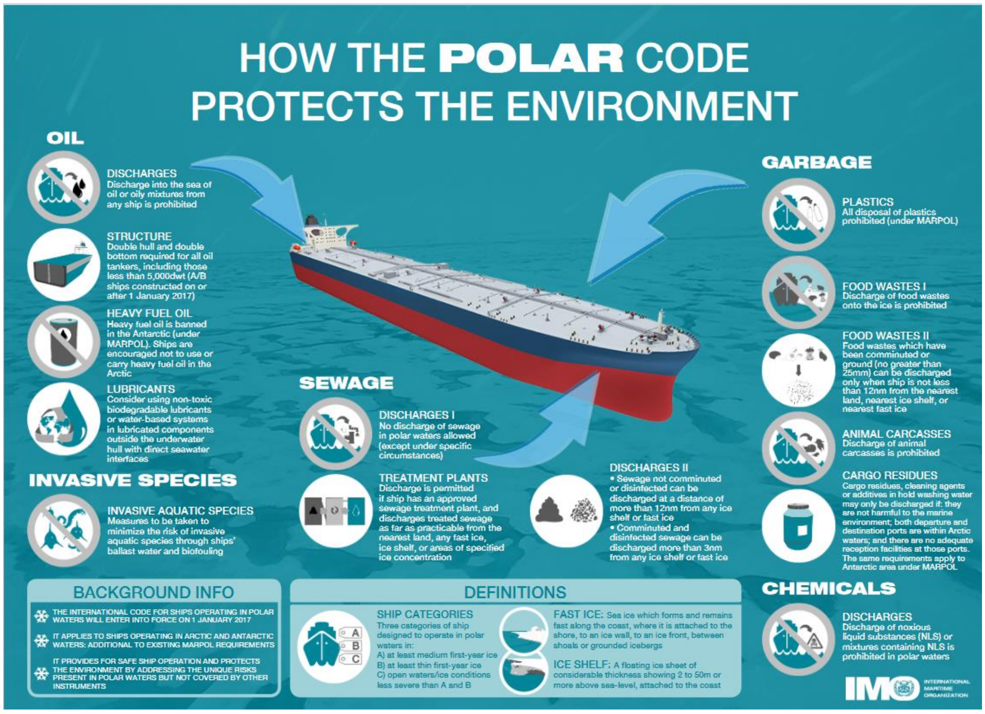

Figure 10. Illustration of the environmental requirements based on the Polar Code (www.imo.org).

Another important IMO convention is the International Convention for the Prevention of Pollution from Ships (MARPOL), as modified by the Protocol of 1978 and the Protocol of 1997. MARPOL addresses prevention of pollution of the marine environment by ships and includes six annexes (UN. 1973). Furthermore, the International Convention for the Safety of Life At Sea (SOLAS) should be mentioned here as an IMO instrument addressing the minimum standards for vessel construction, equipment and operation and safety (UN. 1974).

Tracking systems

Marine Traffic vessel tracking system

MarineTraffic is an open, community-based project providing real-time information on the movements of ships and their current location in harbours and ports. The database of information on the vessels includes for example details of the location where they were built, the dimensions and gross tonnage of the vessels and their International Maritime Organization (IMO) number. Users of the system can also submit photographs of the vessels, which other users can rate.

Data is collected by receipt of Automatic Identification System (AIS) transmissions. The automatic identification system (AIS) is an automatic tracking system based on transceivers on ships and is used by vessel traffic services (VTS). When satellites are used to detect AIS signatures, the term Satellite-AIS (S-AIS) is used. AIS information supplements marine radar, which continues to be the primary method of collision avoidance for water transport.[citation needed] Although technically and operationally distinct, the ADS-B system is analogous to AIS and performs a similar function for aircraft
https://en.wikipedia.org/wiki/Automatic_identification_system .

Information provided by AIS equipment, such as unique identification, position, course, and speed, can be displayed on a screen or an electronic chart display and information system (ECDIS). The reader is encouraged to look up the detailed description of the AIS system (IALA 2016) and/or of the use of AIS with ATONs (IALA 2013). IALA also maintains standards for the Vessel Traffic Service (VTS) systems. https://www.iala-aism.org/about-iala/ .

IMO requires ships over 300 gross tonnage to install an AIS transponder on board. The transponder transmits vessel position, SOG and COG (speed and course over ground), ship name, ship size and next port of call. The system is based on the AIS (Automatic Identification System). MarineTraffic uses this information to plot the real time position of marine vessels on a Google Map. The vessels' positions are shown on the electronic map in the shape of boats. The tags are coloured to show whether the vessel is a tanker, passenger vessel, cargo vessel, yacht etc. Clicking on a tag displays information about the vessel and its current destination.

Vessel locations are shown on a Google Maps background using the Google Maps API, Nautical Charts and OpenStreetMap (Memos, D. 2015). The basic MarineTraffic service can be used without cost; more advanced functions are available subject to payment (Sail Magazine 2015). Data is gathered from over 18,000 AIS-equipped volunteer contributors in over 140 countries around the world. Information provided by AIS equipment, such as unique identification, position, course, and speed is then transferred to the main Marine Traffic servers for real-time display via the website. The site uses Google Maps as its base mapping. Similar tracking results may be found from other service providers such as: https://www.vesselfinder.com/ .

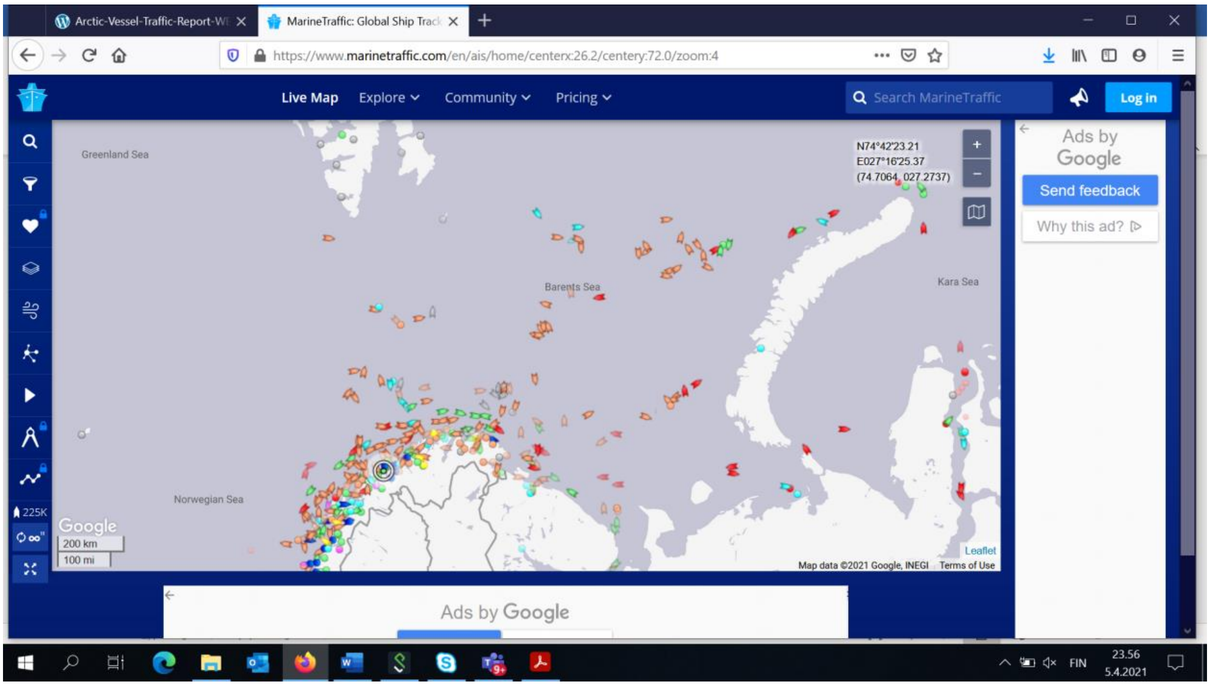

Figure 11. View over Marine Traffic's page showing vessel traffic in the Arctic Sea area. https://www.marinetraffic.com/en/ais/home/centerx:26.2/centery:72.0/zoom:4

AECO vessel tracking system

The AECO's (Association of Arctic Expedition Cruise Operators) Vessel Tracking System is another step towards increasing ship safety in Arctic waters. Information about other vessels, their positions and plans are important parts of the risk assessments operators carry out as part of their Arctic operations planning. The operators have easy access to the tracking information. For the authorities this is useful information which creates redundancy in other systems monitoring ship movements. In connection with Search – and Rescue (SAR) operations we believe this system can provide important additional information. https://www.aeco.no/2013/07/vessel-tracking-in-the-arctic/

The scheme can also be used for coordination of sailing plans with the objective of maintaining a safe distance from other vessels. AECO is following the IAATO (International Association for Antarctic Tour Operators), which made an equivalent scheme mandatory for IAATO-members operating vessels in Antarctica.

The already existing AIS-system (Automatic Identification System) also provides information about ship traffic, and especially in conjunction with the European AIS satellite (during a test period), the authorities can have a comprehensive overview of the ship traffic in Arctic waters. The cruise industry does not, however, have access to AIS-information, except for nearby vessels. The cruise operators can obtain information about each other through the AECO Vessel Tracking System, regardless of their positions.
https://www.aeco.no/2013/07/vessel-tracking-in-the-arctic/ .

The Association of Arctic Expedition Cruise Operators (AECO) is an international association for expedition cruise operators operating in the Arctic and other stakeholders with interests in this industry. The association was founded in 2003 and has since become an important organization representing the concerns and views of Arctic expedition cruise operators. AECO is dedicated to managing responsible, environmentally friendly and safe tourism in the Arctic and strives to set the highest possible operating standards.

Other tracking systems

An example of a typical vessel tracking system and connected webcam service is given in https://www.royalarcticline.com/vessel-tracking/ where the Royal Arctic Line's vessels can be seen in an AIS type of presentation supported by the webcam images onboard the ship.

Commercially available tracking services can also be found from Spire AIS service:
https://data.spire.com/product/ais-tracking-data-northwest-passage-shipping-routes-in-arctic/

This Spire AIS data set contains ship positions and voyage messages. Use Spire's satellite & terrestrial AIS data in the Northwest Passage shipping routes to add to your global maritime domain awareness. Spire provides unique coverage along the Northwest Passage shipping route, an area known for being notoriously difficult for data gathering. Spire is able to achieve this unmatched coverage near the Arctic circle due to our many LEMURS in polar orbits. Data products of this service include tankers, cargo, fishing vessels and security and surveillance. LEMUR is the initial constellation of low-Earth orbiting satellites built by Spire.

The Lemur-2 satellites (Figure 12) carry two payloads: the STRATOS GPS radio occultation payload and the SENSE AIS-receiver.

The following payloads are on board:

- Spire satellites, which orbit close to the Earth's atmosphere, use the SENSE payload to detect GPS satellite signals - which are impacted as they pass through the Earth's atmosphere. Using a process called GPS radio occultation, Spire measures the change in GPS signal readings to calculate very precise profiles for temperature, pressure and humidity here on Earth.
- The STRATOS payload enables tracking of ships worldwide by receiving their AIS signals.
- Later satellites, beginning with the 78th satellite launched, also carry the AirSafe ASD-B payload to track airplanes.
-

The first generation of Lemur satellites features two solar panels, each with two segments. The second generation, beginning with the 78th satellite launched (?), have enlarged solar arrays, each with three segments. https://space.skyrocket.de/doc_sdat/lemur-2.htm .

Figure 12. Lemur-2 satellite by Spire.

PAME's Arctic Ship Traffic Data (ASTD) project has been developed in response to a growing need to collect and distribute accurate, reliable and up-to-date information on shipping activities in the Arctic. The ASTD System collects a wide range of historical information, including ship tracks by ship type, information on number of ships in over 60 ports/communities across the Arctic, detailed measurements of emissions by ships, shipping activity in specific areas (e.g. the EEZ's, Arctic LME's and the Polar Code area), and fuel consumption by ships.

The ASTD System was launched in February 2019. Its access is restricted. Access is admitted to the Arctic State approved government agencies and ministries; Arctic Council Permanent Participants and Arctic Council Working Groups have free access to the database. Others, such as Arctic Council Observers, have to pay a small fee for access to ASTD.
https://pame.is/projects/arctic-marine-shipping/astd .

Norway and USA provide data for ASTD from the Circumpolar Arctic. PAME has compiled a data document which answers questions on ASTD data collection, data quality, AIS limitations and others. The image below, Figure 13, shows the ASTD area. ASTD has data from within that area only. Data can be extracted from any region within the ASTD area.

Figure 13. ASTD area as shown in https://pame.is/projects/arctic-marine-shipping/astd#astd-geographical-scope .

Arctic Infrastructure

There are numerous challenges to be met when constructing safe and environmentally sound systems to support Arctic navigation. The support system could be called infrastructure, or more accurately the lack of infrastructure due to the large distances, lack of support stations, lack of ports and poor logistic network between existing terminals, offshore structures or inland population settlements. From the shipping point of view the most vital problem is the insufficient infrastructure to support safe marine shipping and to respond to marine incidents in the Arctic.

Both terrestrial and maritime infrastructure in the Polar Code Arctic region is extremely limited. Few roads, limited airports and vast distances between communities, as well as a lack of ports and other coastal infrastructure, make transportation in the Arctic difficult. There are a few large, modern ports in the Polar Code Arctic, including Greenland's capital, Nuuk; the ice-free port of Murmansk in Russia; and the Port of Longyearbyen in Svalbard, Norway. Other Arctic ports may not be able to provide a full range of maritime services (AMSA 2009).

Relative to the Northwest Passage, the Northeast Passage contains more physical port infrastructure. There are approximately 15 to 18 marine ports in the Russian Arctic. The largest port on the Northeast Passage is Murmansk, which is a deep draft, ice-free port that operates year-round. Smaller ports, located in regions of the Northern Sea Route with seasonal first-year ice, have moderate facilities (Östreng, W. et al. 2013). Lack of robust port facilities and deep draft ports is a problem in other parts of the Arctic as well. For example, the U.S. Arctic lacks any deep water ports (The Pew Charitable Trusts. 2016). In the Canadian Arctic, a number of mines have private deep draft terminals, and the Canadian Navy is developing a limited wharf capacity based on a closed mine terminal at Nanisivik, but there are no public deep water ports (Ocean Conservancy 2017).

Support systems for safe navigation are prerequisites for the ice-infested waters, where the navigators need to know current ice conditions, water and sea temperatures, wind, daylight and night-time conditions. From the navigator's point of view the most vital information requested, however, is the location of the ship and the hydrographical conditions around and under the ship: modern marine charts are compiled from accurate hydrographic surveys conducted onboard specialized vessels equipped with echo sounders that measure water depths, and satellite navigation systems, such as the Global Positioning System (GPS), that determine the geographic positions of these soundings. Navigation charts include data on the bathymetry, sea currents and tidal variation. In the Arctic areas there are still many areas where the collected data is not precise due to the limited resources for bathymetric studies or due to the problems encountered due to the ice field or moving ice.

Modern Electronic Chart Display and Information Systems (ECDIS), combined with satellite-based positioning, bring hydrographic data into onboard computers, greatly improving the navigation information available to the mariner, but there are still large areas in the Arctic where Electronic Navigational Charts (ENC) will have varying coverages for the northern waters. The hydrographic data in many Arctic locations is either non-existent or in serious need of improvement.

Canada, the United States, the Russian Federation and Denmark are carrying out charting activities that include portions of the Northern Sea Route and the Northwest Passage. These countries, as well as Iceland and Norway, are all member states of the International Hydrographic Organization (IHO), whose mission "is to facilitate the provision of adequate and timely hydrographic information for world-wide marine navigation." In Greenland, the limit for navigable waters has been set to 75 degrees northern latitude due to the permanent ice cover and the sparse population of its east coast. Within Canada, a high proportion of Arctic waters are inadequately surveyed or covered by frontier surveys only. A similar situation exists in the Russian Federation, where ice conditions have precluded the systematic survey of the central parts of the Laptev and East Siberian seas (AMSA 2009). Only passage sounding data is available for the deep water areas of the Sea of Okhotsk and the Bering Sea.

Ice Information in the Arctic

Sea ice in the Arctic has an annual cycle of freeze and melt. When the sun goes down in the autumn and the extreme cold arrives, the ocean freezes. March is the month of maximum ice coverage. During the summer months, the ice melts and retreats to a minimum extent in September (AMSA 2009).

The needs of mariners for ice information are currently met by a number of organizations, including national ice services that produce information for the Arctic that is generally freely available as a public service funded by tax-payers; academic institutions that provide ice information as part of an ongoing research program or to support field research campaigns; and commercial ice information services providing specific services to individual clients with particular needs. It is also assumed that increasing maritime traffic in the Arctic would also bring new service providers to share accurate and on-line ice and weather information, and to create new products for the maritime society.

Cooperation in the areas of ice- and weather information is well regulated, with agreed procedures and ways of collecting data. The Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology Expert Team on Sea Ice is the international body that establishes and maintains the standards for ice information internationally. The international cooperation also includes the International Ice Charting Working Group (IICWG) and a set of ad-hoc working groups coordinating ice information services internationally and advising the Expert Team on Sea Ice. As a result of this collaboration, there is an internationally accepted nomenclature for ice in the ocean, common charting and coding practices and cooperative information sharing among the ice services.

Marine Weather Information

Modern weather information, including information for shipping, is based on numerical models. Numerical weather prediction analyses and predictions are available for the Arctic from all the major meteorological centres using global weather models. Countries having the need for more detailed information for the Arctic areas have developed high resolution models covering the Arctic region according to their needs.

Within the coverage of INMARSAT Global Maritime Distress Safety System (GMDSS) transmissions, marine safety information in the form of gale and storm warnings is available, consistently with all other high sea areas in the world. The GMDSS is an international safety system, which uses satellite and terrestrial technology and ship-board radio systems to prevent accidents from occurring and to automatically alert the rescue authorities and nearby vessels quickly in an emergency. https://www.inmarsat.com/en/solutions-services/maritime/solutions/safety.html

Under the Safety of Life at Sea (SOLAS) convention, cargo ships of 300GRT and upwards and all passenger ships on international voyages must be equipped with satellite and radio equipment that conforms to international standards.

Although weather forecasts for the Arctic are based on the same tools and use the same techniques as in other areas of the world, the scarcity of observations in the Arctic makes monitoring of the weather more difficult than in areas with more observations. Meteorological observations in the Arctic rely on drifting buoys placed on top of the sea ice. A new generation of buoys that will withstand multiple freeze-thaw cycles is currently under development and is urgently needed to provide surface observations in the Arctic Sea.

The ability to measure the conditions of the atmosphere and ocean from satellites is, however, developing rapidly and with adequate surface validation, the quality of weather forecasts will approach the quality reached in other areas

Wave information

Global warming will reduce the coverage of the sea ice and increase the area of open water. This fact means that more wave data will be needed for mariners in the Arctic. Wave buoys and radars represent common and proven technology for the wave measurements, which in connection with the wind and wave models will provide good predictions for certain areas under consideration. However, there are areas in the high Arctic where historically waves have not represented a significant problem, especially when sailing through the ice. There is an urgent need for new types of measuring buoys for data collection and model validadtion purposes.

Aids to Navigation and communication tools

Ships usually use a combination of satellite positioning and traditional navigation techniques. Countries around the Arctic area have actively developed modern Aids to Navigation along their coastlines. Of the eight circumpolar countries, six have coastlines. Of these, Canada, Denmark, Norway, Iceland and the Russian Federation maintain active aids to navigation (ATON) networks. Depending on the country the ATONs can be both fixed or floating type devices.

The historical standard for communicating weather, wave and ice information to ships at sea is the radio facsimile broadcast. Although its use is being eclipsed world-wide by digital communications, the analogue radio broadcast remains an important source of information in the Arctic. Communications using VHF, MF and HF as well as satellites are generally sufficient for the lower Arctic areas, but once the high Arctic is reached, voice and data transmission become problematic.

Radio stations in the United States, Canada, the United Kingdom, Denmark, Germany and the Russian Federation broadcast analysis and forecast charts for sea ice, icebergs, sea state and weather, as well as providing vessel traffic services and general marine communications.

VTS (Vessel Traffic Service) is a tool designed to monitor and guide vessels and to promote safe navigation. For example the Norwegian VTS station in Vårdo has as its area of operation the Norwegian Economic Zone (NEZ) outside the base-line, the area around Svalbard and the area outside Tromsø and Finnmark in northern Norway.

The United States marine communications infrastructure in Alaska is concentrated where vessels operate the most. There is excellent very high frequency (VHF) coverage throughout southeast Alaska and into portions of the Bering Sea north to St. Paul and the Bristol Bay area. North of this region there is local VHF coverage at Nome, Kotzebue and Barrow. Barrow and Kotzebue, both north of the Bering Strait, also have high frequency (HF) NOAA radios. Mariners in these areas can speak directly to a weather expert via HF radio. Outside the range of VHF marine coverage, the U.S. Coast Guard relies on high frequency or satellite communications (AMSA 2009).

The Danish Navy operates a year-round high frequency radio station on the southwest coast of Greenland and maintains the IMO mandatory ship reporting system, GREENPOS, for all ships on voyages to or from Greenland ports and places of call. Furthermore, Denmark maintains a number of stations with limited communications capabilities in the south/southeast and lower western half of Greenland. Iceland has an advanced system of AIS along its coast, with 23 base stations and repeaters with a total coverage of the coastline. The maritime radio system has recently been renewed in VHF, MF (medium frequency) and HF bands and two new NAVTEX stations have been established. The traffic monitoring is carried out by the Maritime Traffic Service in Reykjavik, operated by the Icelandic Coast Guard.

Most modern ships are equipped with satellite digital communications equipment - not only for safety reasons but for the management and navigation of the ship. This equipment relies on geostationary INMARSAT satellites that do not provide service northwards of about 80º N latitude. Other systems, such as the IRIDIUM constellation of 66 polar orbiting satellites, provide worldwide coverage including the Arctic. IRIDIUM is capable of providing a Ship Safety and Alerting System that meets IMO requirements, but its data transfer rates are very low (less than 9.6 kb/s). There are currently other satellite systems available for tracking and communication in the Arctic.

The modern satellite services have also brought additional safety measures to the market:

- Ship Security Alert Systems (SSAS), which is used by ships to transmit a security alert to a competent authority when the security of the ship is under threat or has been compromised. Ship security alerts can be sent using Inmarsat C and Mini C, and relevant hardware and software can be added to the existing GMDSS terminals to support the service.
- Long Range Identification and Tracking (LRIT) of ships, which is not part of the GMDSS communication requirements either but its equipment – particularly Inmarsat C and Mini C terminals – can also be used to support the system. LRIT is a SOLAS regulation included in Chapter V, which applies to ships constructed after 31 December 2008, with a phased-in implementation time for existing ships. Regulations require that LRIT reports should by default be transmitted every six hours to the LRIT Data Centre, with a frequency of transmission to be controlled remotely, allowing for reports to increase with changing security levels up to a rate of one report every 15 minutes. The LRIT information that ships are required to transmit to contracting governments and administrations includes their position and the date and time.

Conclusions

Climate change with rapid warming has several impacts both at local and global levels in the Arctic. The rapid decline of sea ice will also increase the possibilities for shipping and the utilization of the Arctic area's sea routes. This development will offer new possibilities for the industry and for other human activities in the Arctic. It has been estimated that by 2050, maritime transport volumes may be manyfold compared to the current figures. There is global interest in transit voyages in the Arctic sea routes, requiring better understanding of the possible impacts and risks related to increased human activities.

The earlier AMSA 2009 report highlighted several recommendations which still have a vital importance when ensuring the safe and environmentally friendly passage of ships along the Arctic sea routes. The key recommendation has been the improvement of maritime safety, where several actions at IMO level and the Polar Code have been perhaps the best known achievements. Work to enhance maritime safety continues, and important phases will be devoted to harmonisation of the marine shipping regulatory regimes to develop uniform safety and environmental protection measures. Vital elements in the safety-related work also include passenger ship safety improvements when sailing in Arctic waters, and better cooperation within the SAR operations.

New routing measures should be implemented in the Arctic to decrease the likelihood of ship groundings and other incidents. Routing measures are also effective when protecting vulnerable and ecologically valuable areas from oil spills. Attention should also be paid to the activities currently under way to build up the Arctic infrastructure with the aid of new services and options supported by satellite and communication systems.

The banning of HFO-type oils in the Arctic and the use of environmentally friendly energy (LNG, sulphur-free marine diesel, electricity, hydrogen) are also actions to minimize the black carbon footprint in the Arctic and thus the impacts of global warming and changes in the Arctic ecosystem. High priority is also given to the determination of the possible long-term environmental, economic and pragmatic aspects of constructing and operating LNG-operated vessels, bearing in mind both environmental benefits and drawbacks. Other vital recommendations are related to long-term shipping fuel/propulsion options for vessels operating in the Arctic that would mitigate the risk of spills and reduce reliance on fossil fuels, as well as to protection of the Arctic people and environment.

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APP4SEA

ARCTIC PREPAREDNESS PLATFORM

FOR OIL SPILL AND OTHER ENVIRONMENTAL ACCIDENTS

Niko Hänninen
Energy and Environmental Engineering Research Unit
University of Oulu
OULU
FINLAND
Tel: +358 40 704 5512
niko.hanninen@oulu.fi
http://app4sea.interreg-npa.eu

http://app4sea.interreg-npa.eu

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