



Arctic shipping

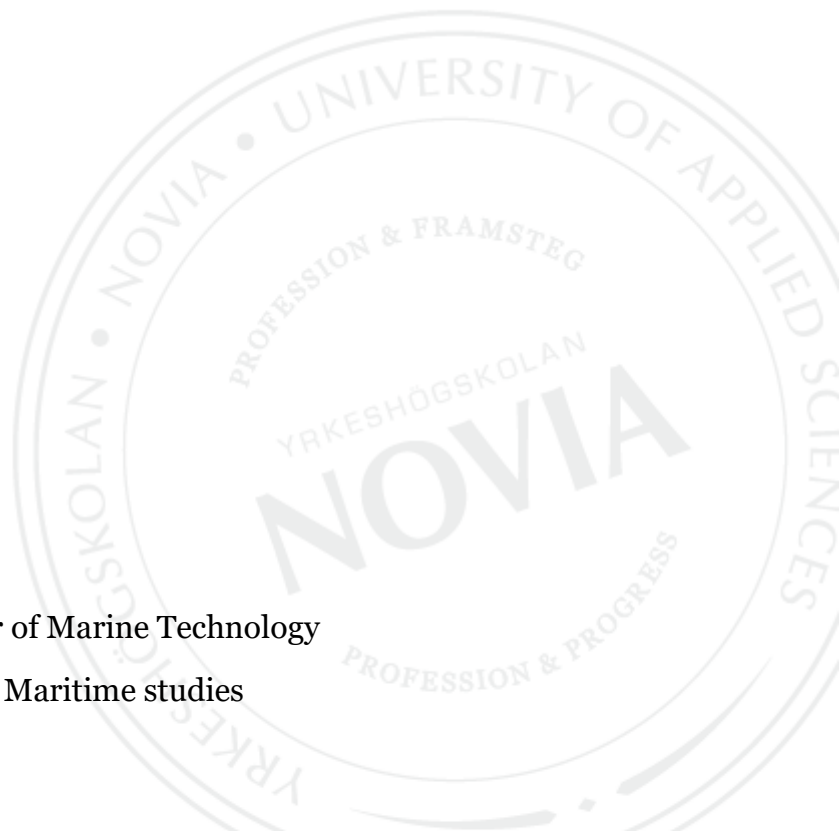
Climate change effects to the Northern sea route shipping

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Summary

This bachelor's thesis covers climate change effects in the Northern sea route and my main focus on my thesis has been to find out changes that may happen in the Northern sea route due to climate change and especially how those possible changes may affect to shipping there.

The Northern sea route is a future road and there is expected big rise in transits in the following years. Reason for the expectations is its unique location and reduction in distance between Atlantic and Asia. Climate change is affecting much more in the Arctic locations than other places in the world and that's why it might change shipping much in the Northern sea route.

At first this thesis introduces the Northern sea route and then tells about climate changes in Arctic areas. The last part focuses on how changes in Arctic Sea affect to shipping. I tried to find out new possibilities for shipping in the Northern sea route.

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Tiivistelmä

Tämä opinnäytetyö keskittyy pääasiassa ilmastonmuutoksen vaikutuksiin Koillisväylällä ja etenkin huomio on keskittynyt ilmastomuutosten vaikutuksista Koillisväylän laivaliikenteeseen.

Koillisväylää pidetään tulevaisuuden väylänä ja sen käytön odotetaan lisääntyvän paljon tulevina lähivuosina. Syynä tälle on sen sijainti ja etenkin matkan lyheneminen huomattavasti Atlantin ja Aasian välillä. Ilmastonmuutoksen vaikutukset ovat huomattavasti suurempia Arktisilla alueilla, kuin muualla maailmassa, joten sillä tulee olemaan vaikutusta laivaliikenteen muutoksille Koillisväylällä.

Opinnäytetyöni kertoo aluksi yleistä tietoa Koillisväylästä, ja sitten ilmastonmuutoksesta Arktisilla alueilla. Lopuksi keskitytään Arktisten alueiden muutoksiin, ja niiden vaikutuksista Koillisväylän laivaliikenteeseen.

Kieli: Englanti

Avainsanat: Koillisväylä, merenkulku, ilmastonmuutos

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Vocabulary

NSR – Northern sea route

NSRA – Northern sea route Administration

LNG – Liquefied natural gas

VHF – Very high frequency

GMDSS – Global Maritime Distress and Safety System

GPS – Global positioning system

GLONASS – Russian global navigation satellite system

MF – Medium frequency

ACIA – Arctic Climate Impact Assessment

NOAA – National Oceanic and Atmospheric Administration

AO – Arctic oscillation

ECDIS – Electronic chart device in safety

FRISBEE – Framework of International Strategic Behaviour in Energy and Environment

DPF – Diesel particulate filter

ECA – Emission control area

HFO – Heavy fuel oil

IMO – International maritime organization

1 Introduction

The Northern sea route locates in the Northern coast of the Russian Federation. It offers a route for commercial vessels between Western Europe to Asia-Pacific region that can reduce the distance between Europe and Asia with about 4000 miles compared to the traditional route through the Suez Canal and it can save even 10 days depending upon service speed. It also reduces bunker costs which is good for ship companies' economy. Northern sea route also offers a great potential to the growing energy, mining and industrial activity in Northern Russia that has already led to increased tanker traffic in the NSR and also has led to large orders of ice class LNG carriers for the future gas export trades.

Because of the arctic location climate change will cause more changes there than other places like in the Southern Europe. The biggest change that affect in the Artic is global warming and it is said that it declines the extent of ice coverage as much as 30%. Also in the Arctic there are very variable winds, waves, temperature and sea level, which climate change affect to.

Climate change can affect a lot of the seafaring in the Northern sea route and in the best possible way it opens new routes to the arctic that would make the route shorter. It can offer a much for seafaring and so far only in nowadays companies has been open their eyes for this route.

1.1 Objective

My main objective is to find out in the different views how climate change will effect to the shipping in the Northern sea route and also to find answers to my research questions.

1.2 Research questions

I have made four main research questions that I try to find out in my thesis. My first question is, how climate change affects in the Northern sea routes. I will also try to find out what causes the possible changes by climate change and in what time period these changes may affect to the shipping in the Northern sea route. My last question is whether these changes are positive or negative for seafaring.

1.3 Delimitation

This thesis mainly focuses climate change in the Arctic area and in the Northern sea route.

1.4 Research method

My research method was written overview, where content has been collected from different sources by using research questions.

2 Northern sea route

2.1 History

The first voyages in the Northern sea route have been in the beginning of the 16th century, but in the end of 16th century shipping became more active. The first successful voyage in the Northern sea route was done by Swedish scientist A.E. Nordenskjöld with the steam schooner ship Vega that departed from the Kara Sea 30.7.1878. Sea voyage from Sweden to the east cape of Asia took about a year but it was first journey ever done in the Northern sea route without any loss or damage. (Klyuchevskiy)

At the middle of 19th century, trade shipping developed in the Kara Sea and especially in the mouths of Ob´ and Yenisey rivers where exporting Siberian mineral resources and importing industrial goods were. At the end of 19th century sea voyages were 60% successful along the Kara sea and cargo was transported 21 000 tons. The Northern sea route was finally open for foreign ship in the 1.7.1991 and in 2000 exports of oil began from Ob´, Varandey and Kolguyev to Europe. Gas was exported from northwest of Siberia to Rotterdam in accordance with an agreement between the EU and Russia. (Klyuchevskiy)

2.2 Today

The Northern sea route has a big role in a future for a seafaring because its location for shorter distances between Europe and Asia-Pacific region. The NSR locates in the Arctic side of Russian and it´s going through via the Kara, Laptev, Vostochno-Sibirskoye and Chukchi seas. (NSR information office)

The Northern sea route distance is about 4800 km but it will vary depending for example selected route, ice conditions and the draft of the transiting vessel. By using the NSR it reduces the distance between Europe and Asia by almost 6000 kilometres compared the normal route via Suez Canal. The distance means that NSR route saves 13 days of voyage. The reduction in distance means also implying greater vessel productivity over a calendar year, smaller bunker consumption and a concomitant reduction in emission. Control of the Northern sea route is in the Northern sea route Administration NSRA. (ABS) (Geoexpro)



Figure 1: Northern sea route (Arctic portal)

The Northern sea route provides also access to the growing energy, mining and industrial activity in the Northern Russia. It has already led to increased tanker traffic in the NSR and also more LNG carriers have been ordered from shipyards for the future gas export trades. (ABS)

As a future route Russian want to develop the NSR all the time and has budgeted millions of euros to it. They has for example:

- Planned to have sorted out all navigational blank spots and upgraded all navigation maps with route depth data by 2016
- €23.4 million euros was invested in 10 emergency and rescue centers to open along the Northern Sea Route by 2015. Main centers are Murmansk (2013), Narayan-Mar (2013), Dudinka (2012), and Andy.
- Russia has been deploying extra aircraft (10 helicopters, and 8 aircraft) to stations in Murmansk, Novaya Zemlya, Dikson, and Mys Shmidta.
- The NSR icebreaking fleet has been built up all the time (ArcticEcon, 2012)

2.3 Routes

The Northern sea route offers a great route option via Europe and Asia because it location. As it mentioned earlier it reduce distance by over 10 days between Atlantic and Pacific oceans. For the route plan ships has to take consideration for the ice condition especially.

The NSR is running through the Kara, Laptev, Vostochno-Sibirskoye and Chukcki seas. To enter to NSR there is four different routes for option:

- from the west through the Yugorskiy Shar strait
- from the west through the Karskiye Vorota strait
- by passing north of the Novaya Zemlya islands around Mys Zhelaniya
- from the east through the Bering Strait (NSR information office)



Figure 2: In a picture it is possible to see the difference by using the Northern sea route or the normal route via Suez Canal. (Ocean 71, 2013)

The depths in the open waters in the NSR vary from between 20 to 200 m and here are depths in different straits:

- Kara strait 50 m
- Matisena and Lenina 20-25 m
- Vilkitskogo 50-250 m
- Shokalskogo 200-250 m
- Yougorskiy shar 13 m
- Sannikova 13-15 m
- Dmitriya Lapteva 8-9 m

- Bering 30-50 m (ABS)

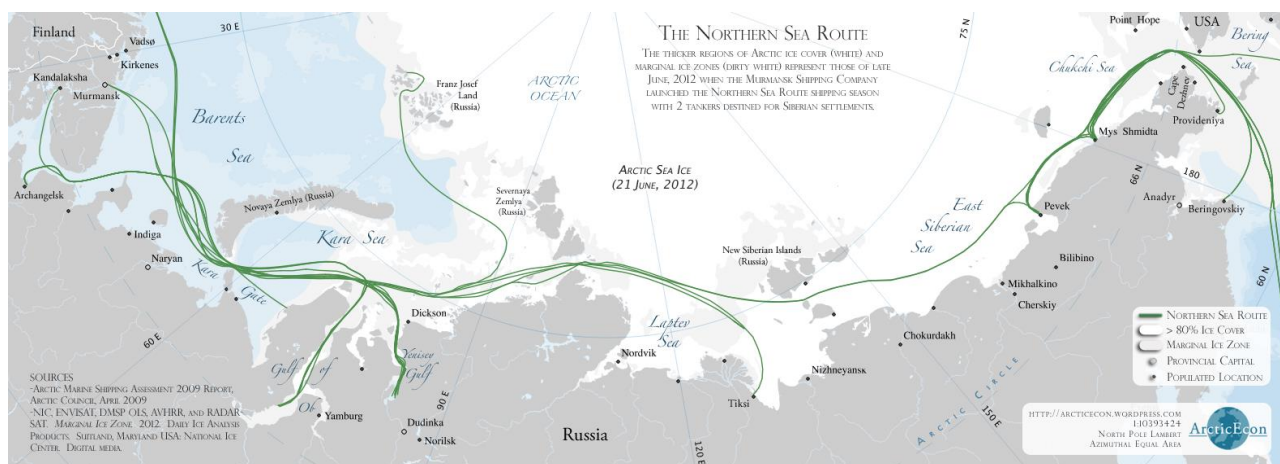


Figure 3: Different route options in the Northern sea route (ArcticEcon, 2012)

An example of route planning in the NSR from Murmansk to Asia is that a ship can either go through the Kara Gate, closer to the Russian shore, or through the strait between Cape Zhelaniya and Franz Josef Land. It will navigate through the Kara Sea and to the Laptev Sea, either north of the cluster of Islands or through the strait at the shore. When navigating to the East Siberian Sea it can either go north of the island cluster or near the shore before approaching Cape Dezhnev. (PAME)

In Arctic also ice condition and other natural factors depends much more and it will change a lot of route plan. For example, the route will change quite much in different seasons just because of ice. (PAME)

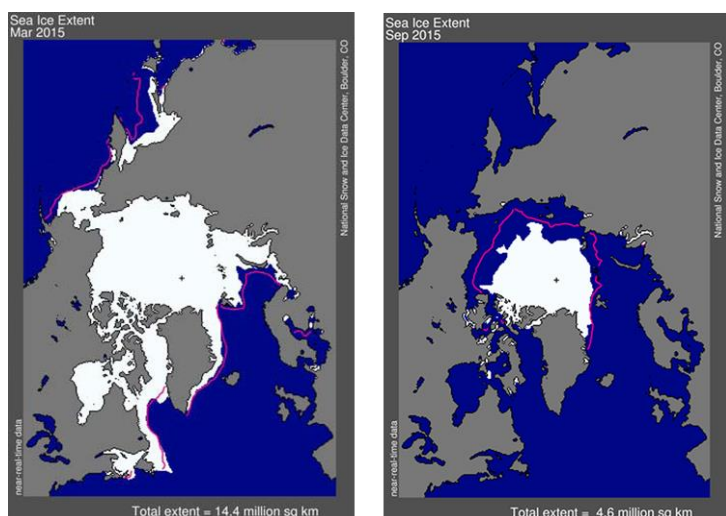


Figure 4: Ice conditions in March 2015 vs September 2015. In the September there was almost 10 million square kilometers less ice than in March. (Arctic report card, 2015)

The Navigation season in the NSR starts usually at the beginning of July and it ends in the late of November. The opening date and ending date are not decided in forehand and the dates are depending on ice condition in the route. For example, in 2011 the navigation season took for large vessels 141 days that takes more than 4,5 months. (NSR information office)

2.4 Cargo flow and transits in the Northern sea route

2.4.1 Transits

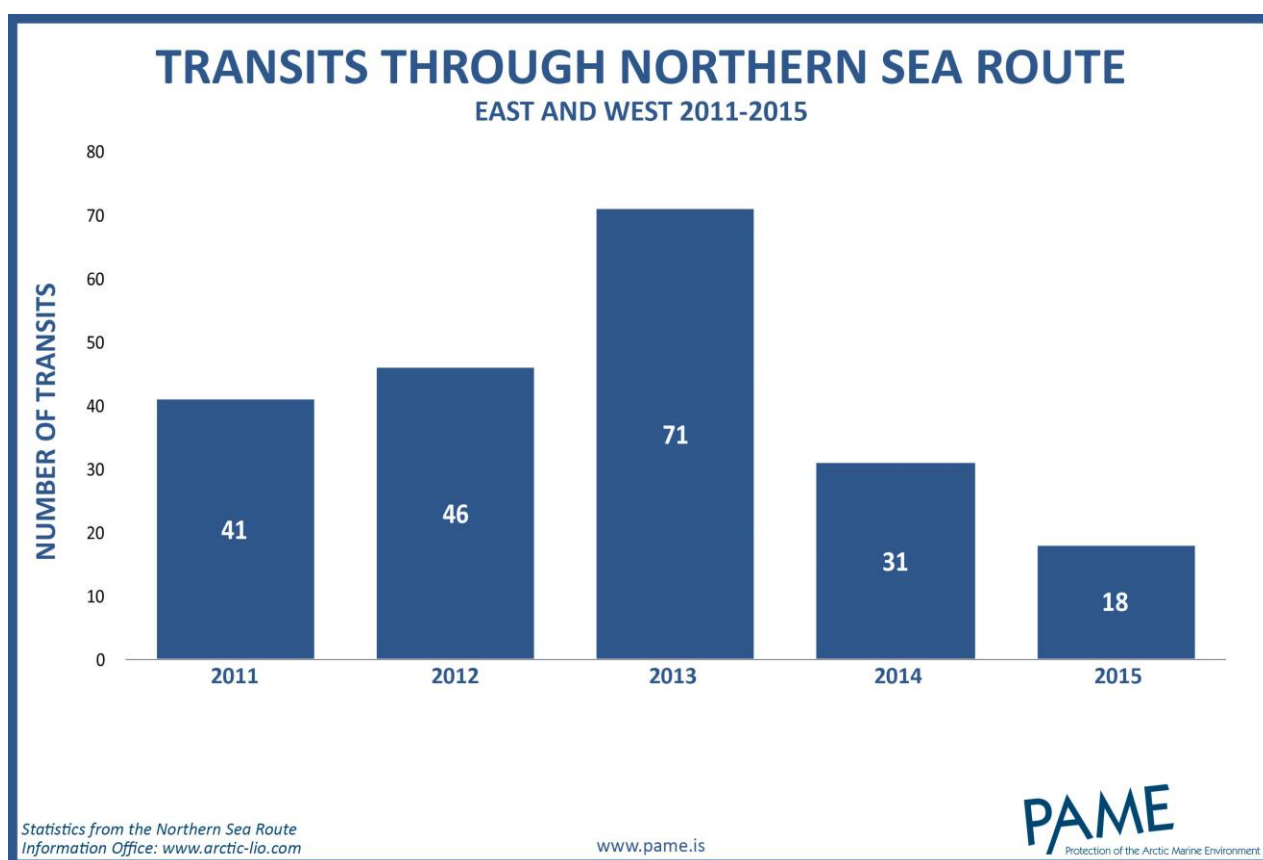


Figure 5: Transits through the Northern sea route (NSR information office)

Through of the Northern sea route there were totally 207 transits between in the years 2011-2015. There was calculated all transits that were using the NSR and was going from Pacific Ocean to Atlantic Ocean or vice versa. As it is visible from the fig.5 transits grew between in the years 2011-2013 and the top year was 2013 where was totally 71 transits. Then it dropped by 40 transits in a year and 2015 was lowest transit year by only 18 transits. (NSR information office)

The drop of transits has been huge and the reason for it has been talked about. The Russian Deputy Minister of Transport Viktor Olersky commented in Reykjavik in October 2015 that “Low bunker oil prices have made the Northern Sea Route less attractive for ship owners”. With a low bunker costs it is not so big difference financial side by using Suez canal and it the otherhand icebreaking costs are still quite high level that make ship owners choose rather the southern route. (Humpert, 2015)

Sergey Balmasov from the NSR information office says that “if round-the-year shipping becomes possible, then the situation could seriously change” and he believes that “the opening of new Arctic oil fields and the new government NSR plan could be which makes the difference”. With icefree NSR there wouldn't be any costs of icebreaking that would save huge sum of money and would add transits in the area. (Staalesen, 2015)

2.4.2 Types of cargo

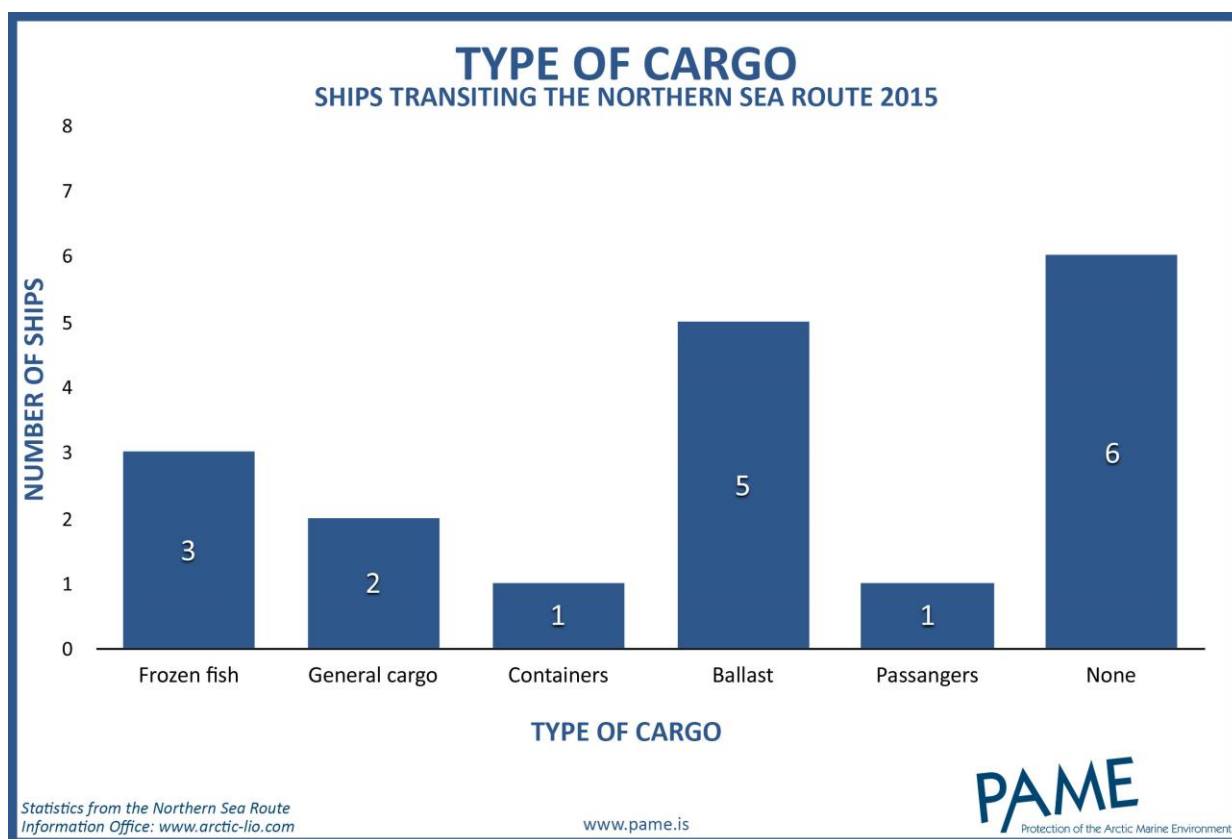


Figure 6: Type of cargo (NSR information office)

In the 2015 18 ships were carrying five types of cargo and one of the third was empty ships. Totally there was transit 39,586 tons of cargo in the NSR in 2015 when 2013 there was even 1,35 million tons. The two biggest type of cargo were ballast and frozen fish.

Only one ship ransited passengers. The future cargo in the NSR could be natural resources that locate there up in the north like LNG or oil. (Staalesen, The Barents Observer, 2016)

2.5 Ice Breaking

Ice breaking is quite big question in the NSR because its location in the Arctic. Most vessels that are entering or using the NSR will need icebreaker assistance. NSRA is providing information of ice condition and with that information ships should decide where they will need assistance. The fee rate of the icebreaking assistance is determined by the legislation of the Russian Federation. The fee is composed the capacity of the ship, the ice class of the ship, the escorting distance and the period of navigation. The fees are one of the biggest problems at the moment in the NSR that also makes it not so attractive. Russian stated high fees which makes it almost as expensive as using southern route that many vessels choose the easier route. (ABS) (Ragner)

At the moment there are 7 companies that providing icebreaking assistance and those are:

- Atomflot in the Murmansk
- Rosmorport in the Moscow
- Far eastern shipping company in the Vladivostok
- Murmansk shipping company in the Murmansk
- OJSC, MMC and Norilsk Nickel in the Murmansk
- LUKOIL Oil Company in the Moscow
- Rosmorrechflot in the Moscow (NSR information office)

At the beginning of icebreaking ship owner and rendering service of the icebreaker assistance agreed together the starting time and place and also ending time and place in the NSR. The ice convoy is under control of the Master of icebreaker and he will make all the decisions and orders. Ship and icebreaker is working on the VHF channel 16. Icebreakers make channels in ice and then group of ships or ship is following icebreaker. It is also possible that icebreaker towing the ship. When moving in the ice convoy the master of the

assisted ship must maintain the ship's placement within the convoy and he has to maintain the proper speed and distance between the ships ahead. (ABS) (NSR information office)

NSRA has given the following recommendations to the ship's Master during the ice assistance of the ship:

- Assessment of ice conditions and possibility of the safe navigation of ship under these conditions
- Selection of optimum route of the movement of ship and of the relevant scenario of the navigation of ship in ice independently
- Selection of speed and ways of performing maneuvers of ship avoiding dangerous interaction of hull and rudder propeller system with ice
- Ways to maintain safe speeds and distance between the icebreaker or ship ahead when moving in convoy
- Ways to execute the instructions from icebreaker Masters rendering assistance. (ABS)

In the recent years there has been easier ice conditions in the NSR than before and it has offer more considerable opportunities for operations. The whole NSR route locates in the area with one-year ice and it grows approximately up to 1,6 meters. Arktika-type icebreaker can open passages up to 2,3 meters' thick ice. In the beginning of July, the ice is not pressurized and ship can easily navigate through that. In September and October, the NSR is totally free of ice and the vessels can keep the same speed as in the open waters. In November the NSR has about 30 cm thick new ice that allows for safe pilotage of a vessel supported by an icebreaker. (NSR information office)

2.6 Ports

The Northern sea route has 12 principal arctic seaports on its route and those ports are:

1. Murmansk
2. Kandalaksha
3. Vitino
4. Onega

5. Arkhangelsk
6. Amderna
7. Dikson
8. Dudinka
9. Khatanga
10. Tiksi
11. Pevek
12. Provideniya

With these ports there are more than 100 informal ports without any equipment and facilities for loading or unloading. (ABS) (NSR information office)



Figure 7: A map of ports in the Northern sea route. (Free world maps)

2.6.1 Port of Murmansk

Murmansk seaport is one of the largest ice-free ports in Russia and it is open around a year. Port of Murmansk locates in the coast of Kola Bay in the Barents Sea. Western coast of Kola Bay has the main capabilities including commercial port with passenger area, fishing port, ship-repair yard, shipyard, oil terminal and Rosatomflot premises. In the eastern side smaller fishing and road handling terminals that includes also to port of Murmansk. Murmansk seaport owns approximately 100 mooring berths and almost 200 stevedoring companies handling cargo in the port. (NSR information office)

2.6.2 Port of Kandalaksha

The port of Kandalaksha is located in the Eastern shore of Lupcha Bay in the White Sea. It is all year round open port and during winters, icebreakers keep the fairways open. Kandalaksha has 5 mooring berths and port admits 200 m long vessels with maximum of 9.8 m draught. The port's speciality is handling of a wide range of general and bulk cargoes. (NSR information office) (Port of Kandalaksha)

2.6.3 Port of Vitino

Port of Vitino is an oil port and locates on the Karelskiy shore in the White Sea. It is open around a year but in the winter there is need of icebreakers. Vitino port has 4 mooring berths and they can take maximum of 230 m long vessels with draught of 11.1 meters. There is working one stevedoring company that handles oil, naphtha and gas condensate. (NSR information office)

2.6.4 Port of Onega

The port of Onega is located at the mouth of Onega River in White Sea and it is open from May until January. Port has 7 mooring berths and they take maximum of 242 meters long vessels and 13.6 meters' draught. There is working four stevedoring companies that handle general cargoes and passengers. (NSR information office)

2.6.5 Port of Arkhangelsk

Port of Arkhangelsk locates in the mouth of the Dvina River in the White Sea and it is open around year but in the winter vessel needs assistance of icebreakers. They can take 190 meters long vessels with draught of 9.2 meters. There is working over 200 stevedoring companies that handle wide range of general cargo and oil cargo. They have also possibility to take passenger vessels. (NSR information office)

2.6.6 Port of Amderna

The port of Amderna locates at the mouth of Amderminka River in the Kara Sea. Ship that are taking cargo to Amderna port are anchoring two to three miles outside of the port where depth is 13-14 meters and discharging cargo to pontoons and barges where they are taking to a shore. Petroleum products are delivered with temporary hoses and pipelines. (ABS) (NSR information office)

2.6.7 Port of Dikson

Port of Dikson locates in the South-Western part of the Kara Sea near the mouth of the Yenisey River. Navigation to Dikson is possible around a year, but in the winter term vessels needs assistance of icebreakers. Port is handling general cargoes and basic bulk cargo and in the summers there is also passenger traffic. Port of Dikson has 8 mooring berths and depth in there is maximum 15 meters. (NSR information office)

2.6.8 Port of Dudinka

Port of Dudinka locates on the right shore of Yenisei river and is open whole year. There is total of 9 mooring berths with depth of 11.8 meters. Vessels can be maximum 260 meters long. There are two stevedoring companies that are handling final products, containers, general cargo and oil products. (ABS) (NSR information office)

2.6.9 Port of Khatanga

Port of Khatanga is located in the right shore of Khatanga river 185 km from the mouth and it is open only in summer from middle of June to end of September. The port is only for Russian flagged vessels and it takes vessels with maximum draught of 4.6 meters and there are 5 mooring berths. Khatanga handles various general cargoes, bulk freight and oil cargoes. (ABS) (NSR information office)

2.6.10 Port of Tiksi

Port of Tiksi is the most important commercial port in the NSR and it locates on the coast of Laptev Sea near the Lena river. Port is open from middle of July until the middle of October. There are 11 mooring berths with depth of 9.7 meters. The main cargoes in the port are general cargo, timber freights and in the summer passenger transportations. The port equipment includes 19 portal cranes, one gantry crane and four mobile cranes. (ABS) (NSR information office)

2.6.11 Port of Pevek

Port of Pevek locates on the shore of the East Siberian Sea in Chaunskaya bay. The port is open only from the beginning of July until the end of October. There is total of 3 mooring berths with depth of 13 meters. Main types of cargo are coal, containers, industrial equipment, ferrous metals and timber freights. The port is equipped with 18 portal cranes. (ABS) (NSR information office)

2.6.12 Port of Provideniya

Port of Provideniya is located in the Easternpart of Chukotka peninsula and it is open from May until the end of December. The port can take vessels with maximum draught of 10 meters and they have 6 mooring berths. Their speciality is handling general and loose cargoes to be delivered to the regions of Provideniya and Chukotka. Also passenger traffic is visible in the summers. (NSR information office)

2.7 Regulations

Administering of the Northern sea route is for NSRA that main task is to organize navigation in the water area of the NSR. In 2013 Ministry of transport of Russian Federation developed Rules of Navigation on the Water Areas of the Northern Sea that based on federal law of Russian. That document contains:

- Procedure of the navigation of ships in the water area of the NSR
- Rules of the icebreaker assistance of ships in the water area of the NSR
- Rules of the pilot ice assistance of ships in the water area of the NSR
- Rules of the assistance of ships on seaways of the water area of the NSR

- Provision about the navigational-hydrographic and hydrometeorology support of the navigation of ships in the water area of the NSR
- Rules of the radio communication during the navigation of ships in the water area of the NSR
- Requirements to ships pertaining to the safety of navigation and protection of the marine environment from the pollution from ships
- Other provisions in relation to the organization of the navigation of ship in the water area of the NSR (NSRA) (ABS)

2.7.1 Application and entering for the NSR

To get permission for a passage through the NSR it must apply from the NSRA's application form up to four months prior to the passage, but not less than 15 days. Application can be made in English or in Russian and in pdf format it can be submitted by the ship owner, ship owner's representative or the ship's master. The application includes next things:

- Information about a vessel and the voyage
- Copy of the classification certificate
- Copy of the measurement certificate
- Copies of documents certifying availability of the insurance

The NSRA inform the ship owner within 12 days before the voyage if application has been granted or not. The same information is also coming from the NSRA's website. Applicant will get also at the same time information of the route and for example need for icebreaker and pilotage.

When vessel has gotten granted permission to enter to the NSR the vessel shouldn't enter before the permitted date in the application. It should also leave the NSR with the date in the application. (ABS) (NSR information office)

2.7.2 On the seaways at NSR

NSRA is following the vessels in the NSRA continuously. That means basically the coordination of ship traffic flows, icebreakers servicing and ice piloting in the NSR and metrological assistance that are changing rapidly in arctic conditions.

There are two boundaries in the NSR and eastern boundary locates the meridian 33° East and western boundary locates parallel 66° North and/or meridian 169° West. When ship is in the NSR it must send a report to the NSRA when crossing Eastern or Western boundary. A report must contain following information:

- Name of ship and IMO number
- Geographical coordinates of the ship (latitude and longitude)
- Planned route and time, including ship's speed
- Ice condition, temperature, wind speed and direction, visibility
- Amount of fuel, fresh water aboard and other vessel information (ABS)

2.7.3 Communication

Radio communication between ships, icebreakers and the NSRA is carried out with the radio within the operating zones of sea regions A1, A2, A3 and A4 of the GMDSS. Vessels must have all the time radio watch on the VHF channel 16 and for example moving in ice convoy or communication between icebreaker and a ship all communication happen in VHF channel 16. (ABS)

2.8 Challenges in the NSR

Arctic location will make many challenges for navigating there and it preserves some risks. For example, because of the ice, vessels use different routes in the NSR and that can cause risks of collision. Ice is also causing that navigating the whole route without icebreaker is not possible and very often vessels must take icebreakers to keep fairways open. When ice is melting in the summer it means also icebergs that can cause risk of collisions. (Gard)

Biggest challenge in the NSR is fast-changing weather conditions and less reliable weather forecasts than most other places. When sailing in the NSR you can never know what will

be next day weather. Also visibility cause challenges because in the Arctic there is 90% of the time restricted visibility because of dark and fog. (Gard)

Passage in the NSR requires also much from the ship and for example vessels ice class and winterization should be in condition. Also sailing needs ice trained crew and especially ability to work in hard conditions and in low temperatures. Charts is still also a problem in the NSR because there hasn't been so much traffic in the area that hydrographic surveys for the area has been quite poor that makes chart data quality bad. Also there might be problems with GPS and GLONASS positioning and also both compasses magnetic and gyro are unreliable in high latitudes. Communication is a problem also because in many areas there is only VHF and MF that works. (Gard)

Emergency response is still very poor in the NSR because of bad resources and long distances. Also distress situations are very challenge. There is no repair facilities and very limited salvage equipment on the route. Basically ships are on their own if some accidents happen and they have known how to survive for it. Also professional foreign savior is uncertain because of Russian authorities. Due to remoteness even towage to repair yards may be challenging. (Gard)

3 Climates

Typically, Northern sea route has two main season summer and winter. Summer season is usually from July to November and winter season is rest of the year. Seasons might vary in different years but those are the main limits. The weather in summer season when route is open from ice, has moderate and strong winds, low air temperature, many foggy days and later in the season long polar nights, snowstorms and possible blizzards. (ABS)

The NSR can divide to three different climatic areas that are Atlantic area, Siberian area and Pacific area. Atlantic area includes Barents Sea, western part of the Kara Sea and part of the Arctic. Typical weather for Atlantic area is frequent storms in winter and dull weather with frequent fogs and precipitation in summer. (ABS)

Siberian area is eastern part of the Kara Sea, Laptev Sea and western part of the East Siberian Sea. In this area is influenced by the Siberian low in the winter season. Air temperature in the area is lower than in surroundings areas in winter and higher in summer

near the continental coast. Northern parts of the Siberian area remain cool even during summer. (ABS)

The third area was Pacific area that included eastern part of East Siberian Sea and Chukchi Sea. In winter there is influenced by Pacific weather system that means that air temperature is higher and wind strength and the amount of precipitation is greater than in surrounding area. Summers are stormy with wide fluctuations in temperatures and frequent dense fogs. (ABS)

In the NSR, there is raining 100-400 millimeters annually and the level of precipitation is similar to that in deserts and Middle Eastern countries. Summers are rainier than winter seasons and the reason for this is when the temperature is comparatively high, this precipitation takes the form of rain rather than snow. (NSR handbook, 2015)

3.1 Polar lows

Typical for Northern sea route are polar lows that are small, intense and usually form quickly causing a rapid increase in wind speed or heavy snow flurries. They can cause significant damage to infrastructure, natural ecosystems and navigation in the region. Usually polar lows form near the coast or near the edge of the ice sheet where cold air flows out onto relatively warmer open air and usually dissipate within a day. (ABS) (Akperov M.G., 2016)

3.2 Air temperature

Air temperature is close to 0°C in summers because of snow and ice, but it can rise to 5-10°C if the weather is mild. At the end of summer and in autumn temperature drops under zero, but in the Northern parts of Kara Sea and Laptev sea and in the central part of East Siberian Sea this will happen already in the end of August. In the South-Western part of the Barents Sea this will happen not until middle of November. In the winter season temperatures drop to -30-40°C. Sea water temperature in the summer is usually +5°C and it never goes under zero. (ABS) (NSR handbook, 2015)

3.3 Currents

The Gulf Stream is carrying warm Atlantic water and moves it northwards along the coast of Norway. It divides into two main currents and continues northwards with one branch on

either side of Svalbard. In the Arctic Ocean the Atlantic water is cooled and it becomes heavier and sinks. After circulating in the North Polar Basin it is now cold and Arctic water leaves the Arctic Ocean mainly through the Fram Strait between Svalbard and Greenland. (The Arctic system)

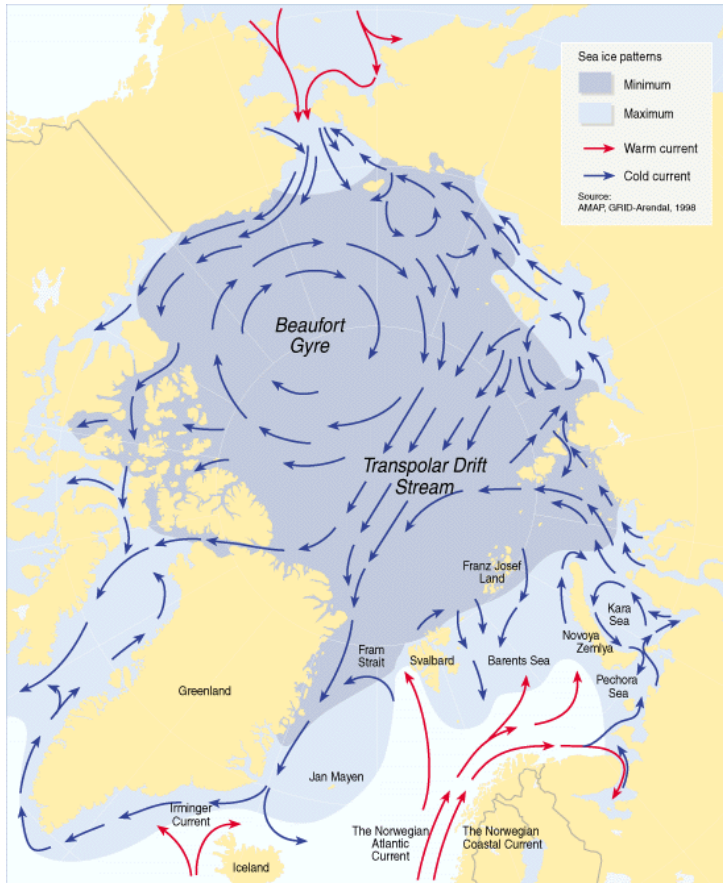


Figure 5: Arctic oceans currents (Rclutz)

3.4 Visibility

In summers clear days are very rarely in the NSR and usually the weather is cloudy. Also frequently fogs are quite common especially near the coast or in the edge of concentrated ice. Sea fog is forming when warm and moist air moves over colder seawater or cold air moves over warmer seawater. In the NSR fogs are in large area and those may persist for long periods. (ABS)

Blowing snow causes also problems in visibility and this is happening when there have been recent snowfalls and then come strong wind that lift snow. Snow can also cause the horizon indistinguishable, when the sky and snow assume a uniform whiteness. This

happens quite often in springs and autumns when the sun is near the horizon and the sky is overcast. (ABS)

Optical haze or shimmer is also visible in the NSR that cause problems in visibility. It occurs when layers of colder and warmer air interact in a convective pattern, refracting light in a manner that causes objects to appear blurred. (ABS)

Northern light, that is also called Auroras, is possible to see in the NSR because it locates just in the Aurora's belt. Only problem for not to see the Aurora might be fogs and cloudy weather that is very common in Arctic. When there is clear sky it helps a lot seafaring because of lighter weather. (ABS) (NSR handbook, 2015)

3.5 Wind

Wind affects much in the NSR for navigating because it moves a lot of drifting ice. Wind is characterizing as either pushing-off or pushing-in with the weakening of compression in concentrated ice. In the South-Eastern part of the Barents sea is blowing variable wind direction typical of monsoon-related changes in atmospheric circulation. In the open sea between September and April wind is blowing from South and South-West, and from May to August it is more Northernly wind. In the winter wind in the NSR can reach 34-40 m/s and in summers 25-29 m/s. (ABS) (Pastusiak, 2016)

3.6 Sea level variations and waves

Sea level variation is much greater in Arctic areas than the values of tidal variations alone. In March to April sea level is in the minimum level and between October and December it is in the highest level. (ABS)

Speed and direction of wind, water depth and the presence and distribution of ice are the biggest effects for development of waves. In the summers wave heights can rise even to 4 to 5 meter but in the winter season there won't be big waves because of ice. (ABS)

3.7 Ice

Ice acts a main role all the time in the NSR. Arctic areas are almost completely covered with drifting ice in the summers. The ice cover starts normally melting in July but in the northern parts of the seas ice starts melting in the end of September. Southern parts of the

NSR are free of ice cover of about two months when it is the highest shipping season in the NSR. In the end of October ice cover is typically 25-30 cm and in until December it has reached 70-90 cm. The thickest level of ice can be even 140 to 210 cm and it appears in May. The highest development of the ice is happening in the March. Second and multi-year ice in the Arctic reaches ice level of 2-4 meters. (ABS) (NSR handbook, 2015)

Sea ice is classified by its age and thickness:

- New ice is about 10 cm thick.
- Young ice is 10-30 cm thick.
- First-year ice is over 30 cm thick, but hasn't survived a summer melt season.
- Multiyear ice that survived summers and thickness varies from 2-4 meter. It contains less brine and more air pockets than first-year ice that makes it more difficult to break.
- Ridges are formed by wind or currents and can be several meters thick.
- Fast ice is ice that forms along the coastline and extends seawards in generally shallow water.
- Drift ice is performing in the open sea and moves by wind and currents (ABS)

4 Climate change effects to the NSR

In generally climate change will change seafaring in the NSR and the main change will be the melting ice. Other changes will be the changes in weather like temperature rising, more storms and cloudiness, but also changes will happen in upper-ocean stratification, and ocean temperature and salinity near the surface. Also summer fogs will come more common and waves will be bigger caused of melted ice. Intensity of polar lows will also increase and finally because all of these changes, weather forecasts becomes more difficult and it will be difficult to give exact details. As it is visible, climate change affects very much in Arctic and it will change shipping in the Northern sea route much. (Vihanninjoki, 2014)

4.1 Ice cover and melting ice

The Arctic is warming faster than anywhere else on the planet and that is effecting to the sea ice that melts to its lowest point in September. Arctic sea ice cover has steadily declined over the past three decades and in the years 2007-2012 it was in the lowest levels of the history. In 2013 ice cap rebounded slightly but ice cover has dropped dramatically in its 30-year average. Scientist believes that there might be years when ice cover will grow but the average will drop in long-term all the time. Arctic ice has extent now about 13% per decade that means that with this speed Arctic would be free of ice in summers after 15 years. (NSIDC) (Masters, 2013)

There have been many scenarios how fast will sea ice melt and disappear totally from Arctic. ACIA the Arctic Climate Impact Assessment has published their research and they said that Arctic Ocean will be totally free of ice in late summers in 100 years. Some other publications argue that it will happen already in 30-50 years and some others say that it will take over 100 years. (Ragner)

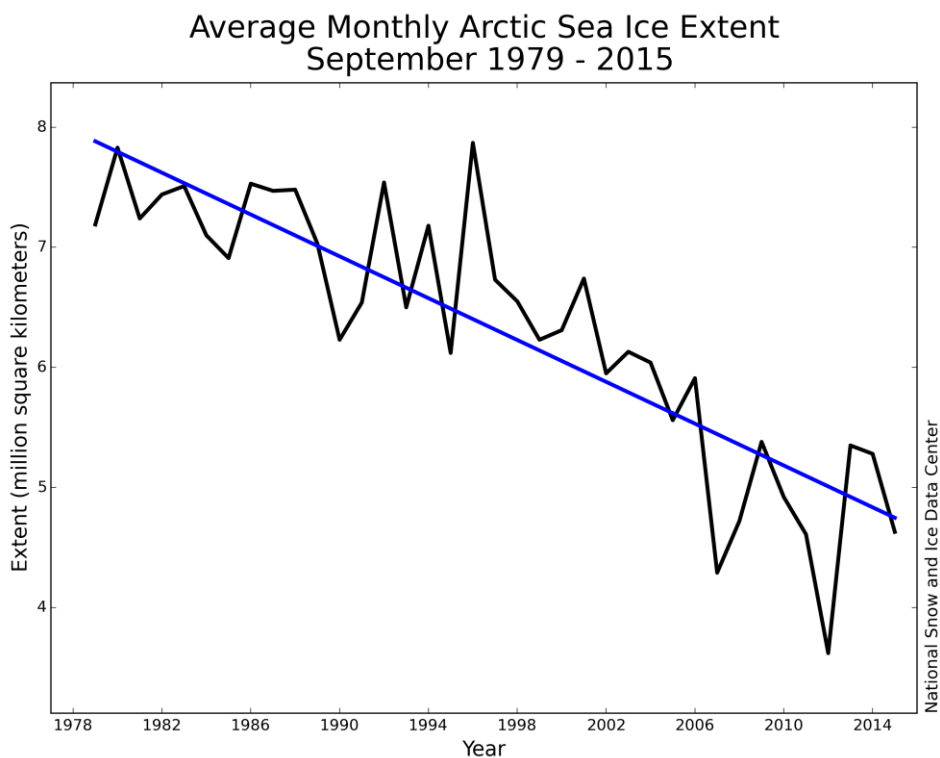


Figure 8: Steady Decline in Annual Summer Sea Ice (NSIDC)

ACIA says in its report that sailing season will be longer in the near future just because of the melting ice. Another reason for that will be new larger, stronger and ice-strengthened vessels that are built to operate in ice. ACIA predicts that average sailing season will grow in 100 years up to 170 days. These are days that vessels can make on their own and season will be much longer when ships are using icebreakers but then using NSR will be much more expensive. (Ragner)

4.1.1 Icebergs

Warming climate in the Arctic is causing also changes in glaciers when those are melting. This will lead to an increased number of smaller icebergs. These small icebergs will be very dangerous for example in foggy weather when visibility is very poor because only small size of icebergs are invisible in the surface of the ocean. (Vihanninjoki, 2014)

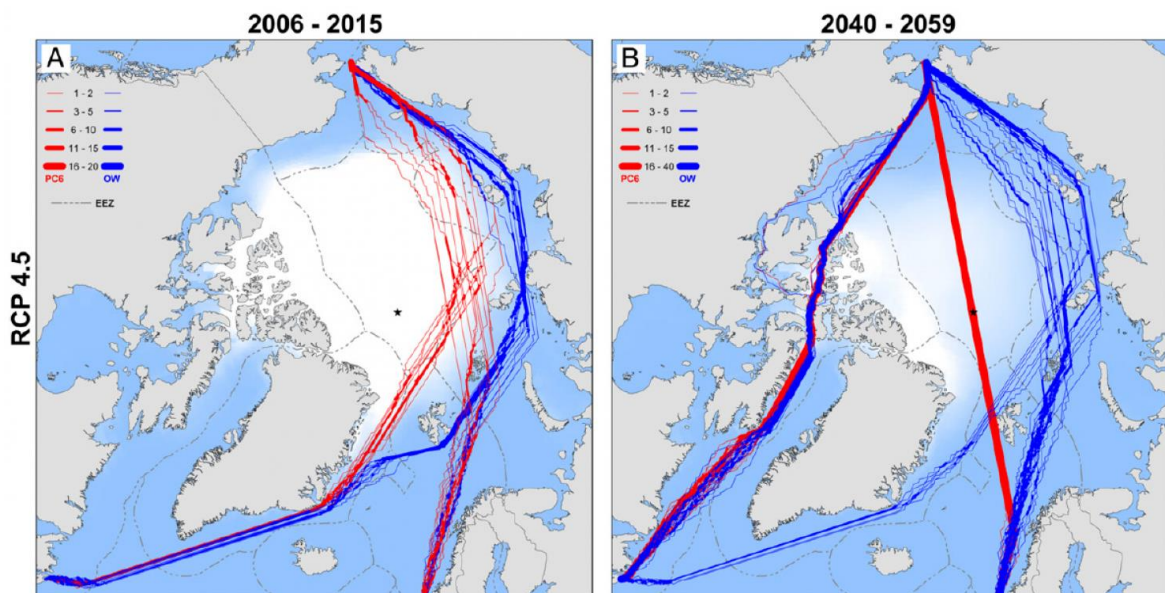


Figure 9: Changing ice conditions (Central, 2013)

In an above picture the blue lines show the fastest routes available for common open-water ships during the summer, while the red lines show routes available for ice-classed ships with assisted by icebreakers. The change will be quite huge in 40-50 years when the NSR will be totally free of ice in summer season. (Central, 2013)

4.2 Sea level rise

The melting ice doesn't affect straight to the oceans sea levels, since the ice is already floating in the ocean. Sea ice melting started to affect sea level since the fresh melt water is less dense than the salty ocean water. Dr. Robert Grumbine of NOAA's sea ice group has researched that if all the world's sea ice would melt it would rise sea water globally with 4 millimeters. (Underground)

Bigger problem concerning sea level rise is that warmer average temperatures is coming to Arctic in following years. This will accelerate the melting of the Greenland ice sheet that holds water to raise sea level with even 4 meters. If sea level would rise this much it would cause huge problems for coastal towns and harbours in the NSR. It would also affect to the routes in the NSR and would change those. (Underground)

4.3 Weather patterns

Continued loss of ice in the Arctic will cause global weather and precipitation patterns in the decades to come. The jet stream will move more up to north and that is bringing warm air to the Arctic that will lead to more precipitations in the Arctic. More frequent and intense droughts in the USA and other mid-latitude countries are caused by this shift of jet stream and it will cause more strength monsoons and hurricanes in the future all over the world. During 1979 to 2006, years that had unusually cold summer, the reduction in temperatures was 10-20% between the Equator and the North Pole and this was resulted in reduced winter precipitation over all of the USA, Alaska and Northern Europe. For example, Spain, Italy and Japan had increased precipitations during these winters. (Underground)

4.4 Global ocean circulation

Ocean surface currents are driven by the winds, but the vertical ocean circulation is determined by the temperature and salt content of the water. In the leading role of thermohaline circulation is in the North Atlantic, where warm water travels to the North and to Arctic Ocean in the Gulf Stream current. When warm water reaches cold air, evaporation cools the water and sea ice formation increases the salt content of the surrounding water. This new cold, salty water is very dense and sinks in a process called overturning. It doesn't only slowdown forming new ice but it injects huge amount of freshwater into the Arctic Ocean. This means that it would rise sea level but it also

freshening Arctic sea water would lead to exceptional changes in the world's ocean circulation and would also affect to shipping in the NSR. (Underground)

4.5 Ecosystem

Marine ecosystem is in a huge part in Arctic areas and sea ice is important for marine ecosystem in three different ways:

- It provides a habitat for algae and invertebrates and fish, and regulates the temperature of the water below it. Although it seems counterintuitive, the sea ice insulates the water beneath it, keeping it from becoming too cold
- Melting ice in summer seasons releases the organisms into the water, providing fuel for Arctic marine food webs
- It provides breeding and hunting grounds for marine mammals and birds that call the chilly North their home. (Underground)

The impacts of melting ice extend well beyond polar bears. Also birds, seals and whales also use the ice for hunting. Birds nest in the sea ice and use it for protection while raising their young in the potentially deadly environment of the Arctic. The retreat of sea ice especially in the warm winter months has decreased the available platforms that seals, walruses and polar bears use to rest on and hunt from. Scientist estimates that retreating sea ice will loss 2/3 of the polar bear population and put rest bears to a smaller and iceless area. (Underground)

4.6 Coastal erosion

When sea ice is melting it will cause bigger waves that are coming to the coastline and this is a very common in the fall seasons. Only melted ice is not a reason, but storms are the heaviest in that time of the year. There has been already news for the people who have has to leave their homes because of these happens. For example, Alaskan town Shishmaref had to evacuate totally and half of the nearby town called Kivalina were evacuated because of 25-40 mph winds drove a four-foot storm surge into the town. The U.S. Army corps of engineers completed a 16-million-dollar sea wall to protect the Kivalina town. (Underground)

When ice continues melting it leaves more ocean surface exposed to air, more moisture and heat will be available for strong storms. These storms bring higher winds and higher storm surges to coastal area in Arctic and leads to erosion and flooding of low-lying areas that will case rise of sea level. Kivalinas town has been lost 8 feet of shore each year due the erosion that is caused by storms. These same kinds of stories will be many when climate change is continuing affects in the Arctic. One change is to move these towns away from the coast but it would costs hundreds of millions euros. (Underground)

4.7 Waves

Although climate change makes positive things in the NSR it also causes problems. When ice is melting around the Arctic it will rise a sea level that will cause extreme waves deriving from different parts of the Arctic basin. Kohn's hypothesis entails that wave heights in Arctic can increase by even two meters by 2060. This will cause problems for the vessel and especially to the crew onboard a ship. These kind of thing put ship owners to think that is this reduce of time and distance worth of it. (Javaid, 2014)

5 Reasons for changes in the NSR

5.1 Global warming

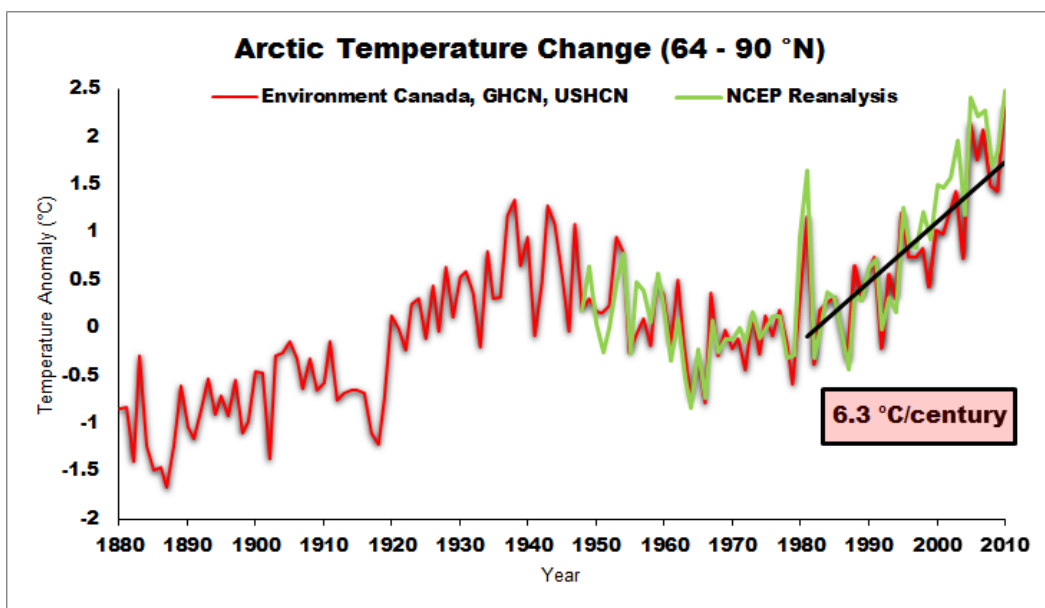


Figure 10: Arctic temperature change (Skeptical science)

Global warming is effecting in Arctic much more than anywhere else on the planet. The average temperature rises approximately 0,09 °C per decade in the last 100 years when global average is only 0,06 °C. From 1964 to 2003 temperature rises in Arctic with 0,40 °C per decade and the global average was 0,25 °C. This shows how warming has accelerated and spatially differentiated. In 2005 surface air temperature were measured and it was higher than for any five-year period ever recorded. Warming is highest in autumn and early winter and in the rest of the world it is smallest. Arctic Ocean temperatures have been the past ten years over 4 °C warmer in autumn and winter compared to the average. There wasn't any bigger increase anywhere else on the Earth. (Vihanninjoki, 2014)

5.2 Arctic oscillation

Periodical climate pattern affecting in the Arctic areas are known well but their general effects is unclear. The Arctic oscillation, AO is such a pattern and its influences on Arctic weather are recognized. The AO is acting by difference in air pressure over the Northern Arctic to lower Arctic latitudes. The cycle of oscillation has both positive and negative phases. Positive phase is that low pressure over the Northern parts of Arctic pulls warmer and wetter air northwards that will rise of observed temperatures. Negative phase is that pressure is high in the far North and the Arctic is cold and dry. Although the negative phase of the AO, temperatures has continued rising in Arctic areas. Arctic oscillation is not the only reason for temperature rising, but is one cause. (NOAA, 2016)

5.3 Black carbon

The Northern sea route is shortening distance between Atlantic and Asia a lot of and that means also less fuel and therefore emit less CO₂ while transporting. Also speed is lower because of natural condition that only increases efficiency. Anyway this means that when ships are moving with a lower speed and higher variability in engine load, it will produce more particulate emissions like black carbon. This happens because engine is operating below its optimum combustion efficiency. A recent report says that black carbon will double in only by 2030. (Azzarra, 2013)

Black carbon affects to snow and ice and when it deposits on those, it reduces the sunlight reflected and increases heat absorption that leads to snow and ice melt. And in whole picture this accelerates Arctic warming. (Azzarra, 2013)

6 How changes effects to seafaring?

6.1 Melting ice

When ice is melting it will open many new options in the NSR. The main effect will be longer sailing season that may increase traffic in the NSR. It will also open new routes and especially shorter routes between Atlantic and Asia when ships doesn't need to navigate in the ice. Far in the future might have possibility to navigate through the North Pole but it will take hundreds of year time. The possibility of new intra-Arctic routes through the North Pole relates particularly to an improved access to natural resources, especially oil and natural gas. (Vihanninjoki, 2014)

Maybe the most important thing in melting ice for the ship companies are that vessels won't need icebreakers assistance so often and this will save even 400 000\$. This will make the NSR much more attractive and more economical route. Only problem that melting ice is causing to shipping are icebergs that are cutting off from the glaciers. (Vihanninjoki, 2014)

6.2 Sea level rise

Rising sea level will affect to shipping in the NSR in positive ways. It will give more depth for example to fairways that leads to port. Together with sea level rise and coastal erosion it might cause problems for arctic ports, because they might have to move port facilities away from the coast line or otherwise they have to build higher quays. (Vihanninjoki, 2014)

6.3 Changing weather

Climate change will change weather quite much in the Arctic environment and storms for example will be very common as also fogs. This demands more from the vessels and from the crew working on board because ships must be enough strength to survive from the storms and also bridge equipment, like radars, ECDIS or raster charts or GPS system, must be in update to navigate in the bad weather and in poor visibility. Rough weather requires also much from the crew and they must have to ability to work in rough weather in rolling ship. (Vihanninjoki, 2014)

6.4 Potential in changing Arctic

When arctic is changing due to Climate change it will offer new possibilities and ways how to use the NSR better for benefit. Here are next five different aspects that would develop the NSR and would increase traffic on it. These five things are possible just because of changing Arctic. (Vihanninjoki, 2014)

6.4.1 Oil and gas

It is said that Arctic contains one-fifth of world's undiscovered oil and natural gas and these resources depends on the development of sea ice cover. This means that Arctic is hiding 90 billion barrels of oil, 47 trillion cubic meter of natural gas and 44 billion barrels of natural gas liquids. It is estimated that undiscovered oil and gas in the Arctic occurs offshore and the resources located in either ice-free or seasonal ice-free areas that means that those resources are already available. (Vihanninjoki, 2014)

The estimations of future Arctic oil and gas production vary much. One modeling tool is called FRISBEE that "describes future supply and demand of oil and gas through elaborate modeling of oil and gas investments and production". The main target of the model is petroleum markets but it is also modelling the global markets for coal and regional markets for electricity. These scenarios include levels of oil price and also those modelling the rates of oil and gas production in the Arctic. (Vihanninjoki, 2014)

6.4.2 Minerals

Globally the number of current mining operations in the Arctic is very small but the extraction of hard minerals is in a bigger foot. There is working largest zinc mine in the world called Red Dog in the Alaska and also the largest nickel mine called Norilsk in Siberia. Both of those mines are dependent on sea transports and the development of the NSR will affect also to these. Also in Greenland is working company called Kvanefjeld that is working with a multi-element deposit containing rare elements, uranium and sodium fluoride that is also dependent on the NSR because shipping is the only way to carry these scarce commodities to global markets. In coastal Greenland there is also other smaller but growing companies which future depends on the NSR. (Vihanninjoki, 2014)

6.4.3 Fishery

Fishing vessels makes a big part of Arctic shipping and there is moving many fishing vessels in the NSR. Arctic has been shared to four different fishing areas:

- The Northeast Atlantic (The Barents and Norwegian seas)
- The Central North Atlantic (the waters around Iceland, the Faroe Islands and East Greenland)
- The waters off North-eastern Canada (Newfoundland and the Labrador area)
- The Bering Sea

The main fishing places locate in the Bearing and Barents seas, in the west coast of Greenland and in the surroundings of Iceland and the Faroe Islands. (Vihanninjoki, 2014)

Because fishing happens in areas where no ice is or those are seasonally ice-free it means that climate change effects will cause fishing in the Arctic areas. Due to warming of climate some fish stocks with notable economic bearing, such as cod and herring, may become more plentiful in the Arctic waters in the future. Although that may happen, consequences of the climate change won't be positive for shipping as some other species lose their natural habitat. (Vihanninjoki, 2014)

6.4.4 Local community re-supply

There are many different communities in the Arctic that needs essentials supply possibilities. Those communities are very dependent on external services that are provided by assistance of shipping. "Re-supply activities provide a lifeline to many communities that have no or very limited road access and no or limited capacity to handle heavy aircraft; most communities services are ice-locked for parts of the year and rely heavily on marine transportation during the summer months for their dry foods, fuel, building materials and other commodities." (Vihanninjoki, 2014)

These re-supplies in the Arctic increase population and development of the regions and that's why those are so important. With ice-free arctic these transportations would be more efficiency and faster so that's why climate change and future of NSR affects so much to these. (Vihanninjoki, 2014)

One big problem that climate change causes for these communities in the Arctic is that possibilities for travelling by ice roads that are many in there. Many cargos are transported with trucks using by ice roads to different places, but it's not possible far. Some of these transportations may be possible to replace by new shipping routes but not all. (Vihanninjoki, 2014)

6.4.5 Tourism

Marine-based tourism is at the moment the largest Arctic tourism industry and it is playing a big role there. The types of passenger vessels vary a lot, but almost all traffic is happening in the ice free areas and that's why climate change will affect to that. Arctic tourism suffers from physical in-accessibility, lack of infrastructure, poor regulations, high costs, and large travel distance but cruise ship industry has grown already in the Arctic. (Vihanninjoki, 2014)

6.5 Environmental regulations

Technologies try to minimize exhaust gas from the ships to help remove sulfur oxides, nitrogen oxides, and particulate matter, such as black carbon, which are the main airborne threats to a healthy Arctic environment from shipping. Scrubber technologies, liquefied natural gas, and diesel particulate filters combined with the established use of low-sulfur fuel could reduce emissions of black carbon and other pollutants from 40% to 90%. Decreasing black carbon emissions from Arctic shipping by 70% in 2030, it would result in a 60% decrease in black carbon radiative forcing that would benefit direct to Arctic. These things could become elements of an ECA for the Arctic similar like is already in place to control Sox in the USA, Canada and parts of Europe like in the Baltic Sea. (Marine Insight, 2016)

Additionally, implementing fuel restrictions, such as forbid of using HFO is already in discussion as part of the Polar code within the IMO because it is considering restrictions on the emission of black carbon from ships, to protect the Arctic environment. While the Arctic Nations recently signed an Arctic Spill Response Treaty, the ability to respond to such an event is limited at best. (Humans at sea, 2016)

7 Discussion

7.1 How climate change will effect in the NSR?

Climate change will be a big factor in the NSR and it will change conditions quite a lot. The biggest change in a long period will be melting ice that will open many new fairways and reduce distance between Europe and Asia when ships can make their journeys nearer the North Pole. When nowadays traffic in the NSR is very small, I believe that when ice has melted more, ship companies starts to rethink their route options between the Suez Canal and the NSR.

Then there are other factors that climate change will cause like sea level rising, bigger waves and stormier weather that requires more from the vessels and also from the crew of it. But shipbuilding is developing all the time so hard storms won't be problem in the future.

I think I found many different factors that is effecting to the shipping caused by climate change and the most difficult was to collect the right ones. It is still quite difficult to say all the possible effects and how strongly those will show up, but these basic effects are much easier to notice.

7.2 What causes the possible changes by climate change?

There are many different factors that cause the changes and many of those cause domino effect. Main cause is a global warming that is the main reason for changes and it is the first changer. In addition of temperature rise in the Arctic cause ice melting, and it makes icebergs which are a huge risk for ships. At the same time melting of icebergs causes sea level rise.

Second example is that when temperature is rising it causes more storms and windier weather. Wind is causing waves that are reducing speed of the ships. Waves also cause corrosion of the shore that makes harm for the harbours. These are like big domino effects that are causing a lot of harm for shipping. The biggest factor caused by climate change is temperature rise that is making both positive and negative aspects.

At first I thought that this research question will be the most difficult one, but I found many factors that cause the changes. The biggest thing was to find the domino effect system that showed how these things follow up of each other.

7.3 In what time period these changes may affect to the shipping in the NSR?

Climate change is not happening fast and it takes tens of years to see the differences. There might be warmer periods than normally but that doesn't mean that climate change is accelerating. At the same time the colder periods doesn't mean that climate change has stopped.

For example, temperature has risen much in last 30 years and if it continues in the same way changes are happening much faster. Also Arctic ice has extent now about 13% per decade which means that with this speed Arctic would be free of ice in summers in 15 years. But then other researches says that Arctic is totally free of ice in 100 years and others says that it happens in 30-50 years.

Basically it is impossible to say how fast climate change is happening and this research question is very difficult to answer. It is possible to say that it happens in 1, 10 or in 100 years, but no exact numbers can be given because of so many factors. It is also impossible to say when climate change is finished because there is not any roof how much for example temperature can rise.

7.4 Are the changes positive or negative for the seafaring in the NSR?

Basically ship companies, Russian and all maritime companies wait that global warming is melting ice so much that it is always most economical to use Northern sea route. These possible users wait positively these changes but on the other hand these changes are not so good and makes harm quite much for the nature.

If we think positive aspects for seafaring the biggest one will be melting ice that opens new and faster fairways between Europe and Asia. It is also better for ships that they don't have to make their voyages in the ice. If there wouldn't be global warming and ice wouldn't melt like it has done for today there wouldn't be any Northern sea route and it is critically important for the NSR that it continues melting.

Then these negative things for seafaring are especially bigger waves and stormier weather. It will reduce speed quite much and it requires much from the crew that they can work many days in the stormy weather. Corrosion in the shore cause also problems for the ports and they might to rebuild their quays when land is disappearing from under of those.

7.5 Future questions?

Northern sea route is very hot topic and there are many different things that are under interest of research. Because of rear traffic in Arctic Sea there is a lot of potential that hasn't used yet. Future question could be, what kind of potential there is in the NSR and how ship companies could utilize it?

Arctic area has a lot of undiscovered oil, gas and minerals that would increase shipping traffic in the NSR. Also for example tourism is still quite small in the Arctic and big cruise companies hasn't yet find Arctic areas as a cruising area. I see that it would be success to take people to watch icebergs, polar bears, Aurora and winter to the near North Pole. It would be success especially for people that's living in the Southern parts of the world.

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