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Sea transport in the Arctic

Educational package

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Introduction

This educational package contains materials aimed at preparing students for the debate on the perspectives of developing sea transport across the Arctic Ocean. The materials in this package will help you assess whether this shipping route should be used despite the environmental risks.

The package contains basic information about possible sea routes through the Arctic Ocean, which are an alternative to currently used routes. The information contained here will help to prepare arguments for the development of maritime transport in the Arctic, as well as counterarguments. The resolution for the debate is:

Sea transport in the Arctic Ocean should be developed

Definitions:

NORTHWEST PASSAGE – sea route from the North Atlantic through the Baffin Sea, the straits of the Canadian Arctic Archipelago, the Beaufort Sea and the Chukchi Sea to the Bering Strait and American and Asian ports on the shores of the Pacific Ocean. It leads across territorial waters of Canada.

NORTHEAST PASSAGE – sea route from the ports of northern Europe through the coastal seas of Europe and North Asia (Barents Sea, Kara Sea, Laptev Sea, East-Siberian Sea, Chukchi Sea) and the Bering Strait to American and Asian ports. On the section from the Karskiy Sea to the Chukchi Sea, it is called the Northern Sea Route. It provides shipping services the Exclusive Economic Zone of the Russian Federation and is controlled by the Russian administration.

ICE CONDITIONS – the state of sea ice cover, determining the possibility of sailing for vessels.

ICEBREAKER – a specially designed vessel, with features that allow it to overcome continuous ice cover; the Russian Federation has the largest fleet of icebreakers, including nuclear-powered vessels

PANAMAX - a commercial ship of the highest ice class available for commercial ships, at the same time - the largest ship that can pass through the Panama Canal

ICE CLASS – the ability of a ship to navigate at sea with an ice cover of adequate ice class density and ice thickness rating. PANAMAX vessels cannot work as icebreakers

SEA-ICE COVERAGE – percentage of the sea surface covered with ice; if sea ice coverage is up to 30%, ice class vessels can navigate independently, in case of larger coverage – icebreaker escort is required

NAUTICAL MILE (NM) – distance unit used in shipping. 1NM equals approximately 1.85 km, i.e. the length of the meridian arc corresponding to 1 '(arc minute).

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Alternative sea routes across the Arctic Ocean

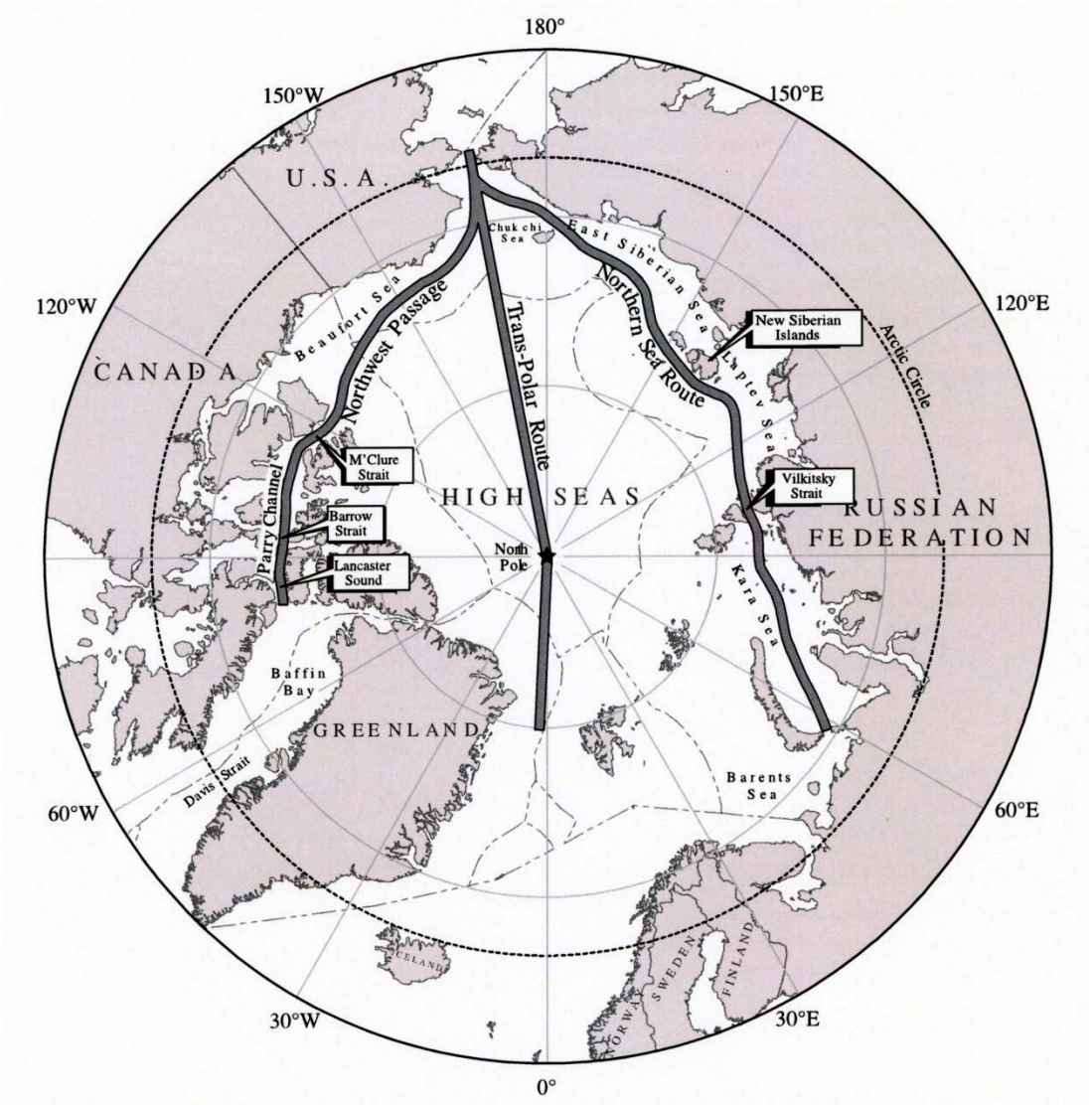


Figure 1. The NSR, The NEP, and Trans-Polar Route (adapted from Stephenson *et al.* 2013b).

Fig. 1 *Shipping routes in the Arctic Ocean - Northwest Passage, North Sea Route, Transpolar Route (Stephanson et al. 2013)*

The map above presents three variants of possible shipping routes across the Arctic Ocean, namely:

- **Northwest Passage, NWP**
- **Transpolar, TPR**
- **Northeast Passage** – to be more precise, the map shows a section of the Northern Sea Route NSR - it is a sea route administered by the Russian authorities, connecting the Bering Strait with Kara Gates.

Thinks and answer the following question:

1. What are the factors determining the attractiveness of sea routes in the Arctic Ocean?

These routes may be alternatives, competing with traditional shipping routes. Currently, in order to sail from Rotterdam to San Francisco, it is necessary to go across the Atlantic Ocean, the Panama Canal and sail through the Pacific Ocean along the western coast of North America. The Northwest Passage is an appealing alternative.
Likewise, sailing from Rotterdam to the east - to Shanghai and Yokohama, ships need to overcome a small stretch of the Atlantic Ocean, Mediterranean Sea, Suez Canal, Red Sea, Indian Ocean. Northeast passage is an alternative route.
The described routes are marked on the maps below. Route III - The Transpolar Route is the shortest one, but at the moment only of theoretical nature, as it is unavailable. It leads from the Bering Strait through the North Pole to the Strait between Greenland and Spitsbergen (Fram Strait).

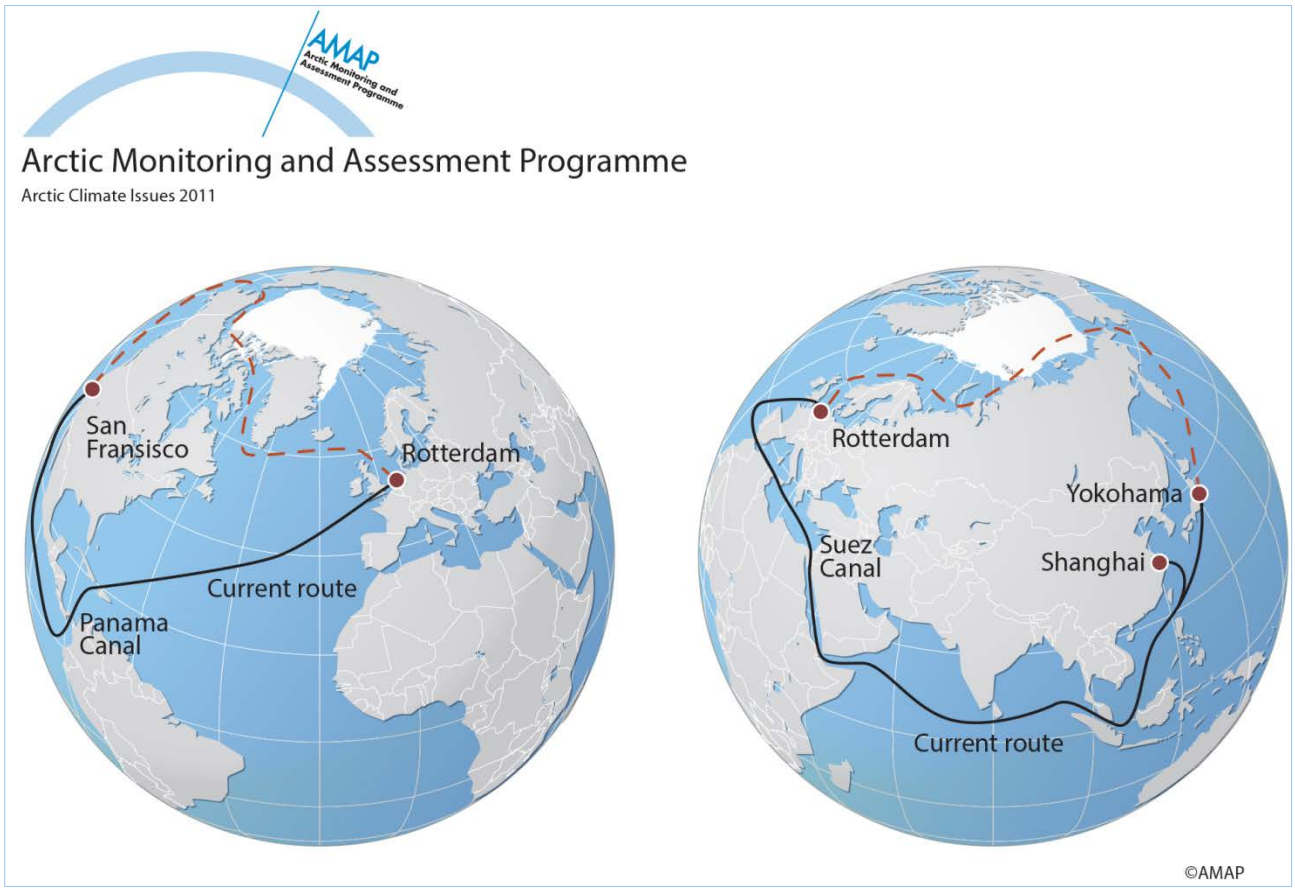


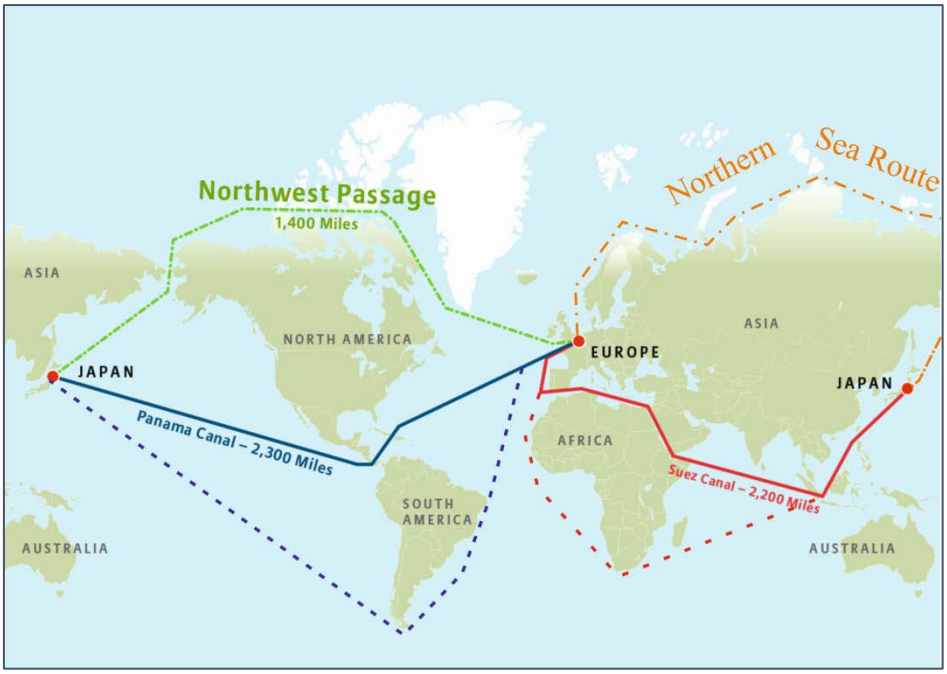
Fig. 2 *Comparison of traditional shipping routes from European ports to those on the Pacific Ocean, (AMAP, https://www.amap.no/) with routes leading through the Arctic Ocean*

Northwest Passage

The sea route from Rotterdam to Japan via the Northwest Passage is shorter than both the sea routes through the Panama Canal and the Suez Canal. The difference between NWP and Panama Canal equals 900 nautical miles, while in case of Suez Canal - 800 nautical miles. Using this route (NWP) would significantly reduce transport duration and fuel consumption.

Fig. 3 Comparison of the length of existing shipping routes from Europe to Japan

with a Northwest Passage Route.



Northwest Passage: history of exploration

Years	Number of vessels, divided by type				
	expedition vessels	icebreakers	Cargo ships and passenger ships	yachts	total
1900 – 1909	1				1
1910 – 1919					0
1920 – 1929					0
1930 – 1939					0
1940 – 1949	2				2
1950 – 1959		2	2		4
1960 – 1969		5			5
1970 – 1979	3	6		1	10
1980 – 1989	1	6	5	5	17
1990 – 1999		13	11		24
2000 – 2009		17	9	48	76
2010 – 2018	4	3	23	108	138

Tab. 1. List of ships that crossed the Northwest Passage; (Own study based on: Headland et al. 2018.)

For the first time, The Northwest Passage was crossed by the Amundsen expedition on the Gjoa ship in 1903-1906, after over two centuries of attempts by several dozen unsuccessful expeditions. From that time until 2018, 279 ships crossed it (details in tale 1 – above).

Most of the ships that have crossed it successfully were yachts. The route is therefore primarily of importance for "sport" purposes. Transitions of merchant and tourist ships were experimental (which was emphasized by the organizers).

INFO CARD 1
Panama Canal - an artificial waterway, over 80 km long (with 12 locks) built in 1904–1914 and officially opened in 1920, located in Panama, on the Isthmus of Panama, connecting the waters of the Atlantic Ocean (through the Caribbean Sea) with the waters of the Pacific Ocean. The channel is 81.6 km long, of which 16.4 km is in the shallow coastal waters of the Gulf of Panama and Colón. While sailing from the Caribbean Sea, ships sail 11.3 km at the sea level, up to the system of three Gatun Locks, which raise ships to 25.9 m a.s.l. - the level of artificial lake Gatún. After leaving the lake, ships enter an 11-kilometer excavation in the rocks, and after traveling another 13 km they reach the next system of locks. After a further 13 km, ships enter the ports of Panama and Balboa. The width of the locks is 33.5 m and the ships that may enter the Canal are the so-called PANAMAX with maximum dimensions: 294.1 m long, 32.3 m wide and 12.0 m draft. (based on Wikipedia)

INFO CARD 2
Suez Canal – a deep-water channel for sea vessels located in Egypt, connecting the Mediterranean Sea with the Red Sea, built in 1859-1869. One of the most important waterways in the world. The total length of the canal is 163 km, it's 160-200 m wide (after modernization - up to about 300 m), permissible ship's draft - 11.6 m (after modernization - up to 23 m). The average channel capacity is 60 vessels per day. In 2008, 21,415 vessels sailed through the channel. The average time of passage of the ship through the channel - 15 hours. (based on Wikipedia)

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INFO CARD 3

Duration of the cruise vs greenhouse gas emissions

A shorter trip from A to B means lower fuel consumption, lower costs and significantly lower CO_2 .

	Duration [h]/[24h]	Fuel consumption [t/24h]	Fuel consumption in total [t]	Cost of fuel [EUR]	Type of fuel, emission factor/ total emission of carbon dioxide during the cruise		
					HFO 3,114 [g/g]	MDO 3,206 [g/g]	LNG 2,75 [g/g]
Panama Canal	1111,35	38	1759,4	560 739,3	5478,8 t	5640,64 t	4838,35 t
	46,3						
Suez Canal	856,4		1345,2	456 584,7	4188,95 t	4312,71 t	3699,3 t
	35,7						
Northern Sea Route	539		855,0	272 497,5	2662,47 t	2741,13 t	2351,25 t
	22,5						

Table. 2
Comparison of cruise duration, costs, fuel consumption and CO_2 emissions for a PANAMAX vessel
Based on: Biernacki D 2017; Klopott M. 2016

Northwest Passage shores: development and infrastructure

INFO CARD 4

Northwest Passage shores: development and infrastructure

The settlements shown on the map below are inhabited by ca. 1000 people, mainly Inuits. The towns are tourist centers and conduct local trade for nearby settlements or periodic Inuit camps. There are airports that can operate small planes. Only Tuktoyaktuk has a land connection with the interior of the country.

The lack of oil and natural gas resources discovered in the Arctic Archipelago clearly limits the possibilities for rapid economic development. Climate change may arise possibility of developing settlements as ports, if new shipping route through the numerous straits of the archipelago are available for long periods of time. For the moment, it is only 4 to 6 weeks per year.

Northeast Passage

Fig. 4 (Imbert B. 1996), near-coastal shipping between the estuaries of the Siberian rivers

Since when has there been commercial shipping along the northern shores of Siberia?

The indigenous inhabitants of the northern ends of Siberia were mainly nomads, their occupation were hunting and breeding reindeers. They practiced fishing on the rivers, and the rivers were also the main communication routes - in the summer of boats, in the winter – as trails. This is still the case today, in winter, frozen Siberian rivers are marked with roads, used by all kinds of vehicles, from snowmobiles and passenger cars to large trucks.

The Russian conquerors of Siberia, the Cossacks introduced near-coast chipping with the help of small sailing vessels called koczi (about 30 m long, weighed about 40 tons). The design of the bottom of these ships allowed them to be pulled on ice with “capstans” -winches (lifts with vertical axis drums, used on ships to raise and lower anchors, large sails, heavy loads). Using such ships, they launched subsequent expeditions, which opened shipping lanes between the estuaries of the great Siberian rivers.

In 1648, the expedition of Semyon Dezhnev went from the Kolyma estuary to the Anadyr River estuary, discovering the Bering Strait on the way. Formally, the strait separating Asia from Europe was discovered by Vitus Bering, a Dutchman in the service of Tsar Peter the Great (hence the name of the strait). Dezhnev was “reawarded” only with Cape Dezhnev, the easternmost point of Asia.

Table 3. Distances between Asian and European ports

Departure port	Destination port: Rotterdam, via:			Difference* [%]
	Good Hope Cape	Suez Canal	Northeast Passage (NEP)	
	Nautical miles [NM]			
Yokohama	14 448	11 133	7010	37
Busan	14 084	10 744	7667	29
Shanghai	13 796	10 557	8046	24
Hong Kong	13 014	9 701	8594	11
Ho Chi Minh City (former Saigon)	12 258	8887	9428	-6

* - difference in distance between the route through the Suez Canal and Northeast Passage (NEP)

Northeast Passage coasts: development and infrastructure

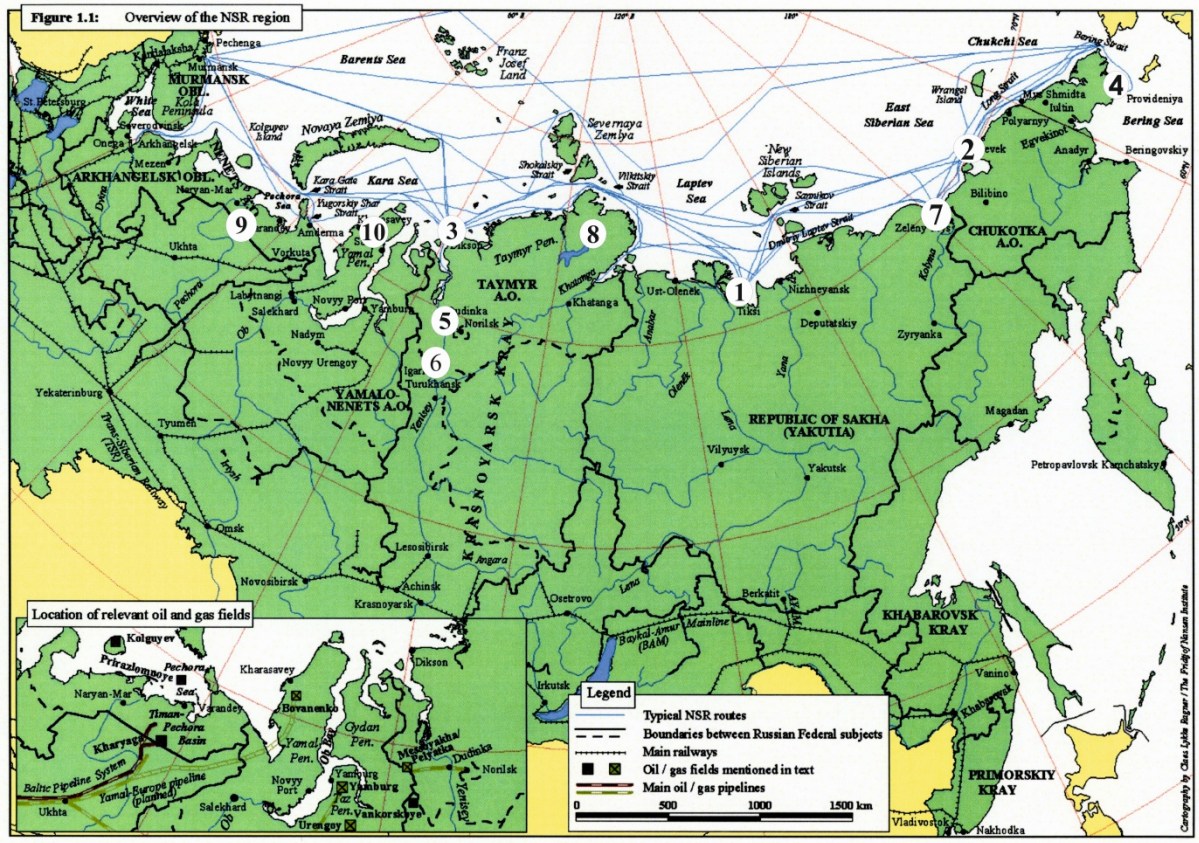

Fig. 5 Development of Northeast Passage (FNI Report 13/2000)

Main ports :

1.Tiksi - sea port available for 3 months a year, airport, approx. 6,000 residents.

2. Pevek - city and port on the East Siberian Sea, approx. 4,500 residents, airport, tin ore mining center.

3. Dikson – city and seaport of the Kara Sea.

4. Provideniya Bay- seaport over Bering Sea, approx. 2,800 inhabitants**.**

5. Dudinka – city, port and airport (44km) in the lower reaches of Yenisei river, approx. 25,000 inhabitants, land connection - road and electrified railway line connecting the sea port with Norilsk located at a distance of 96 km.

6. Igarka – port on the Yenisei river, accessible to seagoing ships, about 8,000 inhabitants, developed wood industry.

7. Ambarchik – marina on the Northern Sea Road near the estuary of Kolyma river.

8. Taymyr, 9. Timan, 10. Jamal - oil and gas extraction centers

Think and answer the following questions:

1. What determines the economic importance of the Northern Sea Route?
2. Is development (including infrastructure development) along the northern shores of Russia the cause or the effect of the growth of shipping in the Arctic Ocean?

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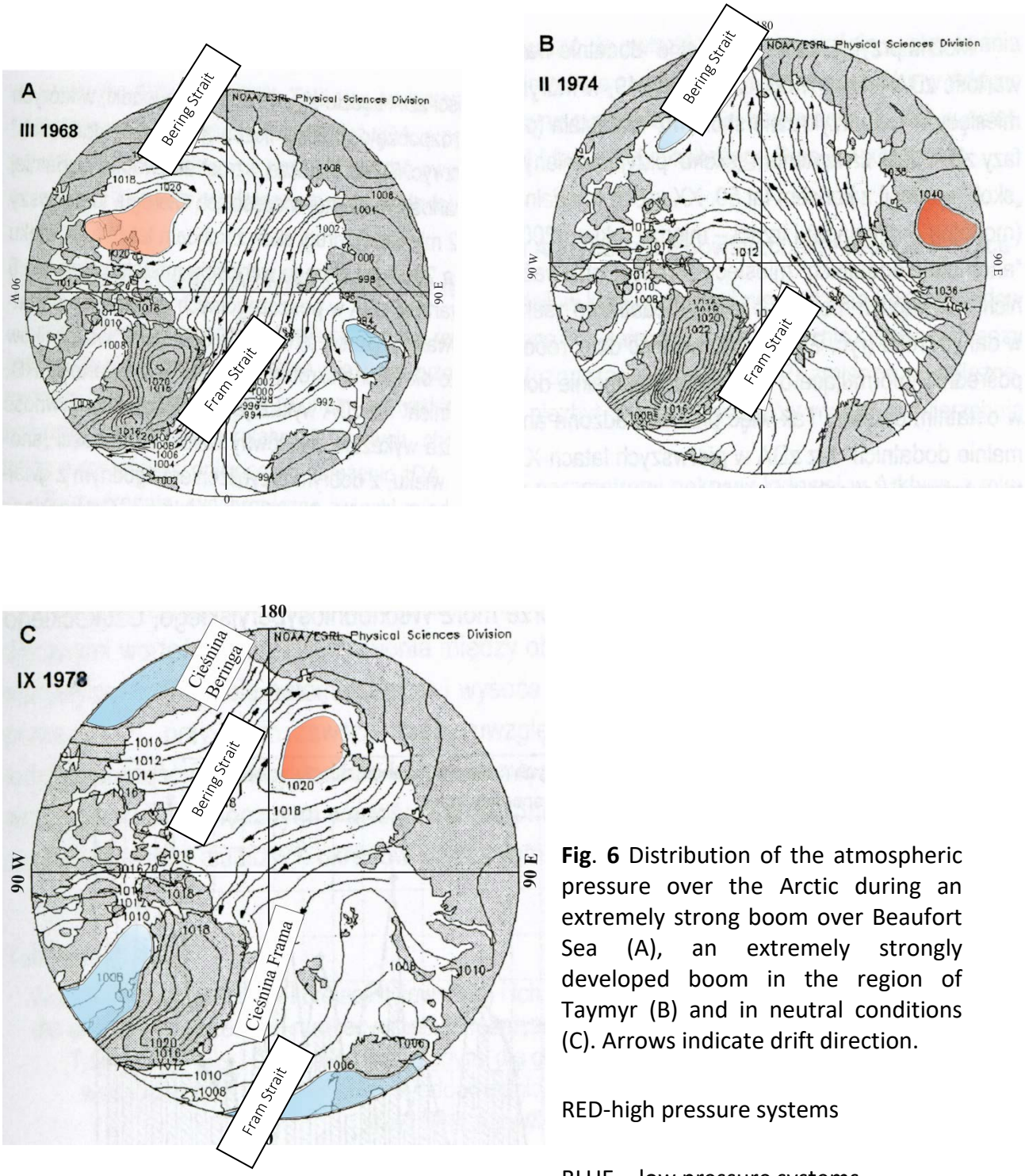

Fig. 6 Distribution of the atmospheric pressure over the Arctic during an extremely strong boom over Beaufort Sea (A), an extremely strongly developed boom in the region of Taymyr (B) and in neutral conditions (C). Arrows indicate drift direction.

RED-high pressure systems

BLUE – low pressure systems

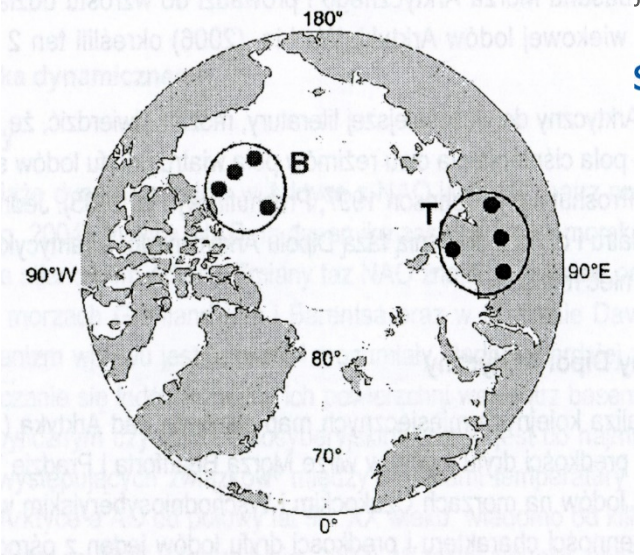

Fig. 7 Points for which the calculated atmospheric pressure values were used to determine the characteristic pressure systems and ice cream movement directions

How do large pressure systems affect the transport of sea ice in the Arctic?

It was found that in the area of the Arctic Ocean and neighbouring land areas there are two privileged regions of formation of large pressure systems (high-pressure and low-pressure). Their centres are located on the Beaufort Sea (Canada) and around the Taimyr Peninsula.

The possible variants are:

A. High-pressure in the region of Beaufort and low-pressure in the Taimyr region - the wind patterns cause the movement of sea ice from East to West, which contributes to the increase of the open sea area in the eastern Arctic Ocean and increase of ice-free sea surface. The ice transported to the west enters the North Atlantic through the Fram Strait (between Greenland and Spitsbergen), where it melts more easily under the influence of the warmer waters of the North Atlantic Current (Gulf Stream, Golfstrom).

B. High-pressure in the region of Taimyr and low-pressure on the Beaufort Sea – the wind patterns provoke sea ice movement from West to East. Ice moves from the central Arctic Ocean into the Chukchi Sea, sea ice does not escape into the Pacific through the narrow Bering Strait, while in the Canadian Arctic a significant amount of new sea ice is forming. The surface of sea ice covering the Arctic Ocean increases significantly.

C. Large pressure systems are not formed or are relatively weak. Sea ice movement does not show clear directions.

The described changes of baric (pressure) systems are responsible for cyclical (one- or several-season) fluctuations of the surface of sea ice.

The observed long-term trends show a steady decrease in the surface of sea ice in the Arctic Ocean.

Impact of sea currents on shipping conditions

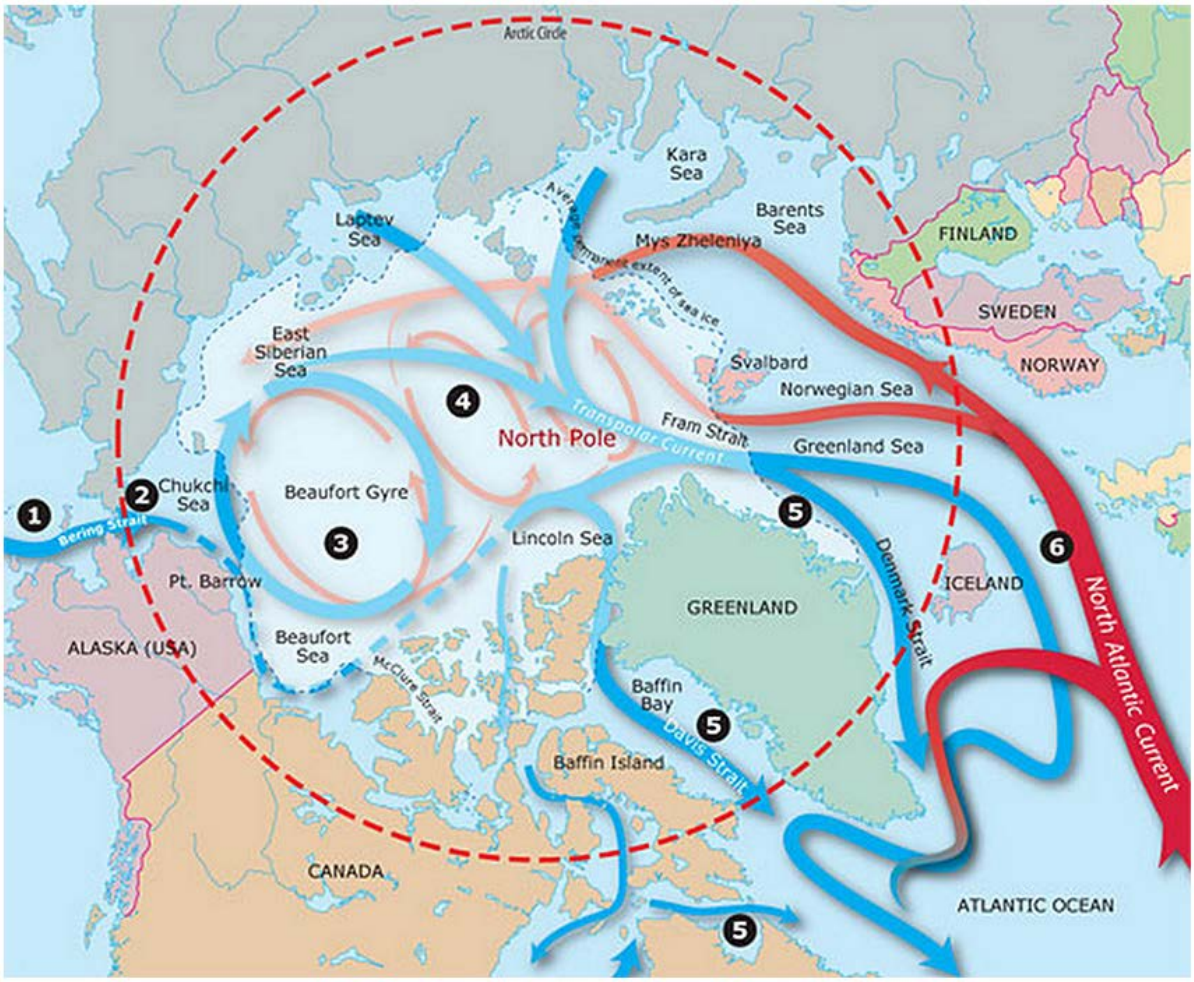

Fig. 8 Distribution of sea currents in the Arctic Ocean

What is the effect of distribution of sea currents in the Arctic Ocean on shipping conditions?

Warm sea current (North Atlantic Current) flowing from the equator causes the surface temperature of the North Atlantic to rise. It also significantly improves sailing conditions in the Barents Sea (towards Novaya Zemlya). As a result, Murmansk is a non-freezing port, even though it lies on 66th parallel (North). This makes it possible to operate ships all year round. Murmansk as a year-round port also served during World War II - convoys from England reached Murmansk.

The complicated system of cold currents in the western Antarctic Ocean (north of Greenland, in the Lincoln Sea and Beaufort Sea) results in the concentration of sea ice in the Canadian Arctic Archipelago, therefore, the shipping routes end in this area.

Changes in ice conditions in 20th and 21st century

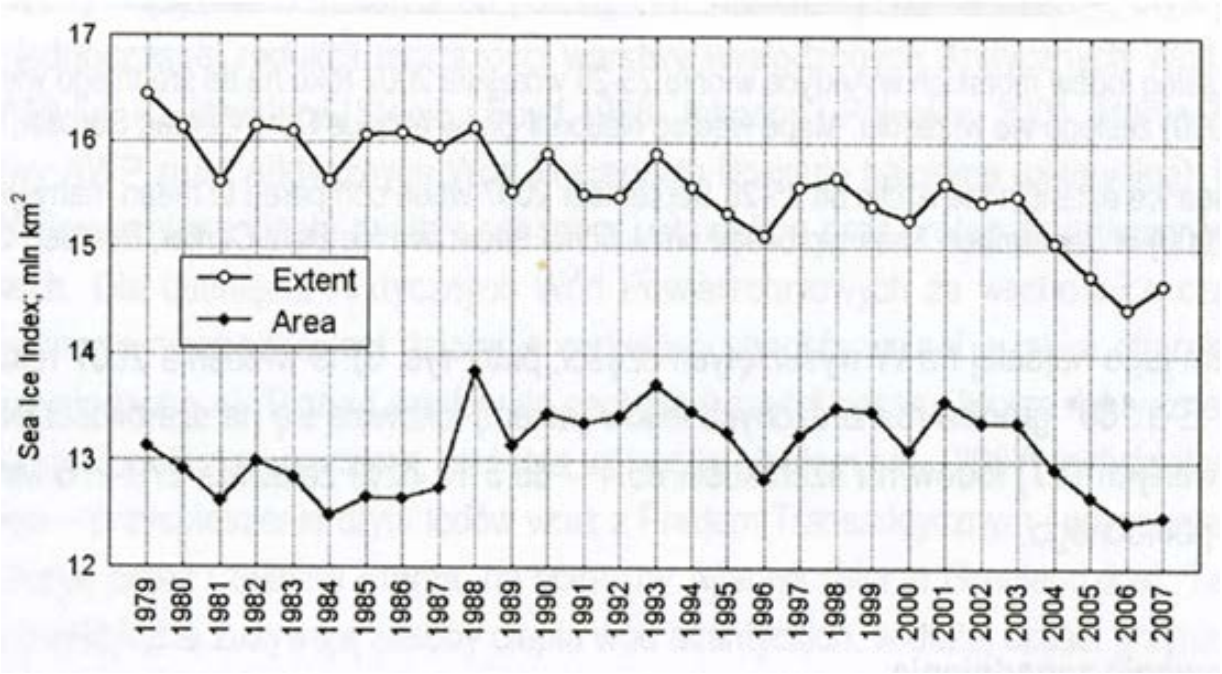

Fig. 9 Variation of annual values of the Sea Ice Index in the Arctic (March 2008)
Extent - range of sea ice covering more than 15% of the surface
Area - sea ice coverage reduced to 100% coverage (March 2008)

How to read the chart?

The chart presents the sea ice ranges over the years 1979–2007. Sea ice often occurs as separate pieces (fragments). Depending on how densely the sea surface is covered with ice, ships with varying properties may float there. The chart assumes the value of ice coverage of at least 15% of the area. Waters cover in less than 15% are treated as ice-free waters (open water) that can be freely used by ships without special reinforcements. This is illustrated by the graph marked as "**extent**". It shows that in 1978 the range of sea ice was 16.5 million km^2.

The second graph, marked as "**area**", shows area (expressed in km^2) that was covered with ice (total surface minus ice-free surface). As we can see, in 1979, ice covered surface extended to 13.1 million km^2.

How have the ice conditions (range of permanent ice cover) in the Arctic Ocean changed in 20th and 21st century?

Despite seasonal (annual) fluctuations, the sea ice **extent** shows a downward trend. Melting sea ice on the outskirts is caused by the inflow of warmer waters from the Atlantic Ocean (Greenland Sea) and the Pacific Ocean (Bering Sea). The sea ice **area** exhibit much larger changes; only since 2001 has it shown a steady downward trend. Those variations are caused by seasonally changing wind patterns of winds and sea current, resulting in higher or lower ice

concentration. It should be noted that with the same sea ice **area**, sea ice **extent** can vary significantly, e.g. with and area of approximately 13 million km^2 in 1982 and 2004, sea ice extent could differ by more than 1 million km^2.

Long-term temperature changes in the Arctic

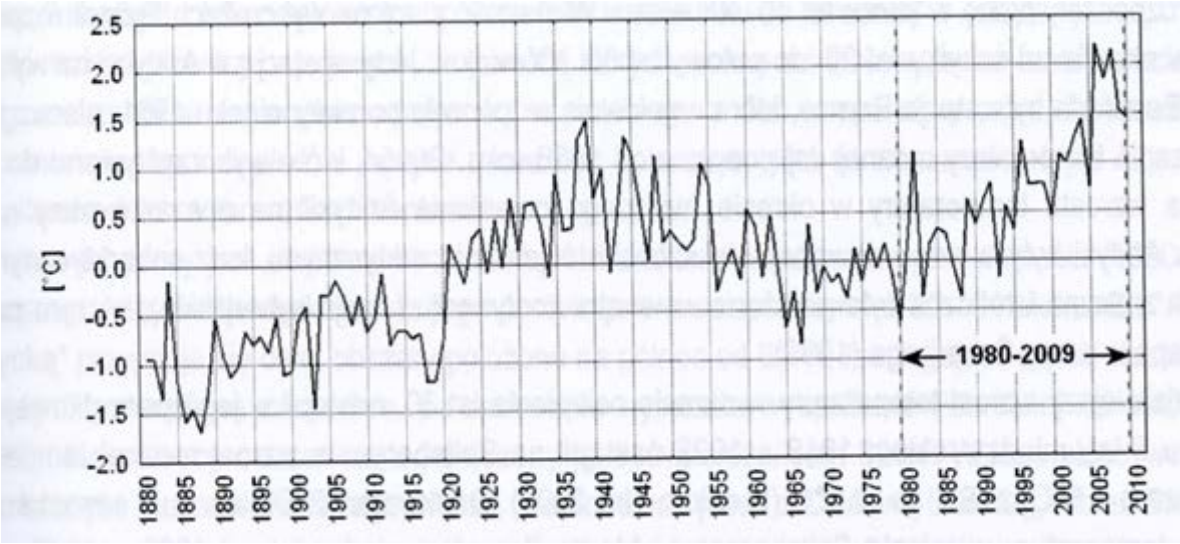

Fig. 10 Presentation of annual anomalies of air temperature [Celsius degrees] over the area of 64-90N (the whole Arctic).
Please notice marked period of "modern Arctic warming" (1980-2009) (Marsz, Styszyńska 2011)

How are the temperature values in the Arctic changing?

The chart presents changes in the average annual air temperature in the Arctic in the years 1880-2009. Until 1920, average annual air temperatures in the Arctic ranged below O^{0}C. Values above zero prevail since then. The chart also shows the period of "warm Arctic" in the 1940s. There was a cooling period, recorded in the 1960s-1990s. A systematic rise in air temperature in the Arctic has been observed since 1990.

Arctic ice cover decline

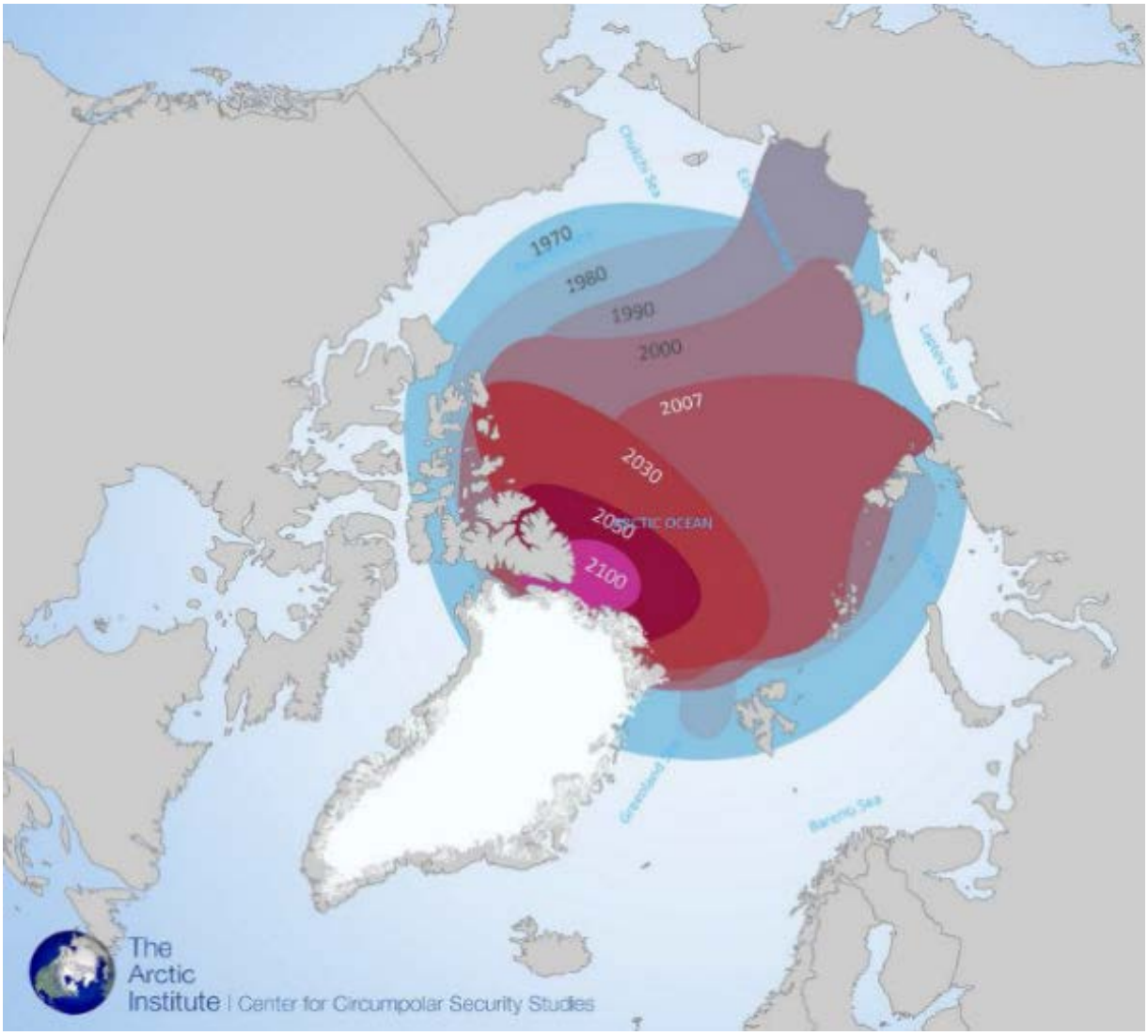

Fig. 11 Model of Arctic Ocean ice cover decline – predictions till end of the 21st century (nmtm-nordost-chart-1.png, The Arctic Institute),

Sea ice extent data from 1970 to 2007 are based on observations. The minimum of sea ice is recorded in September. The ice cover decreases at the highest rate in the eastern Arctic Basin, but extends from the coast of Siberia from Northern Land to the New Siberian Islands. The southern part of the Northwest Passage is now ice free. The forecasted extent of ice cover in the second half of the 21st century indicates a sharp decline the ice surface and limitation of its occurrence to the area between the northern coasts of Greenland and Ellsmere Island and the North Pole. The Northern has Sea Route can offer a vast area from the Asian shores to the North Pole, it is no longer necessary to sail in the shallow shelf zone through the straits between the mainland and New Earth, the Northern Earth and the Novosibirsk Islands.

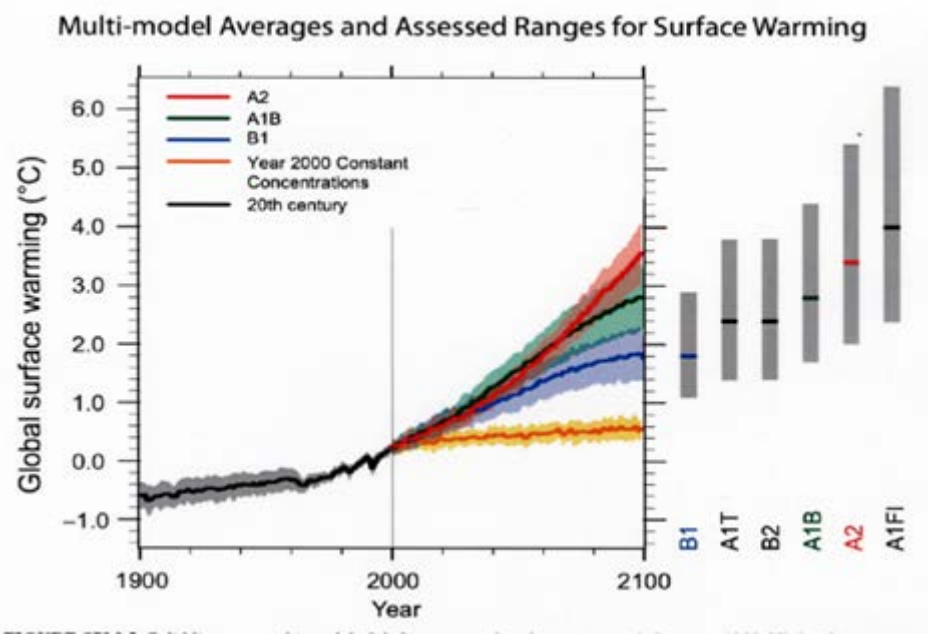

Fig. 12 Earth's Surface temperature rise, selected models

What are the predictions of the Earth's surface temperature rise by 2100?

Temperature rise models are developed based on the analysis of long series of observational data. The figure shows several selected models - from the most optimistic (yellow line) to the most pessimistic (red line).
In the first case, it was assumed that actions leading to the elimination of greenhouse gas emissions, primarily CO_2, proved to be effective and the temperature stopped rising.
The pessimistic model assumes that CO_2 emissions were not successfully reduced. In this case, the surface temperature of the Earth will rise by 2100 by more than 4^0C.

To what extent does vessel movement in the Arctic Ocean cause adverse environmental changes (accelerated melting of the ice cover)?

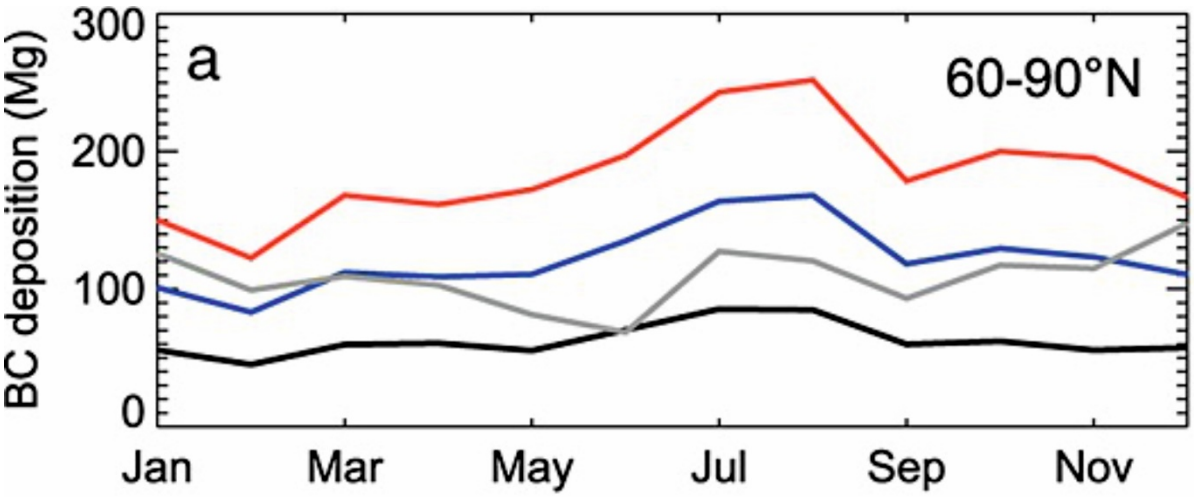

Fig. 13 Comparison of the amount of carbon emissions in 2004 and the anticipated emissions for the medium and intensive development of Arctic shipping (Browse et al. 2013)

How to read the chart above?

- **black line** – arctic shipping in 2004;
- **blue line** – arctic shipping in 2050, assuming minor changes compared to the current state and taking into account environmental protection requirements;
- **red line** – arctic shipping in 2050, assuming a significant increase in shipping intensity.

How do different forms of carbon affect temperature changes?

Soot is carbon in the form of black dust, settling on the ground surface. It influences albedo, so that less sunlight is reflected by the surface. Increased absorption of solar radiation increases temperature, which leads to accelerated melting of snow and ice.

Carbon dioxide (CO_2) is one of the greenhouse gases. The increase in CO_2 concentration in the atmosphere causes an increase in the amount of heat retained at the Earth's surface, and thus, an increase in the temperature.

Open water routes in the Arctic

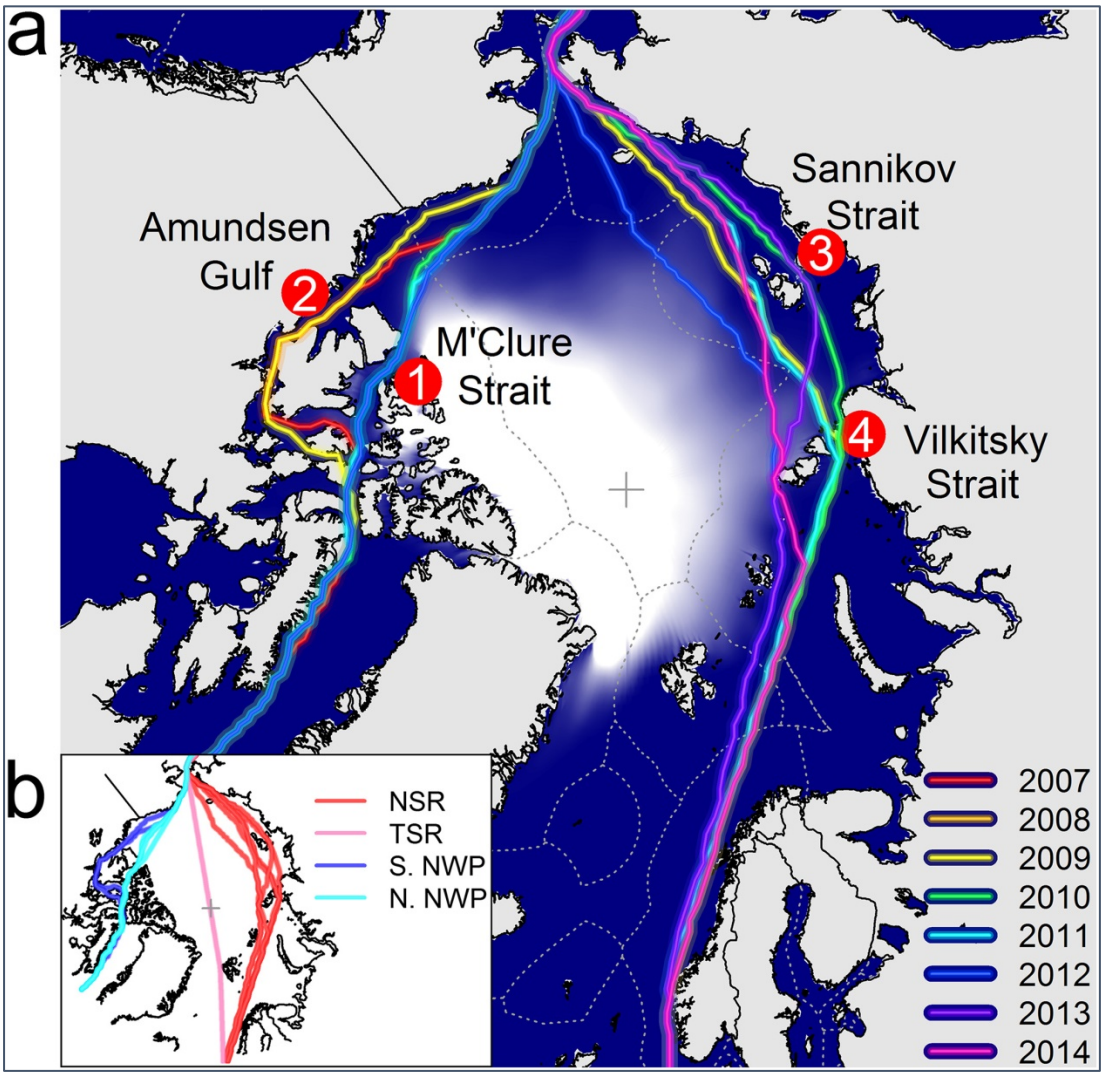

Fig. 14 a) Hypothetical routes of the open sea in September 2007 - 2014; b) Major shipping routes in the Arctic Ocean. (Melia et al. 2016)

The figure shows the hypothetical routes of the open sea in September, between the years 2007 - 2014. The analysis refers to September, which is the month with the most favorable conditions for navigation in the Arctic. This is the period between the summer melting of the ice and the season when it freezes again. Possible variants of shipping routes depend on the current ice situation. For the Northwest Passage (NWP) it is: Mc'Clure Strait (marked with number 1) - the shortest, northern road within NWP, Amundsen Strait (No. 2.) - the longest road within NWP. For the Northeast Passage (NEP) it is: the Sannikov Strait (No. 3.) and the Vilkitsky Strait (No. 4.) – both more shallow and covered with ice for a longer period than the routes, north of Severnaya Zemlya and the Novosibirsk Islands.

The colours of lines indicate the years in which subsequent sea routes were opening. It can be concluded that more routes closes to the North Pole become available for shipping.

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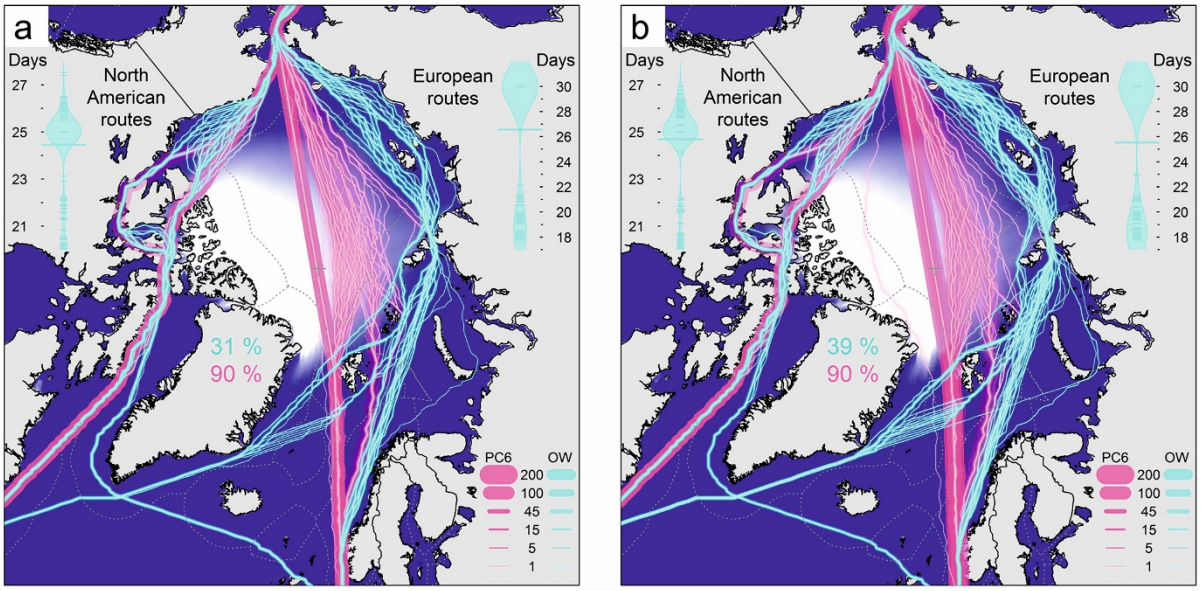
What is the future of shipping routes in the Arctic?

The charts (Fig. 15 - below) present shipping routes in 3 time intervals for two different RCP (representative concentration pathways) climate models: RCP2.6 and RCP8.5. The first one (more optimistic) assumes an increase in temperature from pre-industrial period up until 2100 by 1.6^0 C, while the second one (more pessimistic) - by 4.3^0 C.

Shipping routes in the years 2015-2030

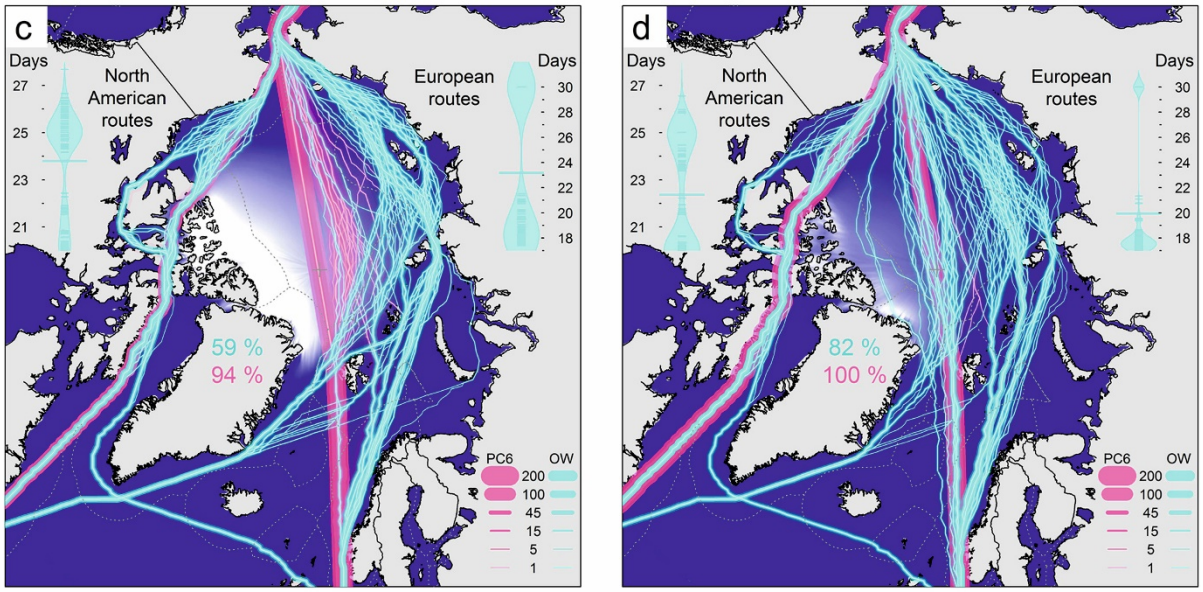
according to the optimistic (RCP2.6) and pessimistic (RCP8.5) climate models

RCP2.6 RCP8.5



Shipping routes in the years 2015 - 2065

according to the optimistic (RCP2.6) and pessimistic (RCP8.5) climate models



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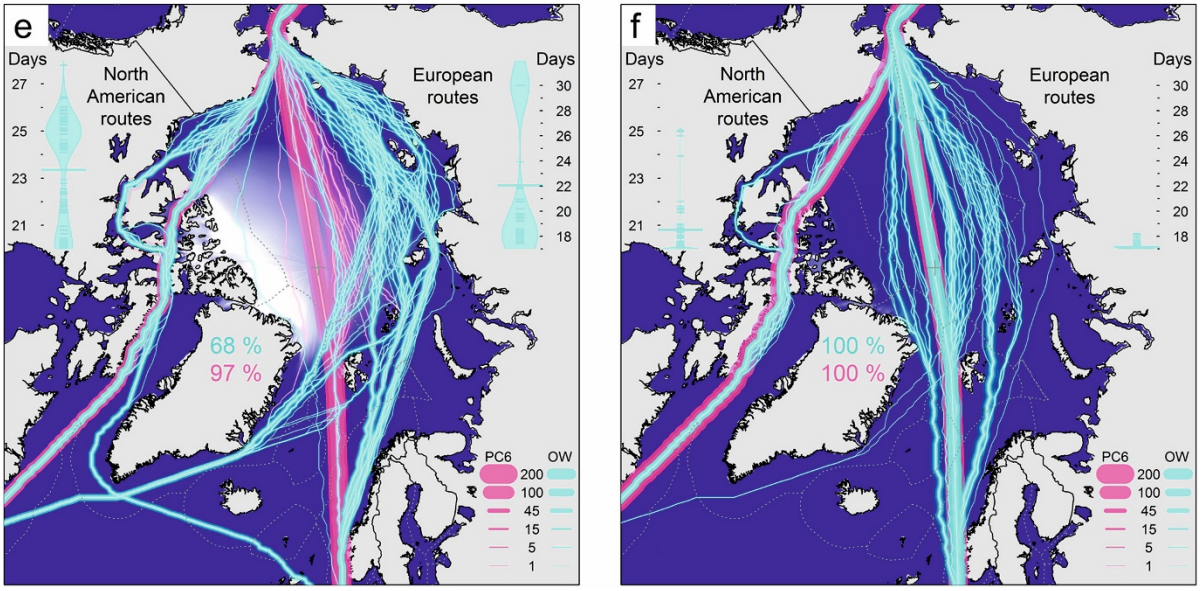
Shipping routes in the years 2075-2090

according to the optimistic (RCP2.6) and pessimistic (RCP8.5) climate models



Transarctic shipping routes, available in September in selected years

Transarctic shipping routes have been generated in the above chart. **Blue lines** indicate routes available for normal ships without ice reinforcements, **purple lines** correspond to ships of the highest ice class PC 6. The width of the line indicates the number of possible passes of a given route in a month. The dashed gray lines show the borders of the current exclusive economic zones belonging to the Arctic states.
The numbers in Greenland's outline indicate the likelihood that ships of the class shown in colour (blue or purple) will cross the route.

STORY CARD 1

Polish episode on the Northern Sea Route

In 1956, Polish shipyards produced 7 ships for the People's Republic of China - three coal carriers with a load capacity of 5,000 tonnes and 4 small general cargo ships. These vessels and cargo were decided to be sent by the Northern Sea Route.

In July, ships were included in the Soviet convoy led by the Sibiriakov icebreaker. Assisted by three more icebreakers, the convoy reached the East Siberian Sea, 500 more nautical miles and they would have reached the Bering Strait. A storm from the east closed the way and threatened the safety of ships. Poles rejected wintering in the ice and the ships returned to the Baltic Sea in October 1956.

Over the next year, they reached their destination, this time however using the route around the Cape of Good Hope.

The impact of Arctic shipping on flora and fauna

STORY CARD 2

Exxon Valdez tanker: the oil spill disaster

In 1989, the Exxon Valdes tanker disaster took place off the coast of Alaska. Despite a rescue operation costing over $ 2 billion, 1900 km of the coast was contaminated, 250,000 seagulls and other birds killed, as well as 5,000 seals, 2,800 sea otters, 22 orcas and 247 American bald eagles. The company has paid more than $ 500 million in damages to residents of Alaska affected by the disaster (fishermen, crab hunters).

(FULL STORY: https://www.marineinsight.com/maritime-history/the-complete-story-of-the-exxon-valdez-oil-spill//

INFO CARD 4

Impact of the intensification of shipping port on Arctic flora and fauna

Arctic marine mammals are often considered to be the most vulnerable to rapid environmental changes in the region and therefore as sentinel species against the effects of climate change. Although the ecosystem's response to shrinking ice and increasing temperatures is already there, the impact of shipping has only now emerged as a new threat that needs to be investigated. There are several risk factors: walruses, beluga whales, humpback whales and narwhals are often exposed to fatal collisions with ship propellers. In the event of oil spills, sea birds, polar bears and young seals are exposed: if oil gets into their feathers or fur, they quickly die of hypothermia. At the same time, with the greater intensity of maritime transport, the level of anthropogenic noise in the marine environment increases. Whales, as well as walruses and seals, will have difficulty communicating, feeding and avoiding predators as a result of increasing engine noises. For species that have an orientation in underwater space due to the advanced evolution of the echolocation system (whales), the strong intensity of external noise can cause significant behavioral problems. Sources of underwater noise are usually engines of vessels, the work of underwater hydrotechnical devices (drilling rigs, dredgers, pile drivers), sonars and fishfinders. The most radical effect of explosions is the immediate death of animals, at a further distance or at lower noise levels, they are threatened by damage to the senses, resulting in disturbances in the echolocation system (also often with delayed lethal effect), causing navigation errors and making feeding difficult. This can be particularly dangerous when it occurs in waters of particular importance for the life cycle, e.g. in breeding grounds, feeding grounds or migration routes. The affected animals flee from places assigned to them by nature. They must stay in others that do not fully meet their life needs. This can have a negative effect on reproductive processes by disturbing mating behavior. Male humpback whales are famous for

songs that carry hundreds of kilometers in dense sea water. They may be “love songs”, but scientists are not sure of their nature. Now it turns out that the noise of ships discourages whales from singing.

The threat also applies to the entire ecosystems. The danger of introducing invasive species along with ballast water, cargo or on ship hulls is particularly serious.

The problem of introducing foreign organisms into inland and sea waters has been known for many years. Invasive species - organisms living in one port that adhere to the hulls or are pumped into ballast water tanks - and get to the destination port, where they can find themselves well and create a lot of confusion in the local ecosystem (bringing diseases or pushing native species out of their niches) .

Preparation for the debate

After reading the materials presented, you can proceed to directly prepare the arguments for the debate. Below are a number of questions. Answers to them can be good arguments for discussion. Some of them strongly support the thesis, others will help in refuting it. Some arguments are debatable and can be used by both sides.

Task.

Answer the following questions. Write answers that are also arguments for discussion in the appropriate place in the table (Worksheet No. 1).

Question card 1	**Question card 2**
The sea route from Rotterdam to Tokyo is currently 2,300 NM (via the Panama Canal) or 2,200 NM (via the Suez Canal). Would opening the Northwest Passage shorten this route?	Will the use of the Northeast Passage reduce the distance between European and Asian ports?
Question card 3	**Question card 4**
Would shortening the route by using the sea routes in the Arctic reduce fuel consumption and thus have a positive impact on the environment?	Are there any restrictions on the size of passing vessels in the Suez and Panama Canal?
Question card 5	**Question card 6**
What are the economic effects of shortening shipping routes?	How could the development of the Northwest and Northeast Passage coast affect the development of shipping?
Question card 7	**Question card 8**
For how long is sailing in the Arctic possible during the year?	What are the trends in changing the duration of the Arctic shipping season?

Question card 9	Question card 10
How can the unpredictability of the Arctic ice conditions affect the reliability and due dates of deliveries?	What are the additional costs associated with selecting Arctic transport routes?
Question card 11	**Question card 12**
What could be the impact of shipping growth on permafrost? What are the possible consequences?	Do all ships in the Arctic use conventional fuel?
Question card 13	**Question card 14**
What can be the impact of marine catastrophes on polar ecosystems?	Can shipping in the Arctic contribute to geopolitical conflicts?
Question card 15	**Question card 16**
What impact does shipping have on whales?	Can sea transport in the Arctic contribute to changes in ecosystems?

Division into PROPOSITION and OPPOSITION teams

Task.

You already have arguments that you can use during the discussion. At this stage, you will prepare yourself directly to formulate the argument in accordance with the assigned role and to justify and defend them. Try to predict which counterarguments the opponents will use and prepare your answer. In order to do this, use worksheet No. 2.

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SEA TRANSPORT IN THE ARCTIC

SEP:
TENTRIO:
NALIVM
Terrarum de:
scriptio.
Per
Gerardum Mercatorem
Cum Privilegio
Frisland insula
Farre insulæ
Scotland insulæ
California regio
Agama
Anian regnum
Bergi regio
Circulus Arcticus
Vng quæ a nostris Gog dicitur
Desertum de Belgian arenosum
ASIAE PARS
Naiam
Stingui
Bargu
Ciorza
Cauona
OCEANUS SCYTHICUS qui et Mare Tabin
Molgomzaia
Samogedi
POLUS ARCTICUS
NOVA ZEMBLA
PETZORKE MARE
MYRMANSKOI MARE
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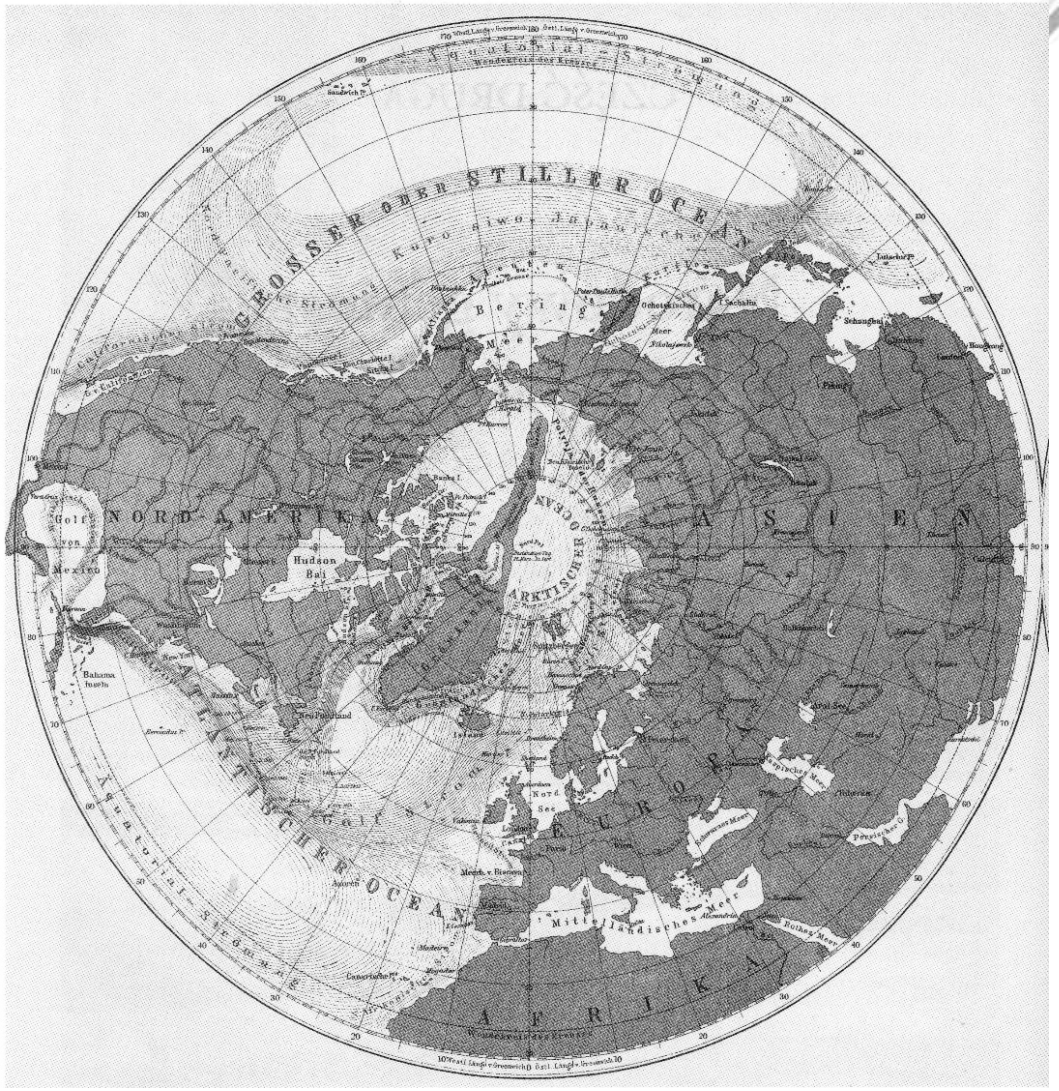
GROSSER ODER STILLER OCEAN
NORD-AMERIKA
ASIEN
EUROPA
AFRIKA
Golf von Mexico
Hudson Bai
ARKTISCHER OCEAN
ATLANTISCHER OCEAN
Mittelländisches Meer

RUSSIA
Arctic Circle
CLIMATOLOGICAL LIMIT OF ARCTIC (50 °F ISOTHERM, JULY)
Sea of Okhotsk
Verkhoyansk
Nordvik-Ungol'naya
Novaya Zemlya
St. Petersburg
BELARUS
Murmansk
FINLAND
Severnaya Zemlya
Barents Sea
SWEDEN
New Siberian Is.
Franz Josef Land
NORWAY
ARCTIC
Svalbard
Wrangel I.
NORTH POLE
Bering Sea
OCEAN
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ICELAND
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Prince Patrick I.
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Dundas
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Devon I.
Uummannaq
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Great Bear Lake
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Yellowknife
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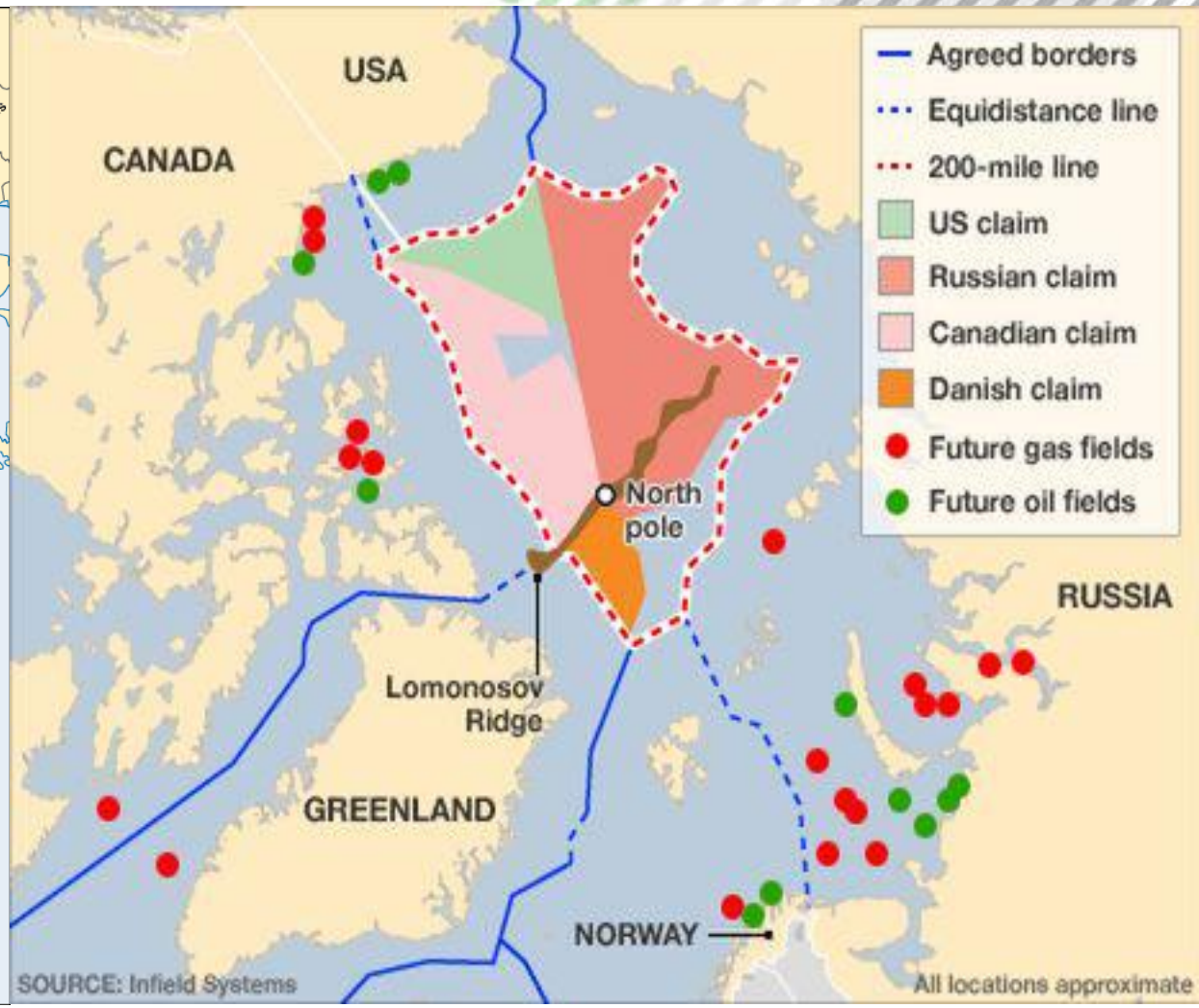
USA
CANADA
Agreed borders
Equidistance line
200-mile line
US claim
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Canadian claim
Danish claim
Future gas fields
Future oil fields
North pole
Lomonosov Ridge
RUSSIA
GREENLAND
NORWAY
SOURCE: Infield Systems
All locations approximate

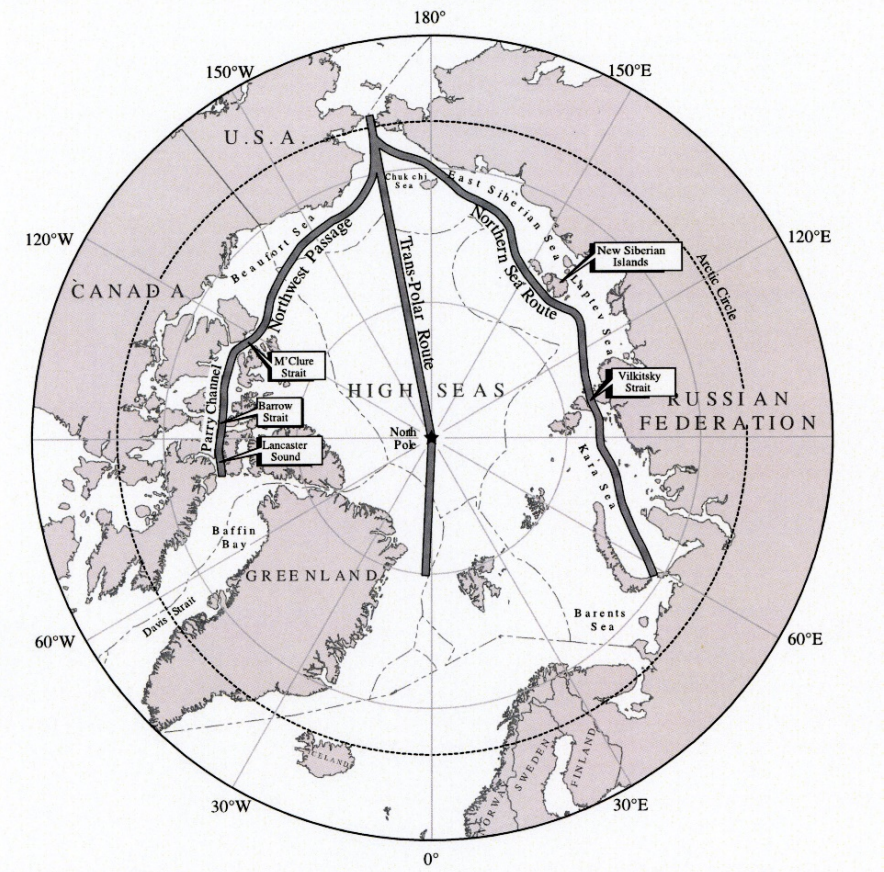
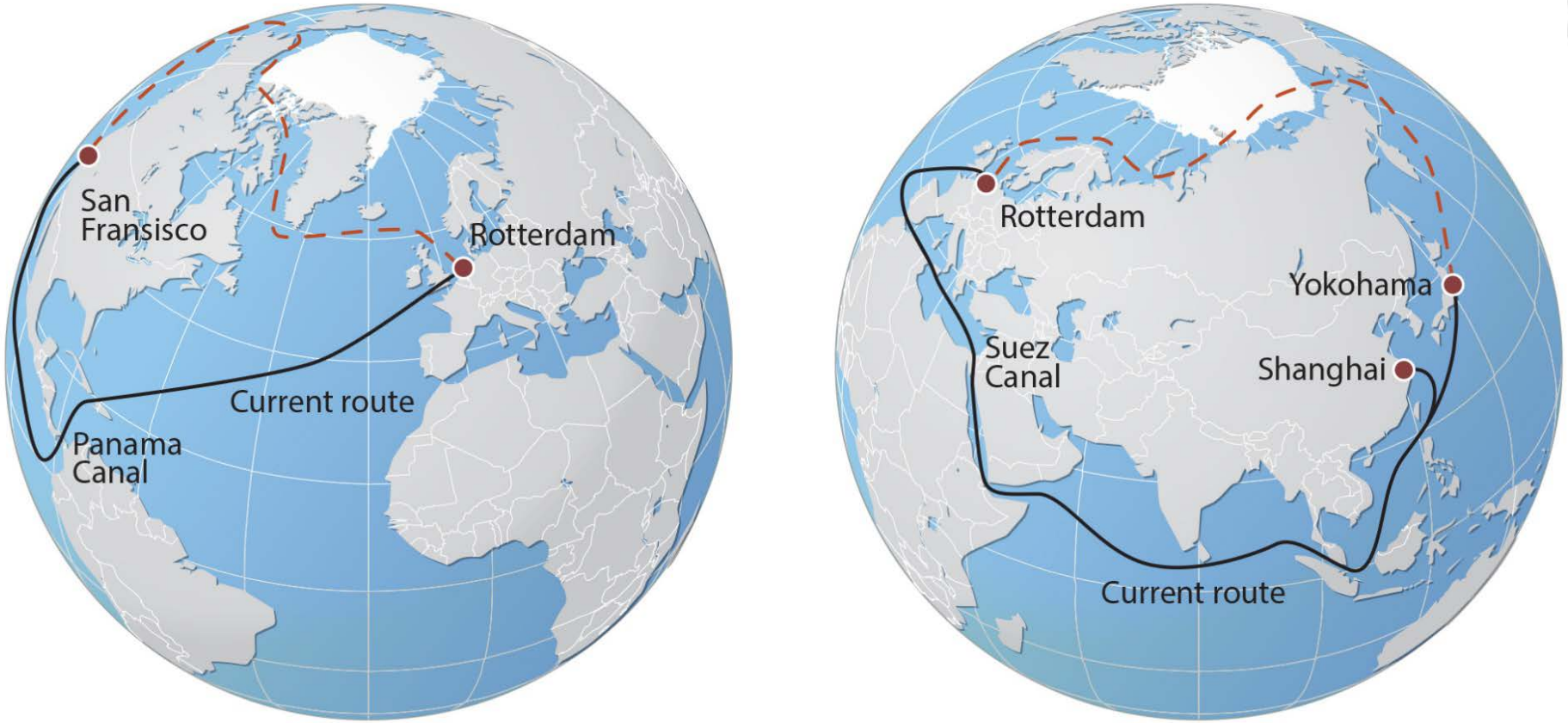


Figure 1. The NSR, The NEP, and Trans-Polar Route (adapted from Stephenson *et al.* 2013b).

Arctic Ocean shipping routes: NWP – Northwest Passage, NEP- Northeast Passage, TPR Transpolar Route; Farre A.B et al. 2014



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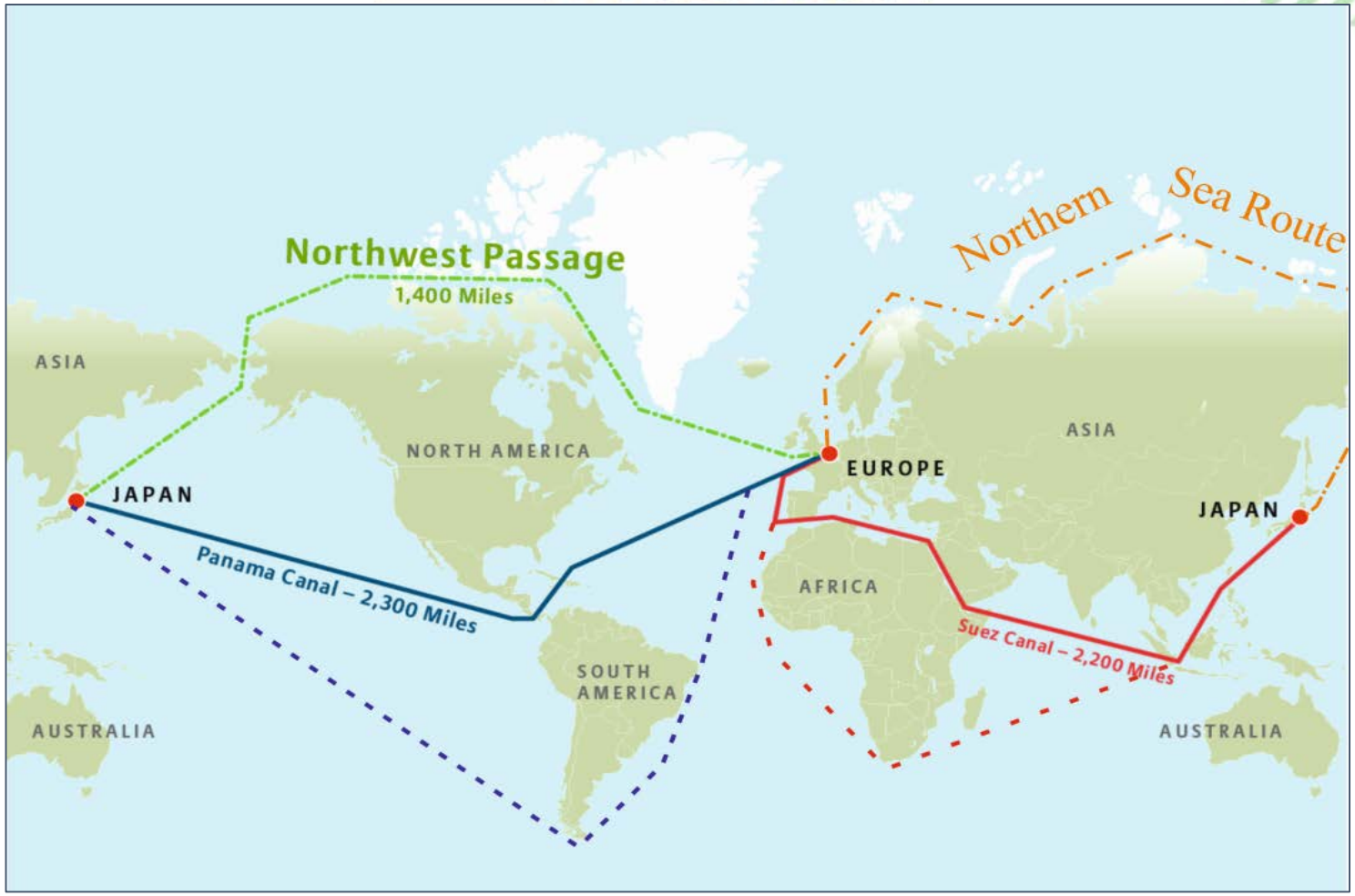
Comparison of traditional shipping routes from European ports to those on the Pacific Ocean with roads leading through the Arctic Ocean, *(AMAP, https://www.amap.no/)*

Beaufort Sea
Fort Ross
Bellot Strait
Pond Inlet
Greenland
Cambridge Bay
Tuktoyaktuk
Alaska (US)
Gjoa Haven
ARCTIC CIRCLE
Nome
Nuuk
CANADA
Labrador Sea

Years	Number of vessels, divided by type				
	Expedition vessels	icebreaker	Cargo and passenger ships	yachts	TOTAL
1900 – 1909	1				1
1910 – 1919					0
1920 – 1929					0
1930 – 1939					0
1940 – 1949	2				2
1950 – 1959		2	2		4
1960 – 1969		5			5
1970 – 1979	3	6		1	10
1980 – 1989	1	6	5	5	17
1990 – 1999		13	11		24
2000 – 2009		17	9	48	76
2010 – 2018	4	3	23	108	138

List of vessels that crossed the Northwest Passage
(Based on: Headland et al. 2018.)



Comparison of existing routes from Europe to Japan with NWP

	Cruise duration [h]/[24h]	Fue consumption [t/24 h]	Fuel consumption in tota [t]	Cost of fuel [EUR]	Type of fuel, emission factor/ total emission of carbon dioxide during the cruise		
					H F O 3,114g/g	M D O 3,206 g/g	LNG 2,75 g/g
Panama Canal	1111,35	38	1759,4	560 739,3	5478,8 T	5640,64 t	4838,35 t
	46,3						
Suez Canal	856,4		1345,2	456 584,7	4188,95 T	4312,71 t	3699,3 t
	35,7						
Northern Sea Route	539		855,0	272 497,5	2662,47 T	2741,13 t	2351,25 t
	22,5						

Comparison of travel duration, fuel consumption and CO2 emissions for different routes taken by PANAMAX vessel
Based on: Biernacki D 2017; Klopott M. 2016

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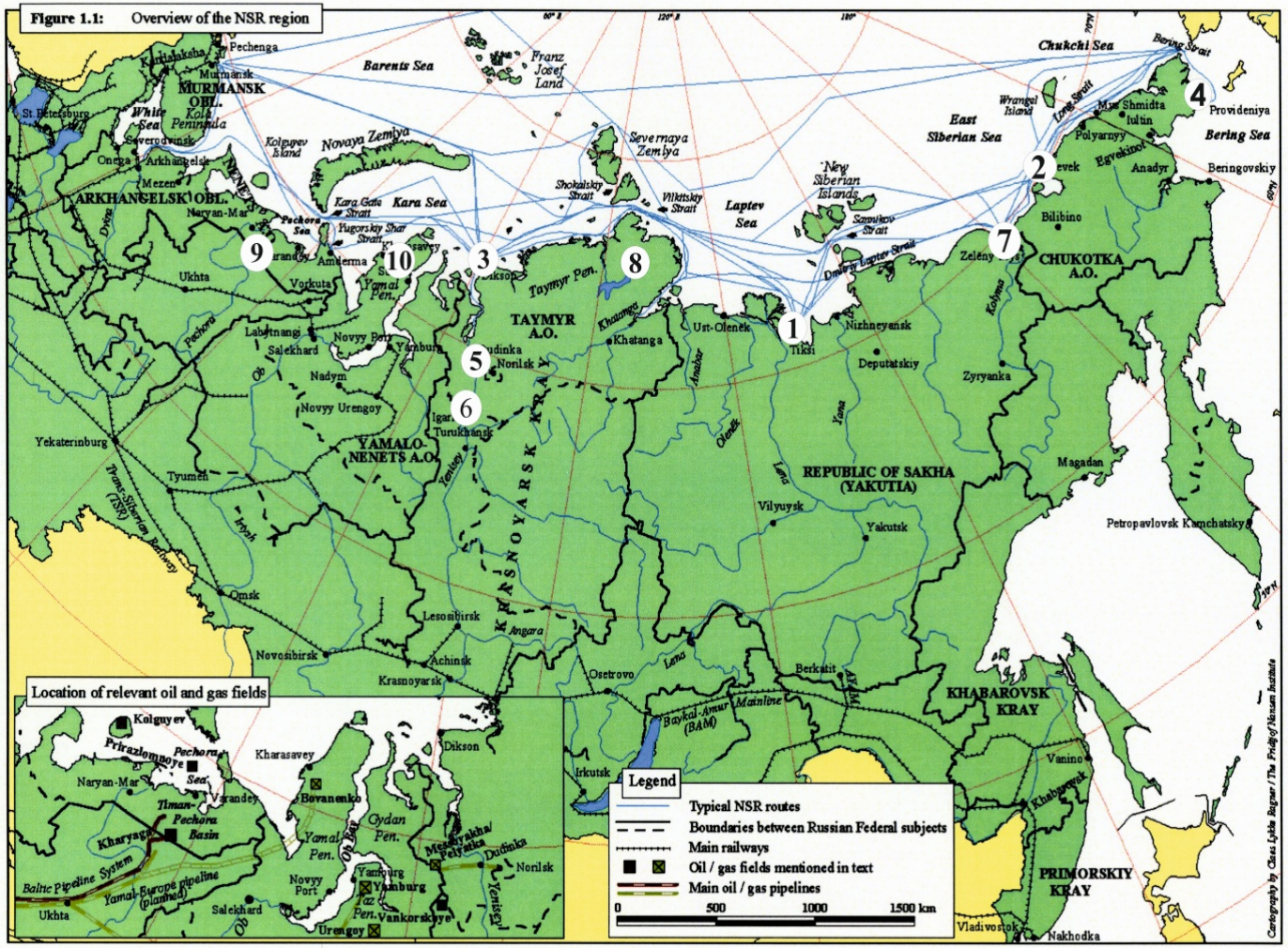


Main ports :

1.Tiksi - sea port available for 3 months a year, airport, approx. 6,000 residents.

2. Pevek - city and port on the East Siberian Sea, approx. 4,500 residents, airport, tin ore mining center.

3. Dikson – city and seaport of the Kara Sea.

4. Provideniya Bay- seaport over Bering Sea, approx. 2,800 inhabitants**.**

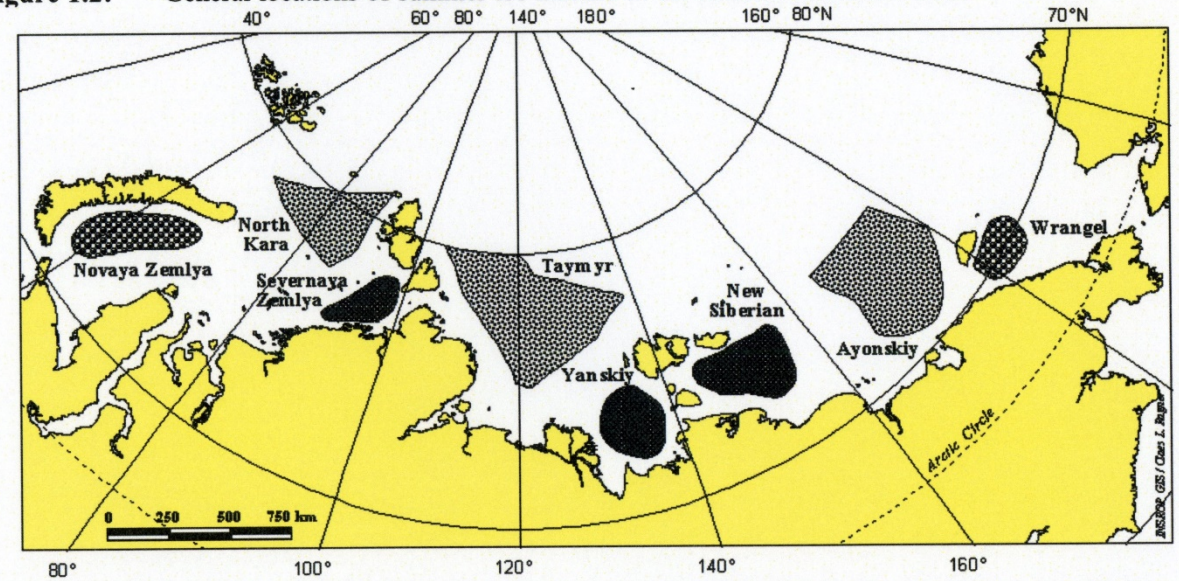
5. Dudinka – city, port and airport (44km) in the lower reaches of Yenisei river, approx. 25,000 inhabitants, land connection - road and electrified railway line connecting the sea port with Norilsk located at a distance of 96 km.

6. Igarka – port on the Yenisei river, accessible to seagoing ships, about 8,000 inhabitants, developed wood industry.

7. Ambarchik – marina on the Northern Sea Road near the estuary of Kolyma river.

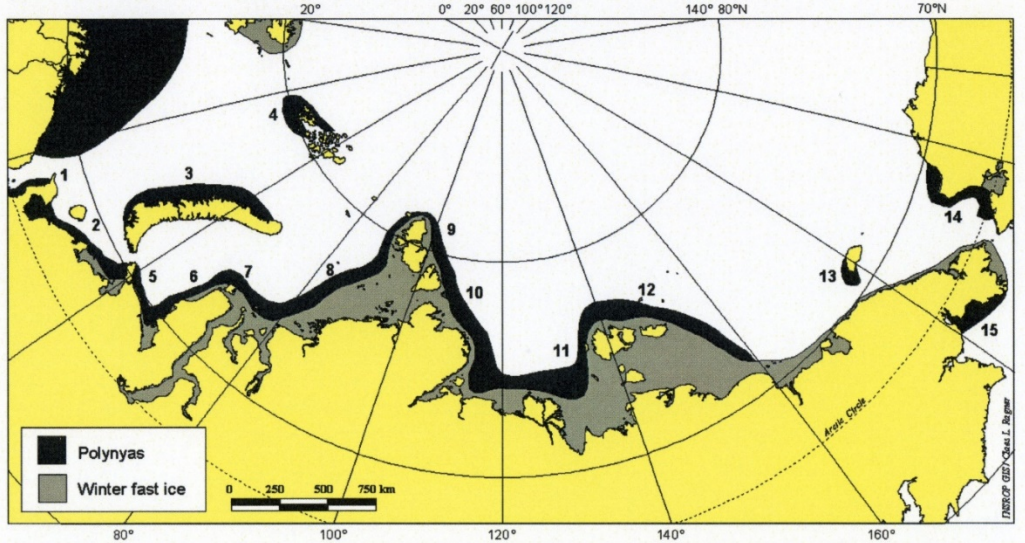
8. Taymyr, 9. Timan, 10. Jamal - oil and gas extraction centers

Figure 1.2: General locations of summer ice massifs in the Russian maritime Arctic[14].



Noted are three types of summer ice massifs: Multiyear ice from the Arctic Ocean (North Kara, Taymyr and Ayonskiy); local drift ice (Novaya Zemlya and Wrangel); and, fast ice remnants (Severnaya Zemlya, Yanskiy and New Siberian).

Figure 1.3: Regions of winter fast ice and *polynyas* in the Russian Maritime Arctic[15].



Polynyas: 1 – Cheshskaya, 2 – Pechora, 3- West Novaya Zemlya, 4 – Victoria Sea, 5 – Amderma, 6 – Yamal, 7 – Ob-Yenisey, 8 – West Severnaya Zemlya, 9 – East Severnaya Zemlya, 10 – Taymyr, 11 – Lena, 12 – New Siberian, 13 – Wrangel, 14 – Alaska, 15 - Anadyr

Сравнение основных показателей Северного Морского Пути и текущего маршрута

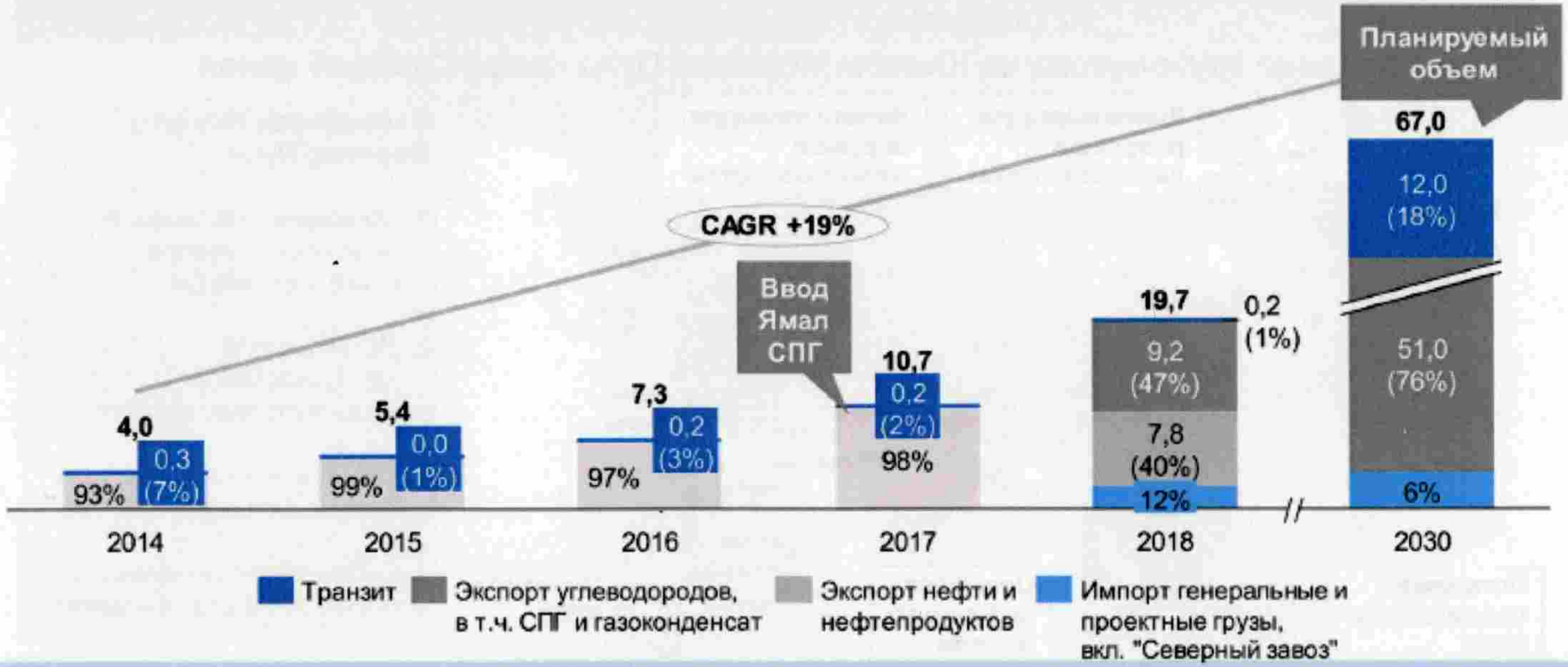
Показатель	Маршрут, вкл. СМП		ЮМП
	Июль-Ноябрь	Декабрь-Июнь	Текущие круглогодичные
Расстояние, морские мили	8 046	8 046	10 557
Средняя скорость судна, узлов	18	9	17
Средний расход топлива, тонн/сутки	113	39	97
Среднее время доставки	19-21	30-32	25-28

IX МЕЖДУНАРОДНЫЙ ФОРУМ 5–7 декабря 2019 года, Санкт-Петербург

АРКТИКА: НАСТОЯЩЕЕ И БУДУЩЕЕ

АРКТИКА НАСТОЯЩЕЕ И БУДУЩЕЕ

Объем перевозок по Северному Морскому Пути по направлениям, млн тонн



IX МЕЖДУНАРОДНЫЙ ФОРУМ
5–7 декабря 2019 года, Санкт-Петербург
АРКТИКА: НАСТОЯЩЕЕ И БУДУЩЕЕ
АРКТИКА
НАСТОЯЩЕЕ И БУДУЩЕЕ
Северный морской путь. 2024 год. 88,2 млн. тонн
Запад
Лето-Осень
По расписанию
Зима-Весна
По расписанию
СПГ ЛК-1
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СПГ ЛК-2
50 лет Победы
Сибирь
Таймыр
ЛК-60-4
Урал
Вайгач
Восток
Лето-Осень
По расписанию
Зима-Весна
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Мурманск
Певек
Диксон
Сабетта
Тикси
Хатанга
СШХ-2
СШХ-1
Дудинка
Магадан
Перевалка груза с / на суда ледового класса
Завоз грузов для жизнеобеспечения Арктических территорий
Завоз грузов для производственно-бытовых нужд сырьевых компаний
Вывоз рудных грузов Норникеля
Вывоз нефтяных грузов Газпромнефти и ННК
Вывоз СПГ НОВОТЭКа
Вывоз угля Востокуголя и Северной Звезды
Вывоз рудного сырья из Мурманска в направлении АТР
Транзитные грузы по СМП
Импортные грузы по СМП
Грузы с ЖД на СМП
5

IX МЕЖДУНАРОДНЫЙ ФОРУМ
5–7 декабря 2019 года, Санкт-Петербург
АРКТИКА: НАСТОЯЩЕЕ И БУДУЩЕЕ
АРКТИКА
НАСТОЯЩЕЕ И БУДУЩЕЕ
Северный морской путь. 2030 год. 134,9 млн. тонн
Запад
Лето-Осень
По расписанию
Зима-Весна
По расписанию
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СПГ ЛК-4
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Сибирь
Урал
ЛК-60-4
ЛК-60-5
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Лидер-2
Восток
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НАСТОЯЩЕЕ И БУДУЩЕЕ
Северный морской путь. 2035 год. 145,4 млн. тонн
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Лето-Осень
По расписанию
Зима-Весна
По расписанию
СПГ ЛК-1
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СПГ ЛК-3
СПГ ЛК-4
50 лет Победы
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Сибирь
Урал
ЛК-60-4
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Грузы с ЖД на СМП
8

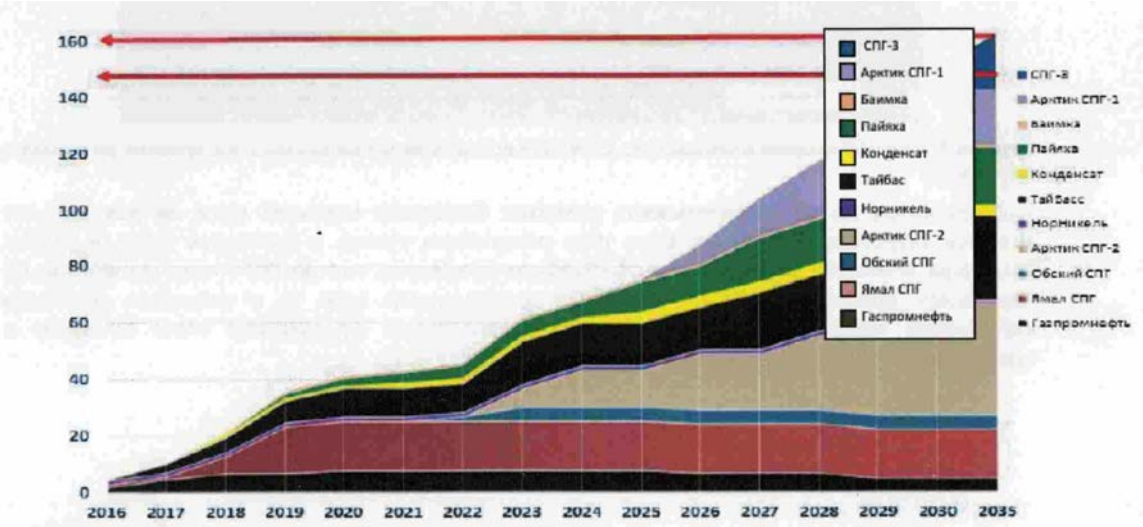


Рисунок 5. Прогноз роста объема грузоперевозок по СМП, млн.т.

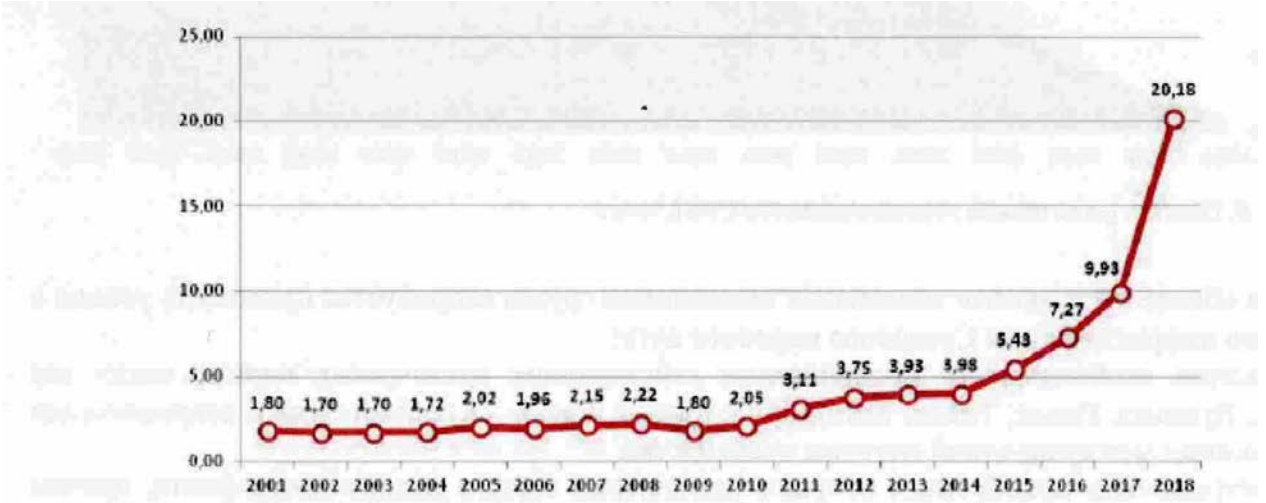
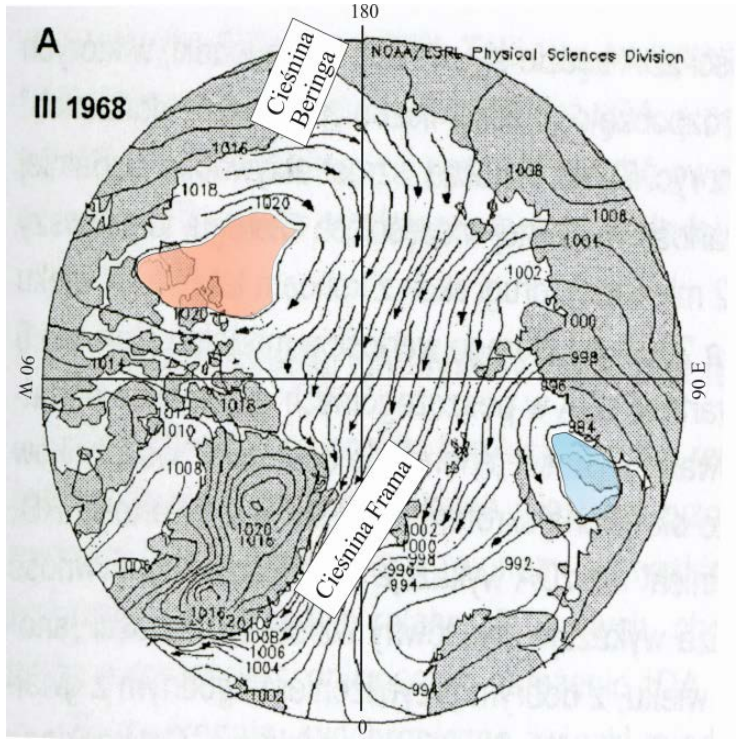


Рисунок 4 Объемы грузоперевозок по СМП, млн.т.


A
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90 W
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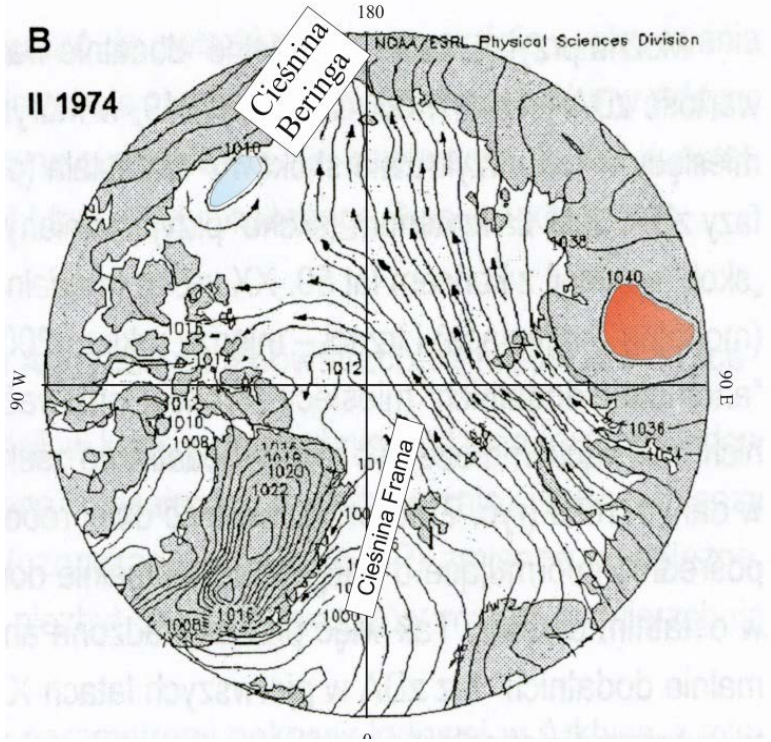
NOAA/ESRL Physical Sciences Division
Cieśnina Beringa
Cieśnina Frama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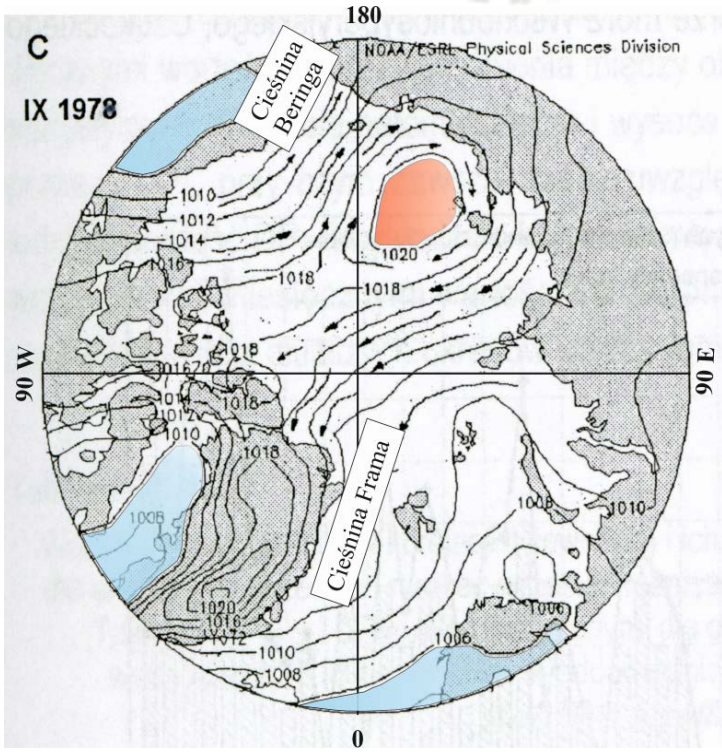
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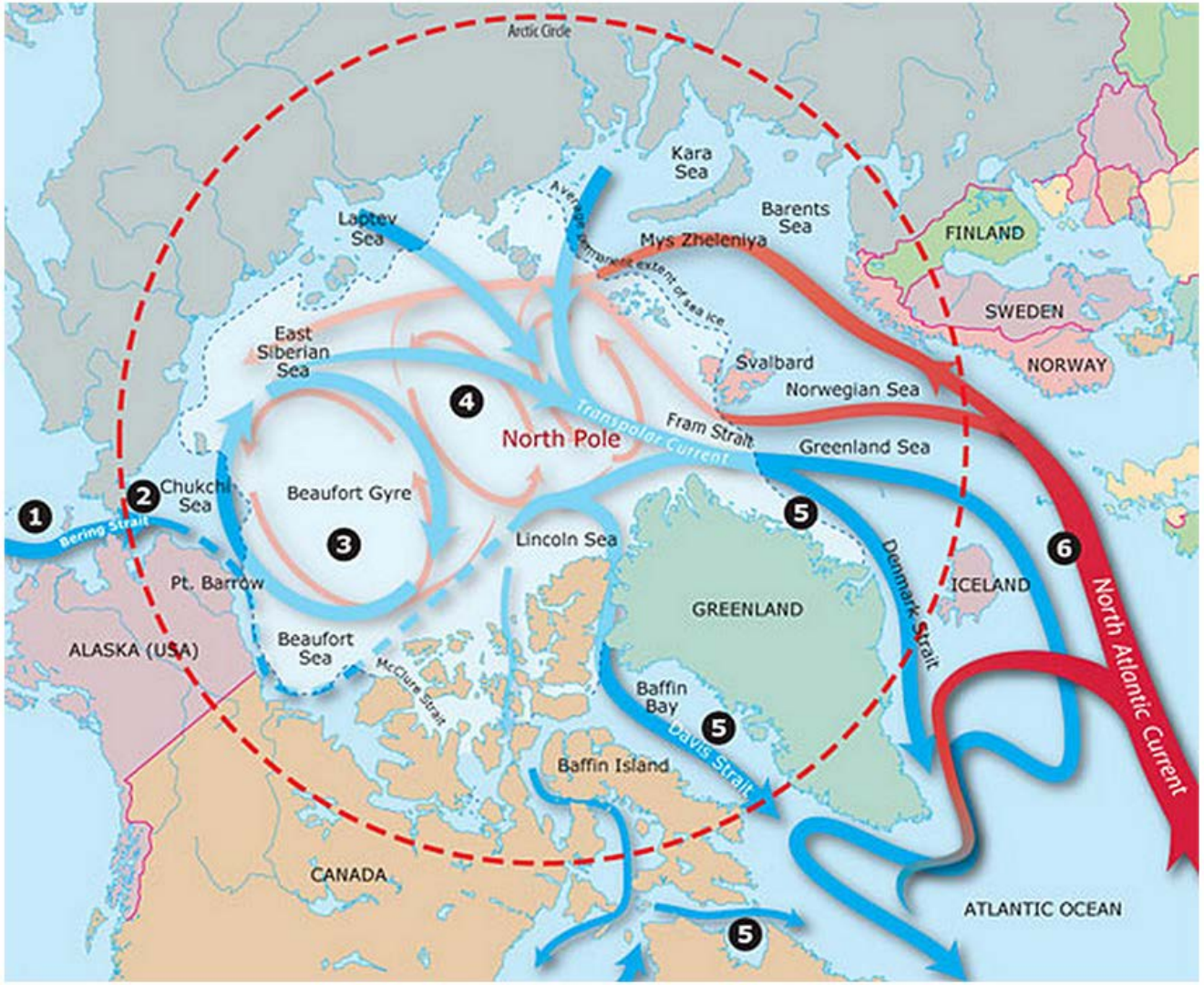
Arctic Circle
Kara Sea
Laptev Sea
Barents Sea
Mys Zheleniya
FINLAND
SWEDEN
NORWAY
East Siberian Sea
Svalbard
Norwegian Sea
North Pole
Transpolar Current
Fram Strait
Greenland Sea
Chukchi Sea
Beaufort Gyre
Bering Strait
Lincoln Sea
Pt. Barrow
GREENLAND
ICELAND
Denmark Strait
North Atlantic Current
ALASKA (USA)
Beaufort Sea
McClure Strait
Baffin Bay
Davis Strait
Baffin Island
CANADA
ATLANTIC OCEAN
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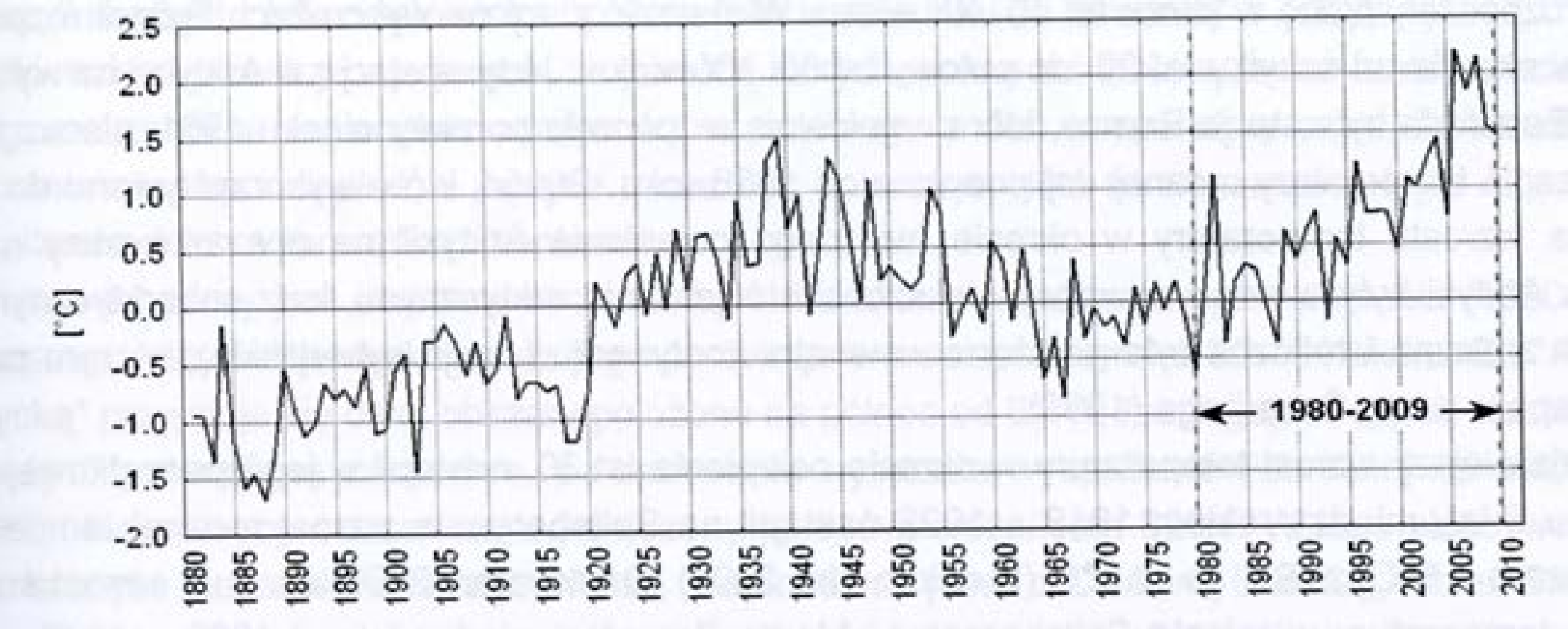
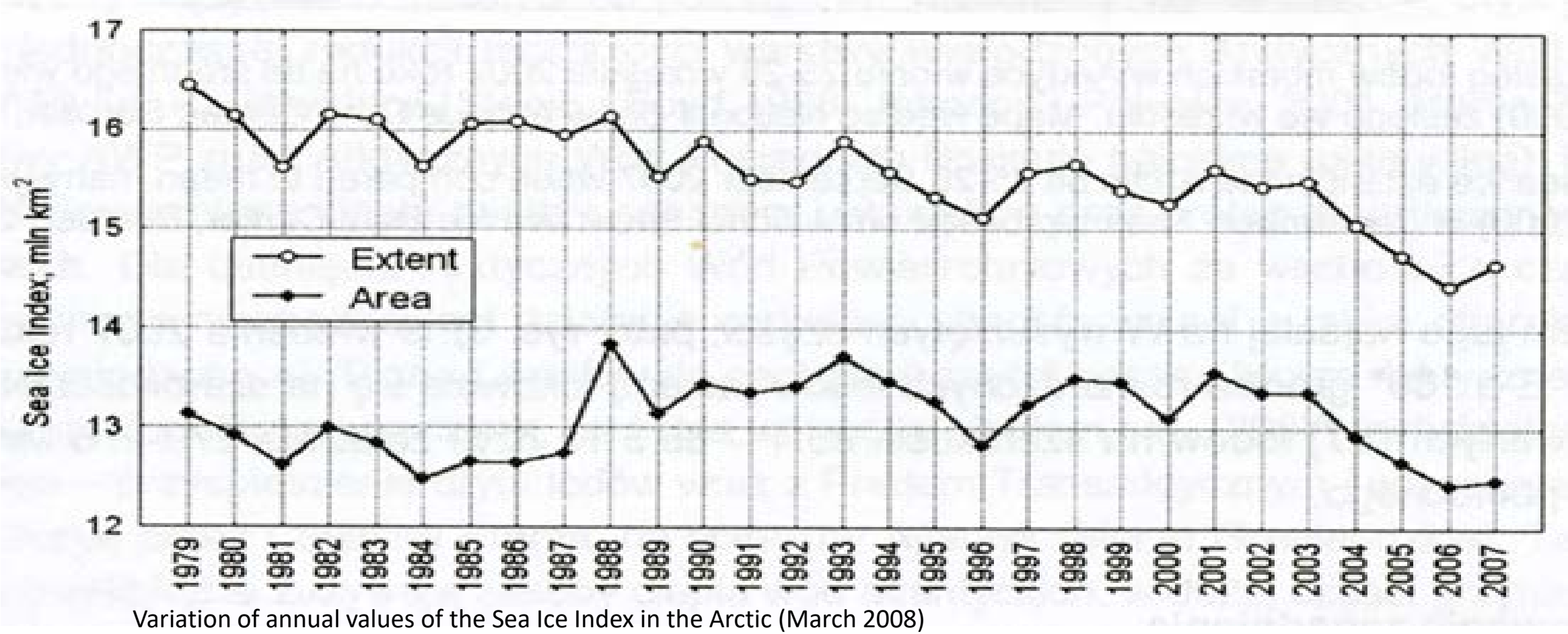


Presentation of annual anomalies of air temperature [Celsius degrees] over the area of 64-90N (the whole Arctic).
Please note the marked period of "modern Arctic warming" (1980-2009) (Marsz, Styszyńska 2011)



Variation of annual values of the Sea Ice Index in the Arctic (March 2008)

- **Extent** - range of sea ice covering more than 15% of the surface
- **Area** - sea ice coverage reduced to 100% coverage (March 2008)

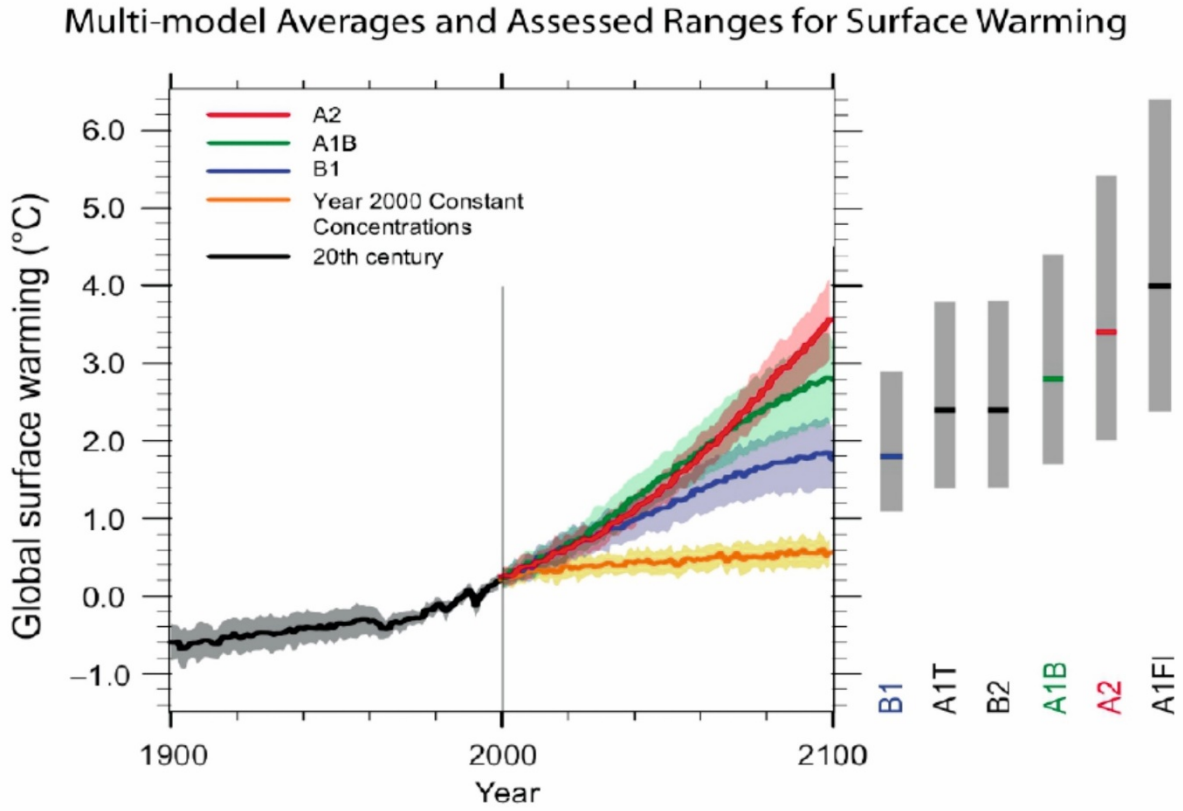
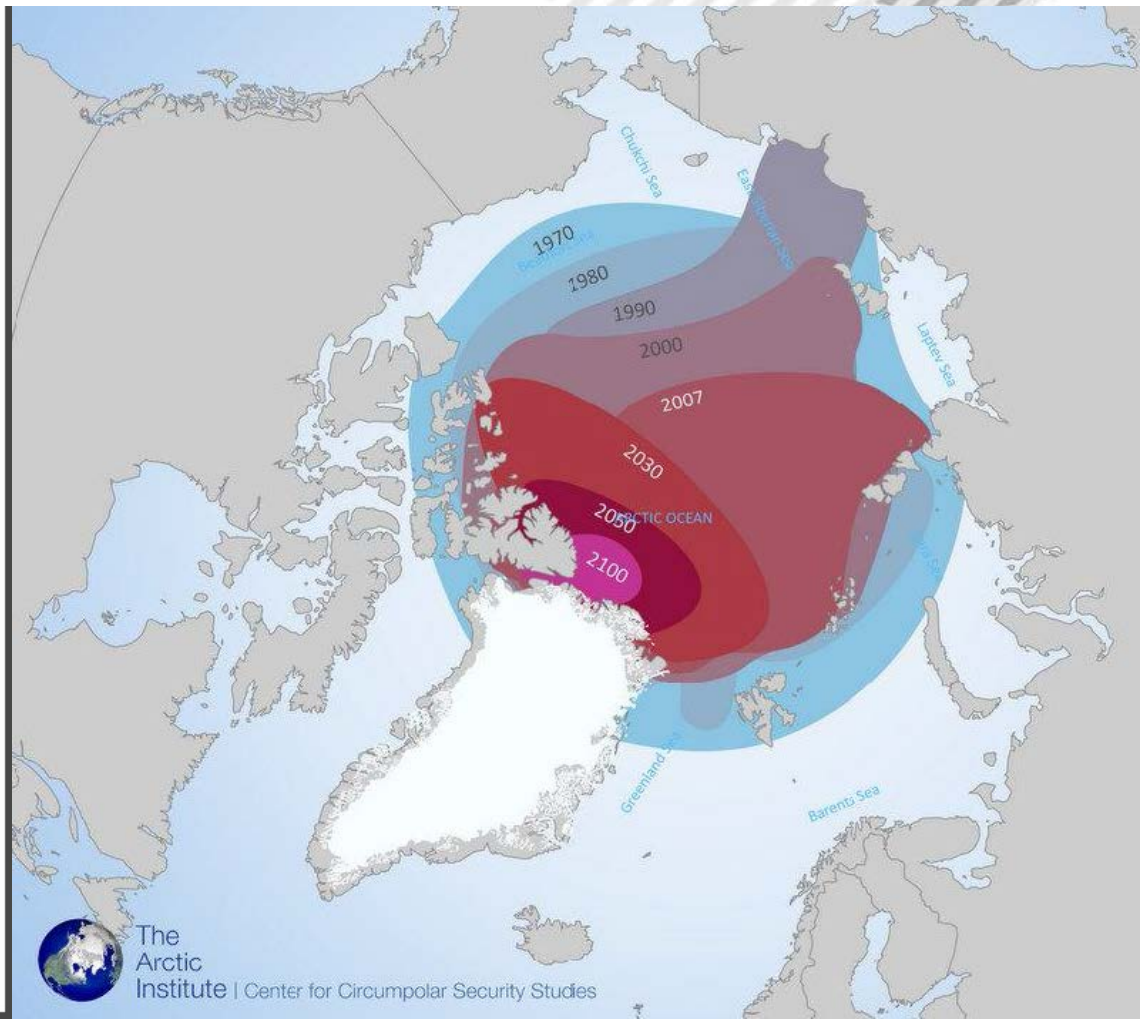


FIGURE SPM-5. Solid lines are multi-model global averages of surface warming (relative to 1980-99) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the plus/minus one standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The gray bars at right indicate the best estimate (solid line within each bar) and the *likely* range assessed for the six SRES marker scenarios. The assessment of the best estimate and *likely* ranges in the gray bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}



Odyssey
Oxford Debates for Youths in Science Education

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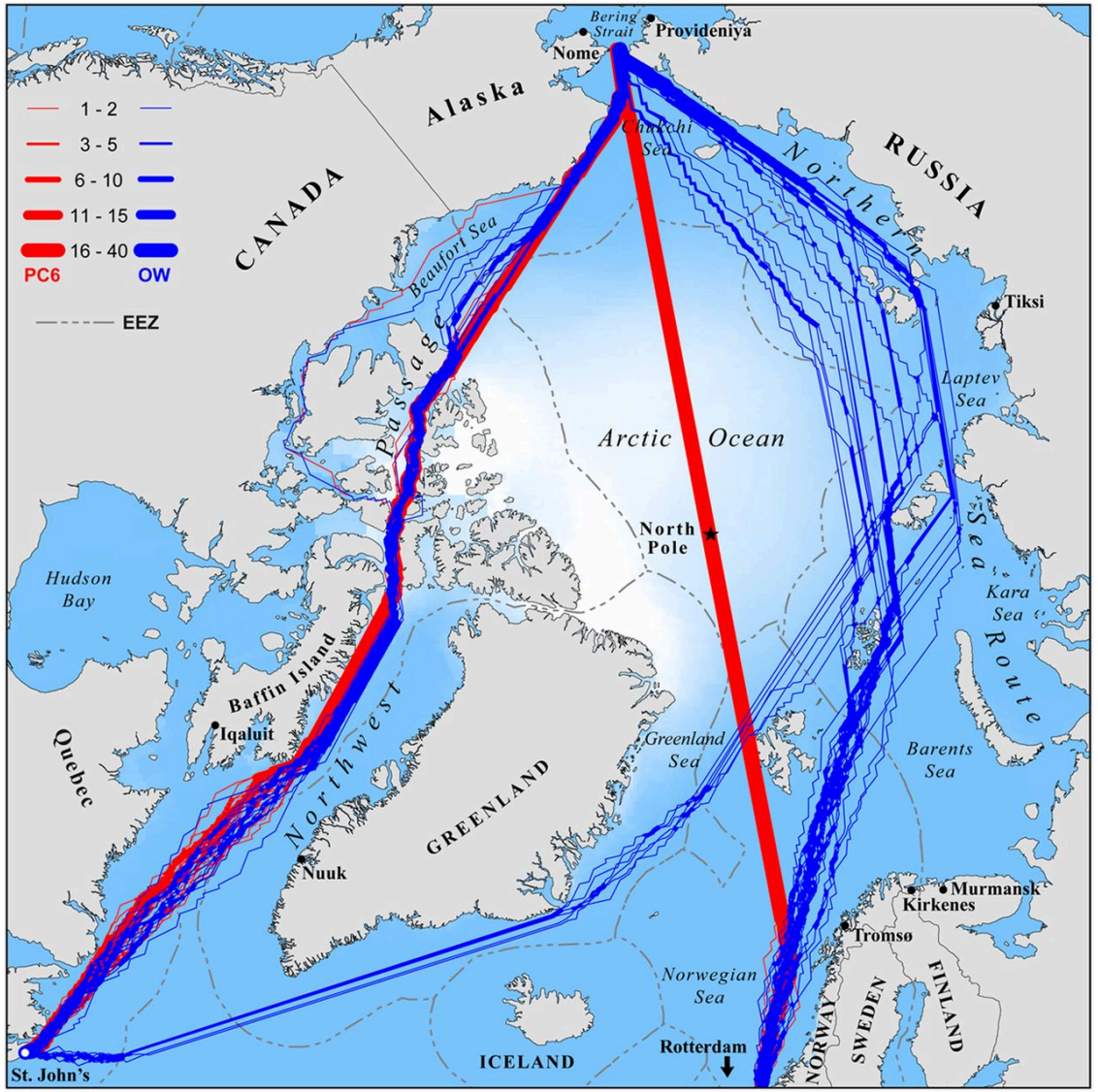


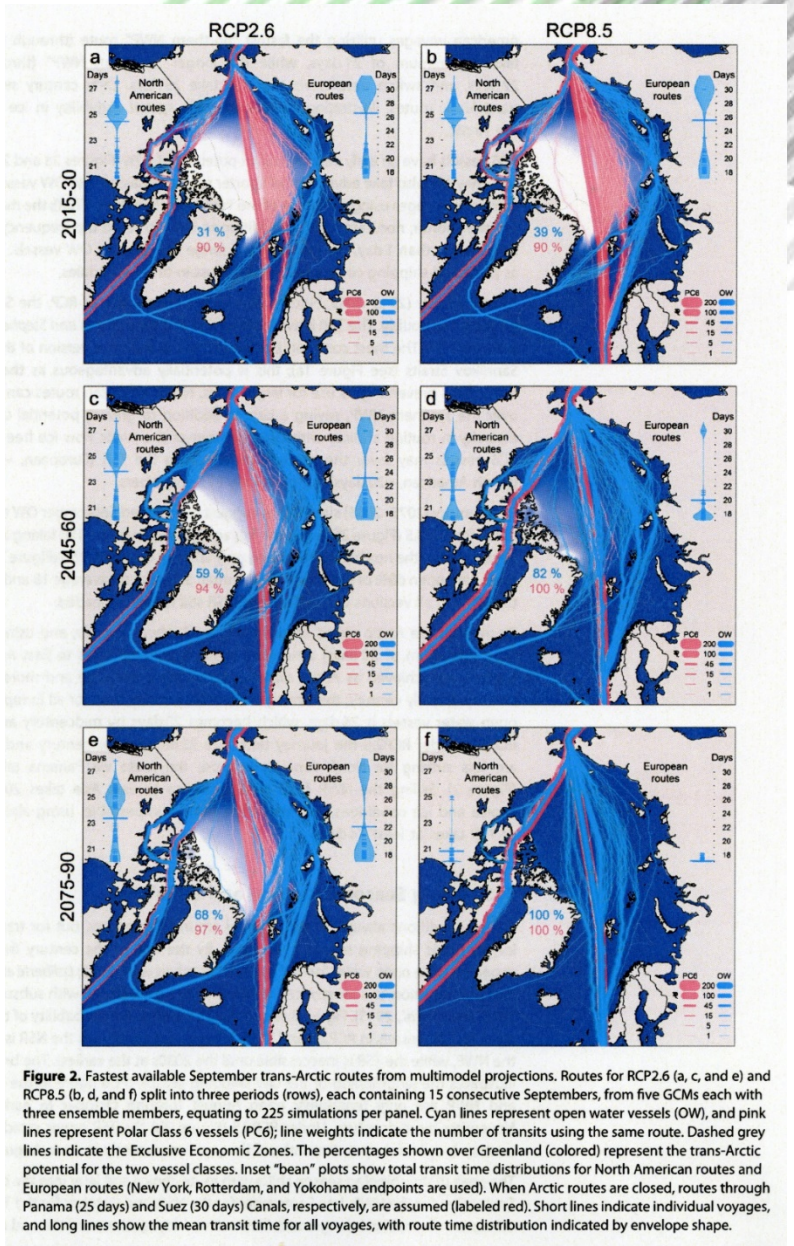


Figure 2. Fastest available September trans-Arctic routes from multimodel projections. Routes for RCP2.6 (a, c, and e) and RCP8.5 (b, d, and f) split into three periods (rows), each containing 15 consecutive Septembers, from five GCMs each with three ensemble members, equating to 225 simulations per panel. Cyan lines represent open water vessels (OW), and pink lines represent Polar Class 6 vessels (PC6); line weights indicate the number of transits using the same route. Dashed grey lines indicate the Exclusive Economic Zones. The percentages shown over Greenland (colored) represent the trans-Arctic potential for the two vessel classes. Inset "bean" plots show total transit time distributions for North American routes and European routes (New York, Rotterdam, and Yokohama endpoints are used). When Arctic routes are closed, routes through Panama (25 days) and Suez (30 days) Canals, respectively, are assumed (labeled red). Short lines indicate individual voyages, and long lines show the mean transit time for all voyages, with route time distribution indicated by envelope shape.

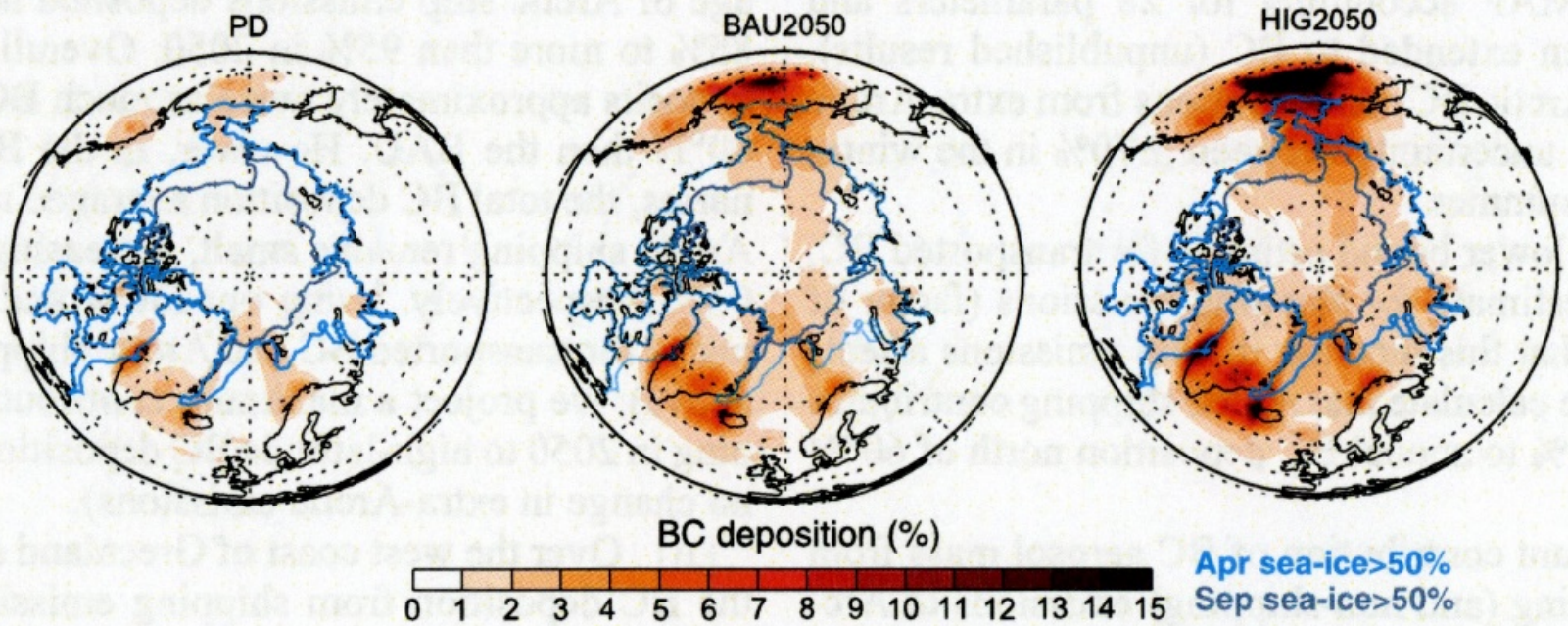
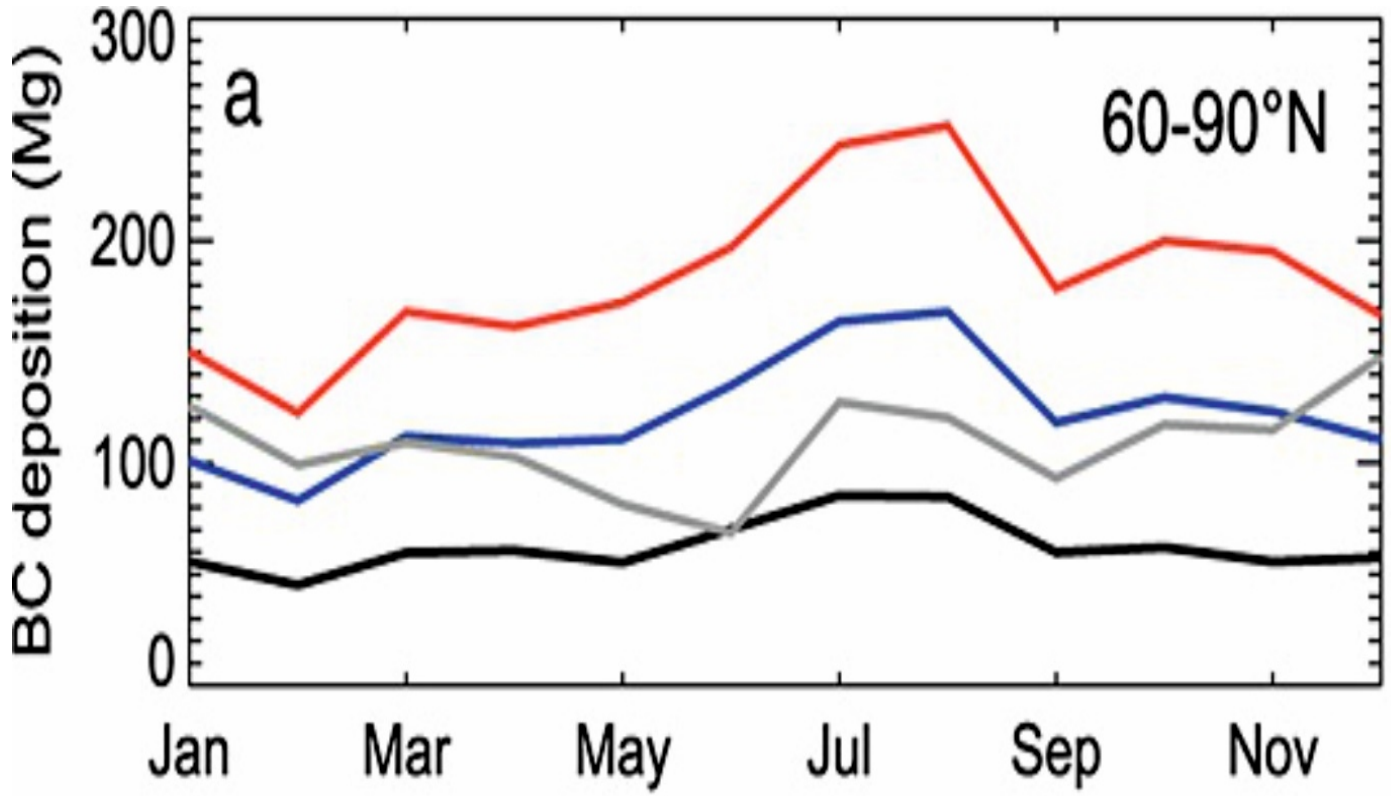


Figure 2. Contribution of Arctic shipping emissions to annual BC deposition in 2004 (left) and 2050 for the BAU (middle) and HiG (right) shipping scenarios. Also shown is the 2000 sea ice edge (sea ice fraction > 50%) in April (maximum) and September (minimum).



BC deposition (Mg) - is the value of total carbon deposition in the Arctic (60-90□N) including both CO2 and soot. The chart presents monthly values in 2004 in megagrams (Mg), i.e. tonnes.

black line - Arctic shipping in 2004;

blue line - Arctic shipping in 2050 assuming minor changes compared to the current state and taking into account environmental protection requirements;

red line - Arctic shipping in 2050 assuming a clear increase in shipping intensity

Comparison of molecular carbon emissions in 2004 and the anticipated emissions for medium and intensive development of Arctic shipping (Browse et al. 2013)

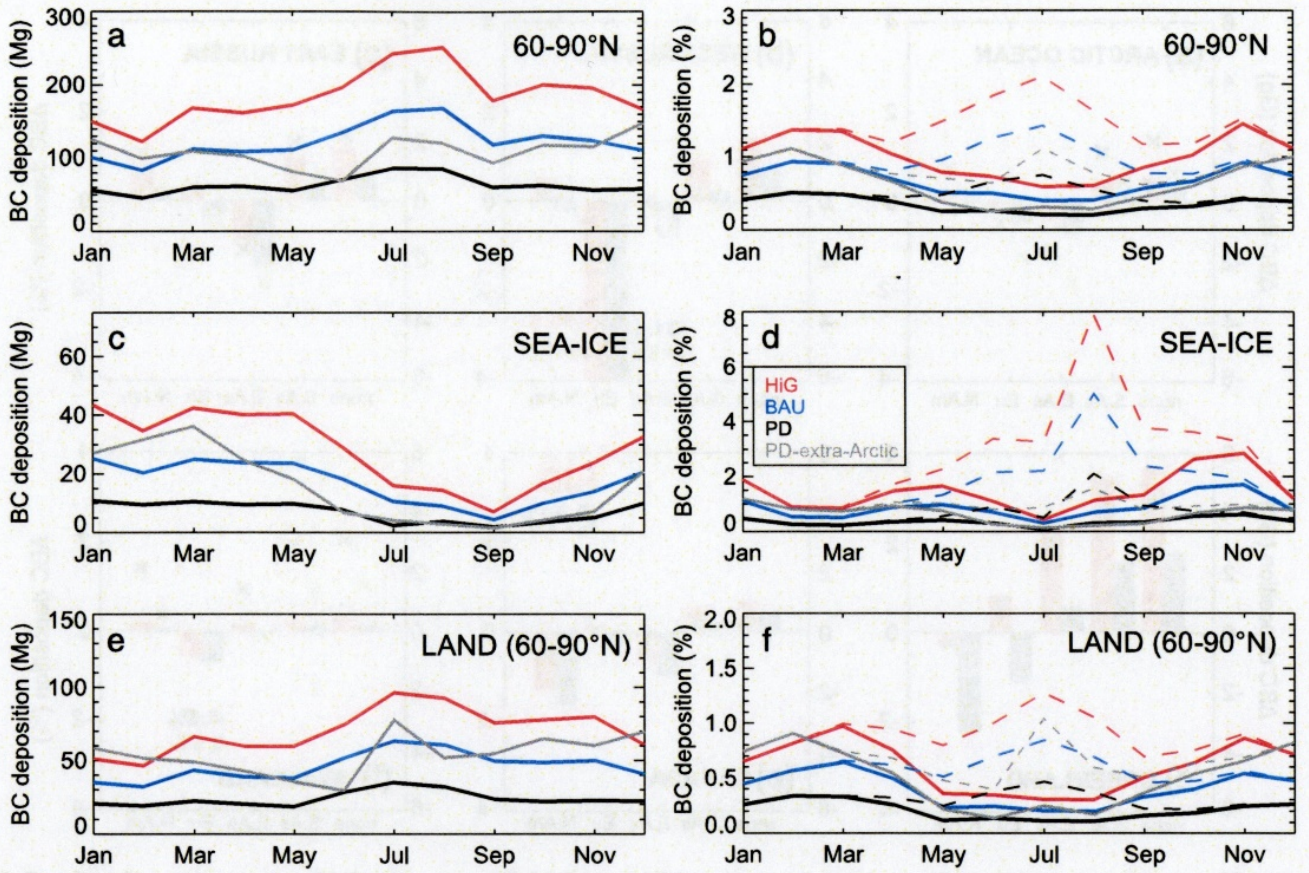


Figure 1. Monthly deposited BC (a, b) north of 60°N, (c, d) over sea ice, and (e, f) over land north of 60°N attributable to present-day (PD) Arctic shipping in 2004 (black), BAU Arctic shipping in 2050 (blue), HiG Arctic shipping in 2050 (red), and extra-Arctic shipping in 2004 (grey). The percentage (Figures 1b, 1d, and 1f) of deposited BC attributable to shipping sectors is shown relative to the total BC deposition (solid lines) and the anthropogenic component of deposited BC (dashed lines).

Odyssey
Oxford Debates for Youths in Science Education

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THANK YOU!

Based on:
Jerzy Giżejewski
Instytut Geofizyki PAN
gizej@igf.edu.pl

The projest has been funded with the support of European Commission within ERASMUS+ program

„ Sea transport in the Arctic”

Material for teachers

With methodological guidelines, a lesson plan and an answer key to worksheets

The educational package " Sea transport in the Arctic " was developed within "Oxford debates for the education of young people in the field of mathematics and science" project.
It is a key material, facilitating the achievement of primary project goals, including increasing reasoning skills and interest in STEM, which in the future may result in taking up a scientific career.
When preparing students for the debate, one should not neglect the development of such skills as: communication excellence, argumentation or public speaking. Students should improve their ability to persuade effectively, argue properly, reason accordingly and speak out correctly. Composition of texts, using rhetorical means in oral statements, speaking in accordance with the rules of language culture, text interpretation, public speaking and presentation of texts, discussions and negotiations are of equally high importance.
In order to achieve the abovementioned goals, the implementation of thematic educational packages should be preceded by classes dedicated to preparation for debating as such. This can be accomplished in consultation with teachers of other subjects and the class teacher. The development of basic communication skills can be included in the class teacher's work plan, and the prepared lesson plans can be used during regular classes. Auxiliary materials can be found in the following documents:

1. **Warm up practice** – Annex No 2 to National frameworks for implementation of Oxford debates in STEM in school practice (pages 37-39);
   This document includes the following exercises: active listening, public speaking and debating skills.

2. **Lesson plans aimed at general development of debating skills** – Annex No 2 do National frameworks for implementation of Oxford debates in STEM in school practice (pages 40-55);

   This material consists of 7 lesson plans prepared by Dr. Foteini Englezou, president of the Hellenic Institute for Rhetorical and Communication Research. Scenarios are a guide to work. It is not necessary to follow all the lessons. The teacher can decide which scenarios (or their selected fragments) are most useful for working with a specific group of students. The document offers the following lesson plans:

   1. Communication skills
   2. Express your scientific argument, not your opinion
   3. Build a valid scientific argument
   4. Searching for evidence
   5. Enhancing students’ linguistic skills
   6. Rebuttal and refutation
   7. Fallacies

3. Methodological Guide for Teachers. ODYSSEY: Oxford Debates for Youths in Science Education

The final stage of preparation for debates based on specific packages is to familiarize students with the principles of debating, described in detail in the abovementioned document.

Sea transport in the Arctic

The " Sea transport in the Arctic " educational package consists of the following elements:

- Multimedia presentation;
- Video- recording based on the presentation;
- Educational package " Sea transport in the Arctic " - material for students;
- Worksheets (the same for all packages);
- " Sea transport in the Arctic " - material for the teacher (with answer key).

It is recommended to implement the package during a minimum of three lesson units.

Materials in the package "Sea transport in the Arctic" will guide the student through the problems of the Arctic from the point of view of the needs of the economy, in particular the transport of countries located in this zone. Students will learn about the economic benefits of shortening the transport route of goods and the resulting shortening of transport time and costs, as well as environmental costs (environmental pollution, acceleration of glacier melting processes.

Lesson 1. Sea transport in the Arctic - introduction

Conducting a debate on the use of alternative sea transport routes across the Arctic requires students to have a good knowledge of the world map, in particular the route of sea transport using the strategic channels: Suez and Panama. A good understanding of the subject and the route of the routes: Northwest Passage, Transpolar Route and Northeast Passage requires careful analysis of the student's materials and the use of physical maps of the world. An additional source of information may be a multimedia presentation and the author's recording of the presentation.

During the first lesson, students should learn as much information as possible about the possibilities of developing transport in the Arctic as an alternative to current shipping routes, and understand and map new routes in the Arctic.

Lesson 2. "Sea transport in the Arctic Ocean should be developed" - arguments for and against the resolution.

The aim of the second lesson is to formulate as many arguments as possible (both for and against the resolution) that will be used by students during the debate, summarizing the work with the package.

Lesson plan

1. Organizational issues, checking the attendance list, familiarizing with the topic and objectives of the lesson [5 minutes].
2. Preparation of arguments [25 minutes]
3. The teacher divides the class into teams of two. Each team receives 16 **question cards** available in the educational package (materials for the student) and 2 copies of worksheet No. 1 (one for each student infividually). Based on the questions, students formulate arguments for the presented thesis, against the thesis and those that are debatable and can be used in the discussion by both parties. Students work together, but each student individually completes his/her worksheet. There are examples of selected arguments for worksheet 1 are in the answer key.
4. Teams: proposition and opposition are formed [10 minutes].

Team selection may be executed in 2 forms, each of them having both advantages and disadvantages.

Students declare which arguments are closer to their beliefs. The teacher divides the class into teams (each with a similar number of students) in the manner reflecting their convictions. The second method assumes a division similar to the one above, with the difference that ultimately the team consisting of the supporters of a given resolution becomes the "opposition" team, while the opponents of the thesis become “proposition” team. The supporters of such a division assume that it teaches the participants of the debate to a greater extent to use arguments supported by facts, and is less based on emotions. Alternatively, division into teams can also be done randomly.

Finally, team selection can also be made by the teacher in a subjective way, ensuring that each team has both leaders and students who require more help, so that both teams have similar “winning potential”. In order to save time for division, the teacher can do it at the beginning of the lesson, for example by distributing worksheets number 1 to the students, printed on sheets of different colour or marked in some other manner.

5. The teacher distributes worksheets number 2 to the students (one for each student) and explains the homework. An example of a filled out worksheet is available in the answer key.
6. Students in each team read prepared arguments in accordance with the assignment to a given group. Each student receives 1 argument, which he/she will develop (as homework) according to the guidelines in worksheet No.2.
7. Each team also appoints 3 people who will present the arguments prepared by the entire group. Students decide the order of their speeches. During the debate, other team members who are not directly involved in the debate, fill out worksheet
8. Summary of the lesson, evaluation of students' work [5 minutes].

Lesson 3. Debate

During the final lesson, the teams conduct a debate according to the guidelines contained in the "Methodological Guide ..." It takes 45 minutes in total to conduct a full debate. During the debate, the teacher does not comment on the arguments or indicate the fallacies made by the students on an ongoing basis.

An exercise-based debate should be structured as follows:

1. Opening of the debate by the moderator/chairperson [3 minutes].
2. Initial vote by the audience [2 minutes].
3. 1st Researcher-Debater of the A research-team: Constructive Speech [4 minutes].
4. 1st Researcher-Debater of the B research-team: Constructive Speech [4 minutes].
5. Cross-fire between the researchers-debaters (1) of both research teams [3 minutes].
6. 2nd Researcher-Debater of the A research-team: Rebuttal Speech [4 minutes].
7. 2nd Researcher-Debater of the B research-team: Rebuttal Speech [4 minutes]
8. Cross-fire between the researchers-debaters (2) of both research teams [3 minutes].
9. Preparation time for the Summary and Final Rebuttal by both research teams [2 minutes].
10. 3rd Researcher-Debater of the A research-team: Summary Rebuttal [2 minutes].
11. 3rd Researcher-Debater of the B research-team: Summary Rebuttal [2 minutes].
12. Grand Cross-fire between the researchers-debaters (1 & 2) of both research-teams [3 minutes].
13. 3rd Researcher-Debater of the A research-team: Final Focus Rebuttal [2 minutes].
14. 3rd Researcher-Debater of the B research-team: Final Focus Rebuttal [2 minutes].
15. Final vote by the audience / Short written feedback [3 minutes].
16. Presentation of the results by the moderator [2 minutes].

If the debate takes place during extra-curricular activities, then it is recommended to devote, for example, 90 minutes for this part. This will allow you to prepare the room for the debate, recall the rules, conduct the debate and discuss its course and finally evaluate the work of students.

In terms of classroom conditions, it would be ideal to allocate two adjoining lesson units to the debate. Taking into account the school circumstances, organizational difficulties and the inability to devote too many lessons to content extending the core curriculum, the debate can be conducted in one lesson, while maintaining high discipline in time. In this case, it is recommended that during the next lesson with the class additional 10 minutes are spent discussing the debate, pointing to strengths and mistakes made by the participants of the debate.

In this format, 6 students (3 from each team) actively participate in the debate. The teacher may also appoint a moderator from among the students and a time keeper. The rest of the students will receive worksheet number 3. Their task will be to listen carefully to the debate and to note the opposing team's strengths and areas for improvement, and to justify their choice. Completed worksheet no. 3 may be the basis for issuing a grade for activity in the lesson for students who did not take part in the debate directly, but participated in its preparation and were active observers of its course.

Worksheet No 1 – answers

FOR	„GREY AREA”	AGAINST
Question card 1. *The sea route from Rotterdam to Tokyo is currently 2,300 NM (via the Panama Canal) or 2,200 NM (via the Suez Canal). Would opening the Northwest Passage shorten this route?* The sea route from Rotterdam to Japan via the Northwest Passage is shorter than both Panama Canal and Suez Canal routes. In the first case the difference is 900 NM, in the second case - 800 NM. Using this route would significantly reduce transport duration and therefore fuel consumption. *Question card 2.* *Will the use of Northeast Passage reduce the distance between European and Asian ports?* Based on the analysis of the table "Distances between Asian and European ports" (Table 3, p. 9) it can be stated that the opening of the Northeast Passage will significantly reduce the shipping duration. On the example of the Rotterdam - Yokohama route, the NEP route compared to the route using the Suez Canal will be shortened by as much as 37%. As for other Asian ports, the routes will shortened by different percentages: Busan (29%), Shanghai (24%), Hong Kong (11%) respectively. Only	*Question card 3.* *Would shortening the route by using the sea routes in the Arctic reduce fuel consumption and thus have a positive impact on the environment?* Shortening the route by using the sea routes in the Arctic can significantly reduce fuel in shipping. On a global scale, this can contribute to reducing greenhouse gas emissions as well as reducing shipping costs. On the other hand, the increase in the attractiveness of this form of transport, the decrease in the cost of cargo sea transport and the increased "processing capacity" of ships can increase the interest in this form of transport. It is difficult to expect that operating ships stay in ports. It is much more likely that the number of journeys will increase, and thus the pollution generated by ships on a global scale will not only not change, but may even increase. *Question card 4* Are there any restrictions on the size of passing vessels in the Suez and Panama Canal? There are restrictions on the size of passing vessels in both the Suez Canal and the Panama Canal. Detailed	*Question card 7.* *For how long is sailing in the Arctic possible during the year?* Ice cover in the Arctic reduces duration of the shipping season. Currently, for ships without special reinforcements, the open time for navigation is about 2 months. *Question card 9.* *How can the unpredictability of the Arctic sea ice conditions affect the timeliness of deliveries?* The ice conditions in the Arctic depend on many factors (including sea currents or wind patterns) and is therefore not entirely predictable. This makes it impossible to precisely determine the duration of the trip. The unpredictability of the ice situation may affect the delay of delivery (see the STORY CARD 1). *Question card 10.* What are the additional costs associated with selecting Arctic transport routes? Selecting Arctic routes allows to avoid fees for using the Suez or Panama Canal; on the other hand, new costs arise, including icebreaker convoy charges (if necessary). In addition, there are transit fees; also, special licenses for ships and crews are required and

the route to Vietnamese Ho Chi Minh City will be 6% longer.

Question card 5.

What are the economic effects of shortening shipping routes?

The economic effects would be advocates for the development of transport in the Arctic. Shorter routes mean many benefits from an economic point of view, which include in particular: shorter charter periods, lower crew maintenance costs, lower fuel costs. In addition, this will avoid restrictions on the size of vessels passing through the Panama and Suez Canals and will avoid fees for using the channels.

Question card 8.

What are the trends in changing the duration of the Arctic shipping season?

According to all climate models, the air temperature in the Arctic is expected to increase, and hence the reduction in ice and the sailing period.

It is anticipated that year-round shipping will be possible in the Arctic by the end of the century.

Question card 12.

Do all ships in the Arctic use conventional fuel?

The Russian icebreaker fleet mainly uses atomic propulsion, which does not increase atmospheric pollution (zero CO_2 emissions).

information is included in the INFO CARDS 1 and 2. The use of Arctic routes would allow the use of larger vessels. This would reduce unit transport costs. The channels also have limited capacity - the average time to cross the Suez Canal is up to 15 hours.

Arctic routes also have limitations, which are ice classes of ships. The graph (Figure 9) shows that in the 2000s ice range with a concentration of over 15% (preventing ship traffic without ice reinforcements) was within 15 million km^2.

Question card 6.

How could the development of the Northwest and Northeast Passage coast affect the development of shipping?

The Northwest Passage shores don't have large urban and industrial centres. It is expected that the development of shipping will contribute to the development of these settlements, the emergence of industrial and service functions. On the one hand, it will be an impulse for economic development, on the other, it may pose a threat to the indigenous population, who are currently trying to live there in full harmony with nature.

The situation is different in the Northeast Passage of transport is the result of the relatively economically developed coast of Siberia - extraction of oil and natural gas on the Asian shelf, exploitation of raw materials on the continent, use of the sea route for commercial contacts.

the need to obtain special licenses for ships and crews on the North Sea.

Question card 11.

What could be the impact of shipping growth on permafrost? What are the possible consequences?

The increase in environmental pollution associated with both the development of shipping and the economic development of the northern outskirts of the continent may cause the degradation of permafrost on the Asian shelf and an additional increase in global warming due to the release of methane accumulated in it.

Question card 13.

What can be the impact of marine catastrophes on polar ecosystems?

As shipping increases, the risk of maritime disasters increases. Their impact on polar ecosystems is much greater than in other climate zones. These ecosystems are very sensitive (see STORY CARD 2).

Question card 14.

Can shipping in the Arctic contribute to geopolitical conflicts?

The discoveries made and the prospect of further oil and gas exploration, are causing international conflicts related to the Arctic territorial division.

Question card 15.

What impact does shipping have on whales?

As for the quality of conventional fuel, it should be expected to improve in relation to the requirements of the IMO (International Maritime Organization).		Shipping in the Arctic poses a threat to whales. There are several risk factors: walruses, beluga whales, humpback whales and narwhals are often exposed to fatal collisions with ship propellers. For species that rely on their echolocation system, the strong intensity of foreign sounds can cause significant behavioural problems, reproduction problems, etc. (see INFO CARD 4). *Question card 16.* Can sea transport in the Arctic contribute to changes in ecosystems? The presence of ships may pose a threat to the sensitive ecosystems of this region. The danger of introducing invasive species along with ballast water, cargo or on ship hulls is particularly serious.

Worksheet No 2 – examples of argument

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals
(claim) The development of shipping routes in the Arctic is an effective way of reducing freight costs. (warrant) Shipping routes connecting the ports of Europe (and Canada) with the ports of the western coasts of the Pacific Ocean, China, Japan and South Korea. they are much shorter than the traditional routes through the Suez and Panama Canals. Their use gives great savings. (evidence) Shorter routes mean faster transport, lower costs - vessel charter, crew maintenance, fuel consumption. The possibility of using larger vessels than those that can pass through the Canals (the costs of operating ships do not	Shipping routes can be used NOW only in a short period during the year, so it is not possible to completely replace other sea routes. Moreover, the possibility of using larger vessels depends on the ice situation, if the ice boundary is shifted to the south, the shipping lanes lead along the shallow parts of the shelf, which requires extra caution in navigation and can lead to disasters.	Currently, there is no need to divert all maritime transport from traditional routes to Arctic routes. As the climate is getting warmer, the period of availability of Arctic routes will lengthen, and thus it will be possible to gradually develop shipping in the Arctic.
		The modern technology on which navigation is based is developed to the extent that will allow avoiding dangerous places and enable efficient navigation. Also, the extensive monitoring of weather and ice conditions allows you to plan safe transport.
	The costs of transport via the Northern Sea Route (part of the North-East Passage) are increased by Russia's requirements for special licenses of ship captains and crews and the possible costs of icebreaker assistance. Thus, the economic calculation is not simple and includes elements that are difficult to predict (ice conditions).	The additional costs imposed by Russia should not exceed the costs of using the Suez or Panama canals. Russia will not impose costs that will make Arctic transport less economically attractive.

increase linearly with their size - the larger the ship, the lower the unit transport costs). (impact) Lower transport costs may contribute to lowering the cost of exported goods, and thus access to these goods will also be available to people with lower income.		The development of environmental monitoring allows for improving forecasting of ice conditions, which makes planning more optimal. In the next decades, if climate change goes in the same direction, icebreaker assistance may not be needed.

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals
(claim) Maritime transport in the Arctic should not be developed as it will further degrade this part of the world. (warrant) The Arctic is an extremely sensitive ecosystem and any interference with the environment can cause far-reaching changes that cannot be undone. (evidence) According to the latest research, already today the increase in the average air temperature in the Arctic is three times greater than the average increase in air temperature on Earth. (impact) The increase in ship traffic will result in more air and water pollution, which will put the plant and animal species in the Arctic at enormous risk.	Environmental protection should be discussed on a global scale. Pollution is of a transboundary nature. The development of transport in the Arctic will shorten the main trans sea transport. This will reduce fuel consumption, which will help to reduce greenhouse gas emissions.	Shortening routes and reducing fuel consumption will reduce the cost of sea transport, which will make this mode of transport even more attractive. It is expected that this will result in an increase in the number of trips and therefore greenhouse gas emissions will not decrease.
		Pollution is of a transboundary nature, but its greatest impact is to be expected near the source of its emission. Dust from ships' engines will deposit on the ice, which will reduce the ability of the ice to reflect sunlight (the albedo of the ice will decrease). More solar energy converted into heat will accelerate the melting of glaciers.
	Economic development from the time of the first industrial revolution was related to the impact on the natural environment. In the era of globalization, we want to use goods produced in distant parts of the world (China, USA). This trend cannot be stopped. The development of technology allows to build engines with lower and lower exhaust emissions. Investments should be made in these technologies so that the development of transport in the Arctic does not degrade it as much as possible.	It is not true that excessive consumerism cannot be stopped. We can already see today that more and more people understand the relationship between the purchase of new goods and the costs borne by the natural environment. So there is a fashion to limit the amount of possessed goods.
		Economic development should follow the principles of sustainable development. It means, without deteriorating the quality of the natural environment. Today, most countries are committed to reducing greenhouse gas emissions and stopping global warming. There is a conflict of interest between halting global warming and developing shipping in the Arctic

Worksheet no. 1

The educational package contains a set of questions to help prepare arguments for discussion on the resolution. On their basis, prepare a set of arguments and group them into those that are clearly in favor of the resolution, against the thesis, and those arguments that can be used by both teams. Write them down in the appropriate parts of the table.

FOR	„GREY AREA”	AGAINST

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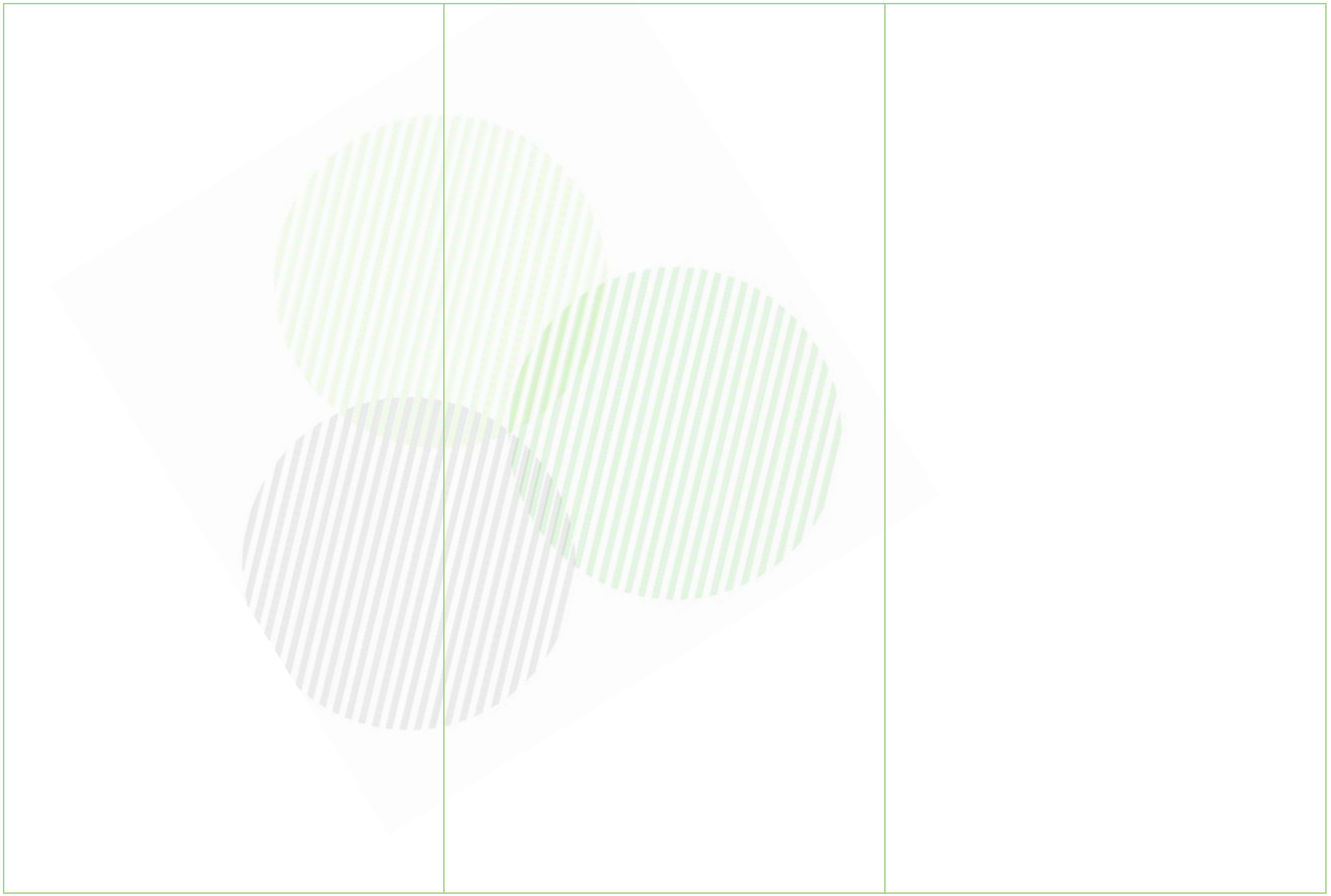

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Worksheet no. 2

Based on the materials provided by the teacher, prepare arguments for discussion. One group of students prepares arguments supporting the resolution, the other one - opposing arguments. Use the proposed template.

ARGUMENT 1.

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals

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ARGUMENT 2.

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals

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Worksheet no. 3

Name and surname:…… Class……. Team: proposition/opposition

During the debate, hear and observe carefully the speeches of the debates from the other team. Then, evaluate which speech convinced you the most and which areas of your opponents' speech should be improved.

1. In terms of **argumentation (**e.g. the quality of the arguments presented, credibility of the data and scientific evidence) in the rival team I was most convinced by the speaker No. .....

Reason:

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2. In terms of **the style of presentation and communication with the audience** (e.g. confident, persuasive, authentic and dynamic posture, moderate gestures, assertive voice variety, good eye contact with the audience, use of moderate humor, friendly and professional approach to all participants, effective use of body language) in the rival team I was most convinced by the speaker No. .....

Reason:

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Indicate the element of the rival team's performance that requires improvement. Justify your answer.

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Reason:

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