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SAFETY OF NAVIGATION IN THE ARCTIC

ABSTRACT

This article presents the results of research based on analysis of ice conditions on the Arctic Sea in recent years and consequences of these changes. The Arctic ice extent are changed due to global warming. Reducing the ice surface leads to intensification of the navigation of the waters of the Arctic Sea, resulting in a significant reduction of the distance between the ports of Europe and East Asia and the North and South Americas. This phenomenon is conducive to the opening of new shipping routes leading through the Arctic Sea. After the entry into force of 1st January, 2017 *The International Code for Ships Operating in Polar Waters* (*Polar Code*) is expected to improve the safety of conducting the navigation of the waters. Analysis of maritime accidents in the Arctic waters shows that the number of accidents has a growing trend, however, last year brings them a significant decreasing.

Key words:
Arctic, Arctic Sea, sea ice, ice condition, safety of navigation.

INTRODUCTION

The issue of global warming, decreasing of the Arctic ice in summer and the safety of navigation in the Arctic waters are of increasing interest in the area. Technical and organizational preparation are taken to reduce the effort of financial outlays on shipping between Europe and the Far East using shortening routs in the Arctic Ocean, covered with a thinner and a reduced extent of ice. In more and more than ever, on the area of the Arctic enters the exploitation of underwater mineral resources, the Arctic tourism and scientific research. Exploitation of the living resources of the seas the Arctic Ocean is not reduced and is covered by a fishing

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policy. The current human activities at sea focused on expanding existing areas of interest including commercial shipping carried out by Arctic waters. Arctic Ocean waters are growing in interest not only in submarine forces, but also in surface naval forces.

At the beginning of the year 2017 the Polish frigate ORP 'General Tadeusz Kościuszko' (273) took part in the NATO forces exercise named TG-17 in waters around the Arctic Ocean. In photo 1 the Polish ship is shown in the waters beyond the Polar circle [1].

Phot. 1. The Polish frigate ORP 'General Tadeusz Kościuszko' (273)
in the Exercise TG-17 in waters near the North Arctic Circle in February 2017 [1]

The forecast made by the Arctic Institute declining ranges the presence of ice on the Arctic Ocean water, is basis for drawing conclusions about the move shipping routes close to the North Pole. At the end of the present century, it will be likely to sail in a close proximity to this point available for widely surface navigation not only for extremely powerful icebreakers. The route leading through the North Pole will be the shortest route from the Pacific Ocean to the Atlantic Ocean.

Nowadays the International Maritime Organization (IMO) says that we can observed trends and forecasts indicate that polar shipping will grow and diversify over the coming years. Ships operating in the polar regions face a number of unique risks. Poor weather conditions, the relative lack of good charts and communication systems and other navigational aids pose big challenges for mariners in the Arctic. And if accidents do occur, the remoteness of the areas makes rescue or clean-up

operations difficult and costly. After the entry into force of 1st January, 2017 *Polar Code* by the IMO is expected to improve the safety of conducting the navigation in the Polar waters and to protect the unique Arctic environment.

DATA AND METHODS

The article aim is to present the characteristic of Arctic waters based on the current research, illustrating the prospects for navigation in the Arctic considering the climate warming, which is conductive to the seasonal reducing of the ice cover. The secondary aim is to summarize up-to-date safety of navigation factors in the Arctic waters according analysis made on the IMO documents.

Following methods were used to achieve the above objectives such analysis and inference. Implementation of the research was based on the historical material gathered by research institutes and in publications.

Nowadays numerous agencies and institutes around the Earth monitor data in the Arctic. Their observations and statistics strongly support the argument that the consequences of the global warming phenomenon are becoming increasingly evident. The primary sources of data for analysis were publications and the data of the National Snow and Ice Data Center (NSIDC), the Arctic Institute — Center for Circumpolar Security Studies and Resolutions and publications of the IMO [14–16].

CHARACTERISTIC OF THE ARCTIC OCEAN AND ARCTIC WATERS

The Arctic, an area of the Earth covering the North Pole together with surrounding the Arctic Ocean and adjacent land continents Europe, Asia and North America. The Arctic Ocean in the geographical range has been defined by the International Hydrographic Organization (IHO) in the Publication S-23. IHO has identified the name as the Arctic Ocean, which is part of the Atlantic Ocean [6]. To the Arctic Ocean also is used the name of the Arctic Sea and the Arctic Mediterranean Sea. The surface area of the Arctic Ocean is 14.75 million km^2. The average depth of the ocean is defined as 1225 m, and a maximum of 5527 m.

In the area of the Arctic Ocean are the following seas: Greenlandic, Norwegian, Barents, Kara, Laptiev, East Siberian, Chukchi, Beaufort and Lincoln, in addition, water Arctic Islands (Hudson Strait, Fox's Basin, Lancaster and McClure Straits), Hudson Bay, Baffin Sea, Davis and Danish Straits. A large area of the Arctic Ocean occupies continental shelf covering the area of about 7.7 million km^2, whose limit

reaches 900–1 300 km from the continent of the Eurasia. Then the bottom of the ocean in the continental slope quickly descends reaching a depth of 2000–2800 m. Coastal Seas of the Arctic Ocean are powered by huge quantities of fresh water from the Siberian rivers (Dvina, Pechora, Ob, Yenisei, Lena, Khatanga, Indygrika, Kolyma) and rivers of the American continent (the most important the McKenzie River), which causes a decrease in salinity of Arctic Waters [13].

Arctic waters means those waters which are located north of a line from the latitude 58º00.0' N and longitude 042º00.0' W to latitude 64º37.0' N, longitude 035º27.0' W and thence by a rhumb line to latitude 67º03.9' N, longitude 026º33.4' W and thence by a rhumb line to the latitude 70º49.56' N and longitude 008º59.61' W (Sørkapp, Jan Mayen) and by the southern shore of Jan Mayen to 73º31.6' N and 019º01.0' E by the Island of Bjørnøya, and thence by a great circle line to the latitude 68º38.29' N and longitude 043º23.08' E (Cap Kanin Nos) and hence by the northern shore of the Asian Continent eastward to the Bering Strait and thence from the Bering Strait westward to latitude 60º N as far as Il'pyrskiy and following the 60th North parallel eastward as far as and including Etolin Strait and thence by the northern shore of the North American continent as far south as latitude 60º N and thence eastward along parallel of latitude 60º N, to longitude 056º37.1' W and thence to the latitude 58º00.0' N, longitude 042º00.0' W [16].

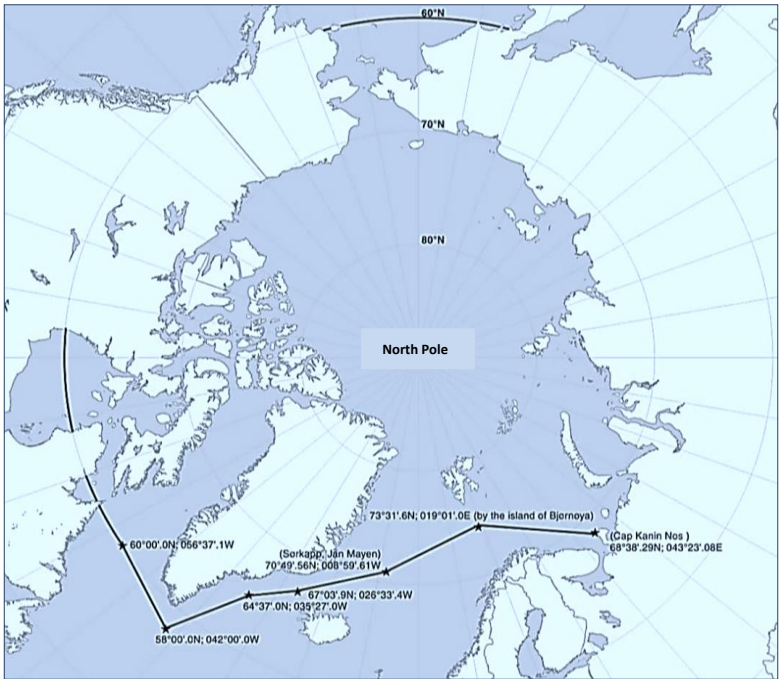


Fig. 1. Arctic waters [14]

The definition of *Arctic waters*, was adopted in November, 2014 by the International Maritime Organization in the Polar Code. Arctic waters are defined in the same form in the SOLAS and MARPOL Conventions.

IMPACT OF CLIMATE WARMING ON THE EXTENT OF ICE IN THE ARCTIC

The changes in the Arctic's ice, and consequently the other areas of global glaciation, are the result of long-term climate changes. The increase in the temperature of the air and the associated reduction in snowfall and rainfall, are the most important reasons for the negative mass balance of glaciers. The rapid melting of glaciers and sea ice of the Arctic and Antarctic since the mid-twentieth century is primarily due to an increase of air temperatures as a result of increased greenhouse effect. However, it should be noted that this phenomenon of melting is seasonal. Further arguments are associated with increased activity of the Sun, which has been observed since the second half of the 19th century. In addition, the ablation process speeds up the contamination of glacier surfaces with industrial dust or other such as volcanic ash or ashes from large forest fires transferred in the atmosphere over long distances. This phenomenon results in a smaller albedo of ice and glaciers surface (that is, greater heat absorption) leading to faster melting of ice.

Based on data from the National Snow and Ice Data Center annual maximum and minimum of the Arctic ice extents (1979–2017) together with trend lines are presented in figure 2.

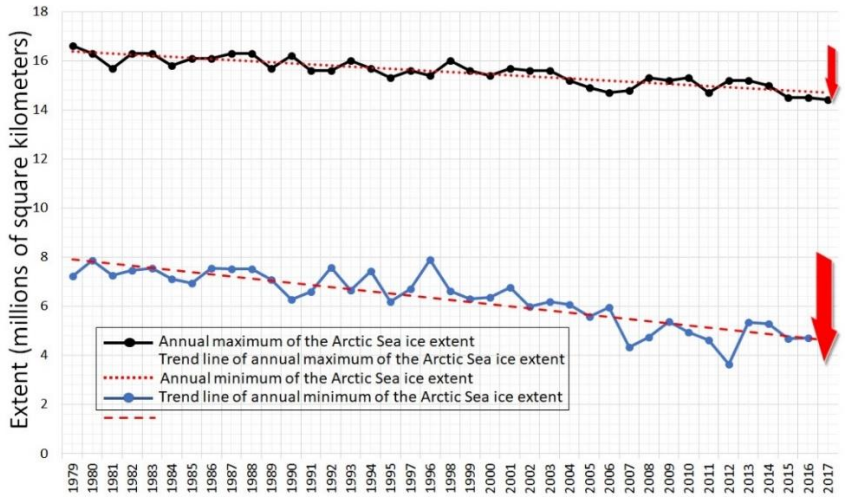
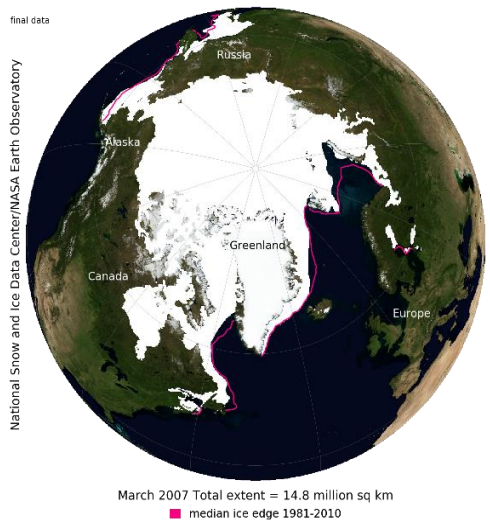
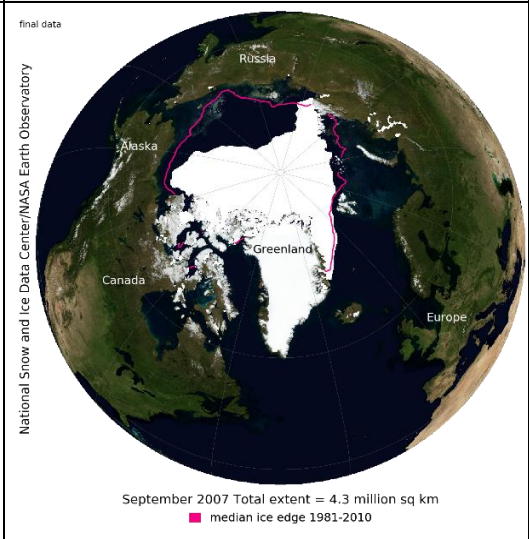
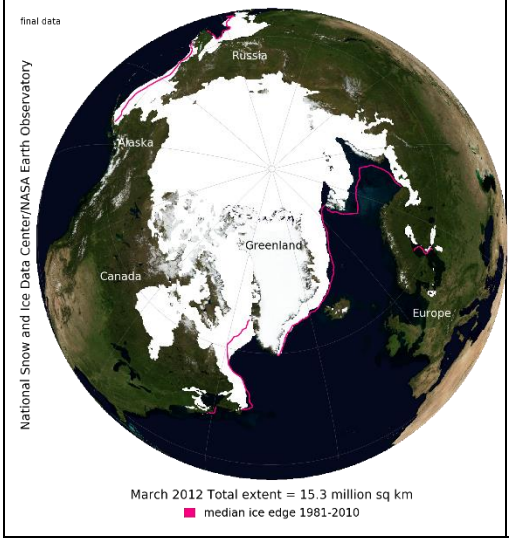
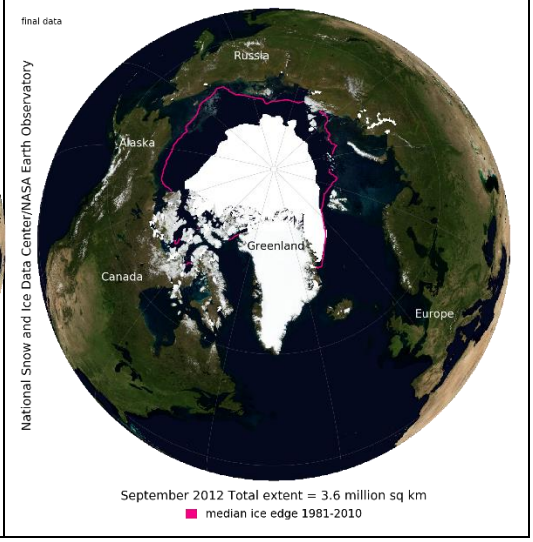


Fig. 2. Annual maximum and minimum of the Arctic Sea ice extent (1979–2016) together with trend lines [own work based on data from the National Snow and Ice Data Center]

These data are from last thirty eighth years (without the minimum of ice extent in 2017) 20th and 21st centuries. In the first decade of the 21st century, the reduction of surface floating ice in the Arctic Sea clearly increased, which resulted in 2007 year the smallest ice surface of about 4.4 million km^2, and the beginning of the second decade of the current century gives an even larger decline in the year 2012 to the surface 3.6 million km^2. This is the current record for the smallest ice extent on the water of the Arctic Ocean.

Maksimum monthly ice extent of the Arctic Sea	Minimum monthly ice extent of the Arctic Sea
	
	

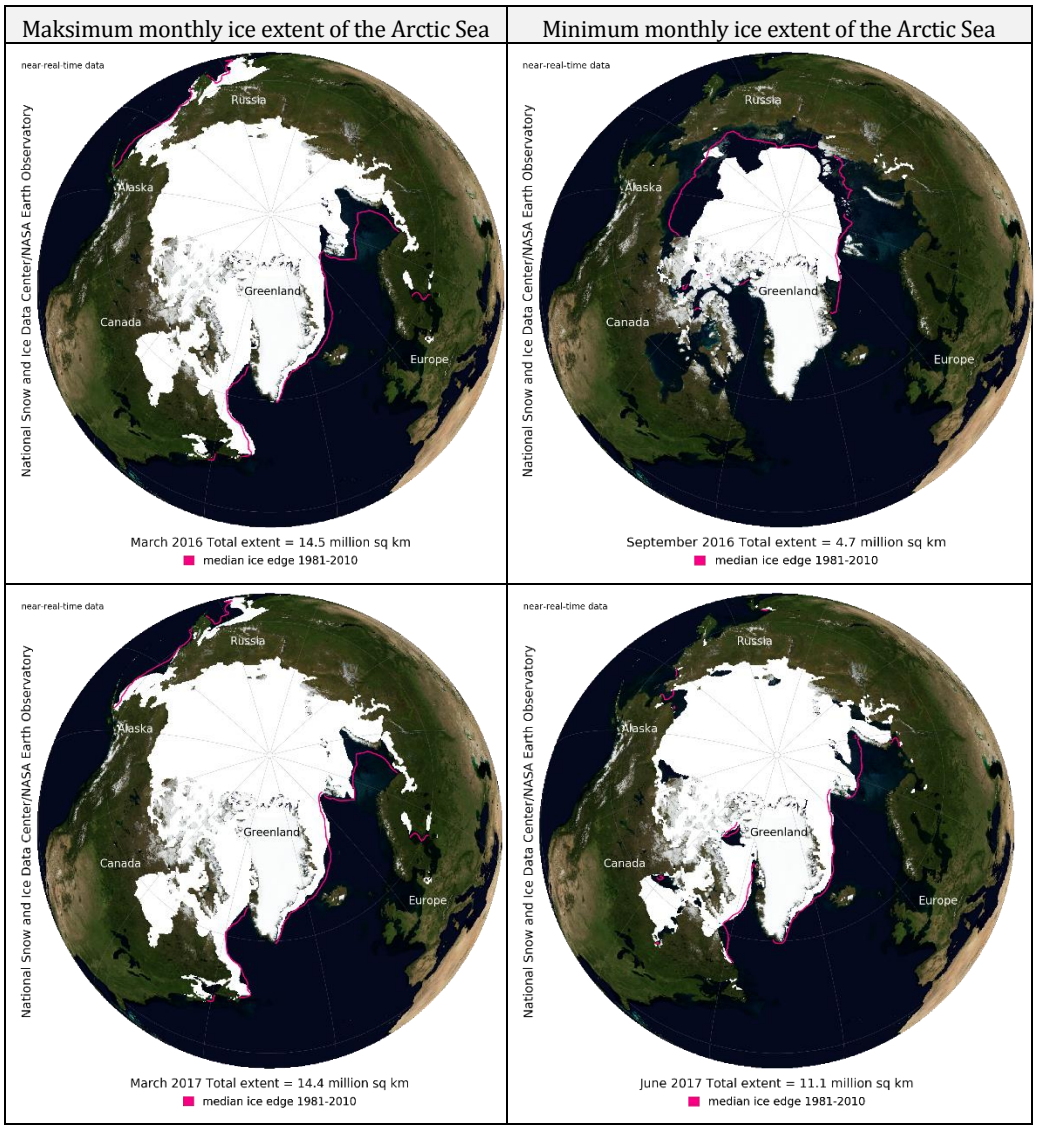


Fig. 3. Examples of maximum and minimum monthly ice extent of the Arctic Sea ice extent for March and September 2007, 2012, 2016 and March 2017 and 26th July, 2017 [21]

In the years after 2012 the yearly ice extent was bigger, but its values were significantly below the long-term average of the surface of the ice cover of the Arctic Ocean. Another consideration is significantly greater weight loss of ice from the loss of the ice surface. In the 90s of the 20th century solid, compact ice accounted for 80% of the sea ice, and in the 2008 year, this indicator was only 3%. Ice in the Arctic Ocean is in constant movement caused the effects of friction force of the wind at the interface

between ice-atmosphere. The average speed of the movement of the masses of ice floating ranges from several to a dozen nautical miles per week. The smaller the thickness of the ice, the movement of the one-year ice masses are conducive to the visible reduction of density ratio of ice in the Arctic.

National Snow and Ice Data Center provides the daily illustration of the Sea Ice Extent which is a quick look at Arctic-wide changes in sea ice. It provides consistently processed daily ice extent and images and data since 1979. Daily images show ice extent at concentrations grater then 15% for a given day with an outline of the typical extent for that day based on a 30-year (1981–2010) median (orange line). The Arctic Sea ice extent for 26th July, 2017 is presented in figure 3. The extent of the Arctic Sea ice is below average and in last two mouth very similar to data from 2012 year.

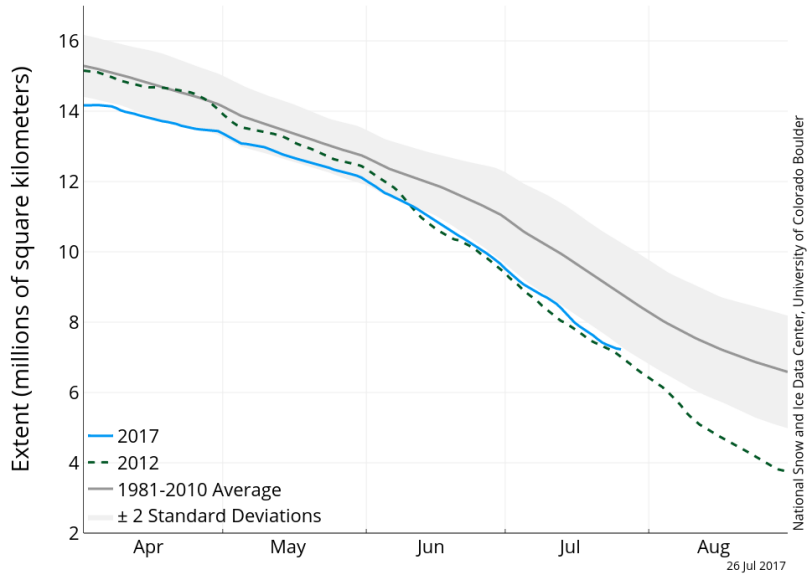


Fig. 4. Arctic Sea Ice extent for 26th July, 2017 (Area of ocean with at list 15% sea ice) [20]

The Arctic Institute-Center for Circumpolar Security Studies taking into account the systematic reduction of the surface of ice floating on the water in the Arctic Ocean has provided an estimate of the minimum extent of ice in the Arctic Ocean for the 2030's, 2050's and 2100's. This forecast is the systematic reduction of the area of floating ice, and consequently the opening to the shipping of waters so far inaccessible to vessels (excluding ice-breakers). This forecast is illustrated in figure 5.

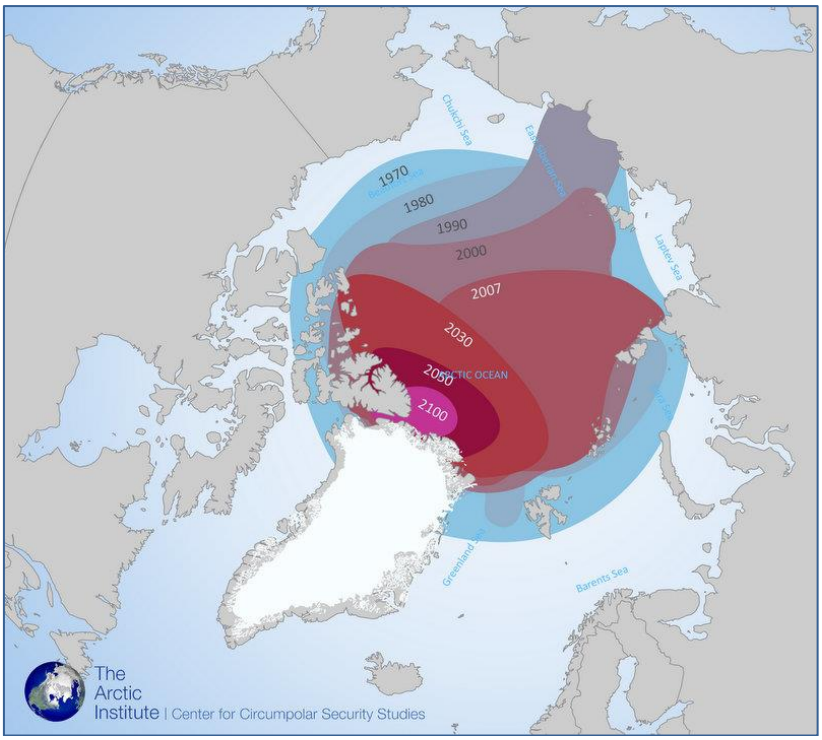


Fig. 5. Recorded and projected minimum ice coverage of the Arctic Ocean by years [19]

The melting of the floating ice in the Arctic Ocean water most likely will result in more accessible to transport and allow easier access to conduct prospecting and mining of mineral resources. However, we should not forget about the difficulties arising from the severe climatic conditions of the Arctic and yearly seasonal changes. The Arctic Institute forecast is extremely beneficial for shipping and for creating opportunities for sailing in water free of ice in a given period of time and the summer Arctic season.

THE FUTURE OF NAVIGATION IN ARCTIC WATERS

The increased traffic of vessels in the Arctic Ocean is the result of a decrease of ice extent in this area, which is the result of global warming and increased economic interest in the Arctic. According to M. Jurdziński [8] the interest of shipping companies in polar areas is due to the following reasons:

– a starting of intensive exploitation of natural resources in these areas;

– an intensification of the navigation of the so far poorly operated polar roads such as the Northeast Passage — NEP (which includes the Northern Sea Route — NSR), connecting Europe with Asia, and the Northwest Passage — NWP, connecting America with Asia.

The two above mentioned passages are also called the Northeast Route and the Northwest Route. It should be added that none of these routes is the waterway, because the navigation is determined by depending on the ice conditions prevailing in each section of passage.

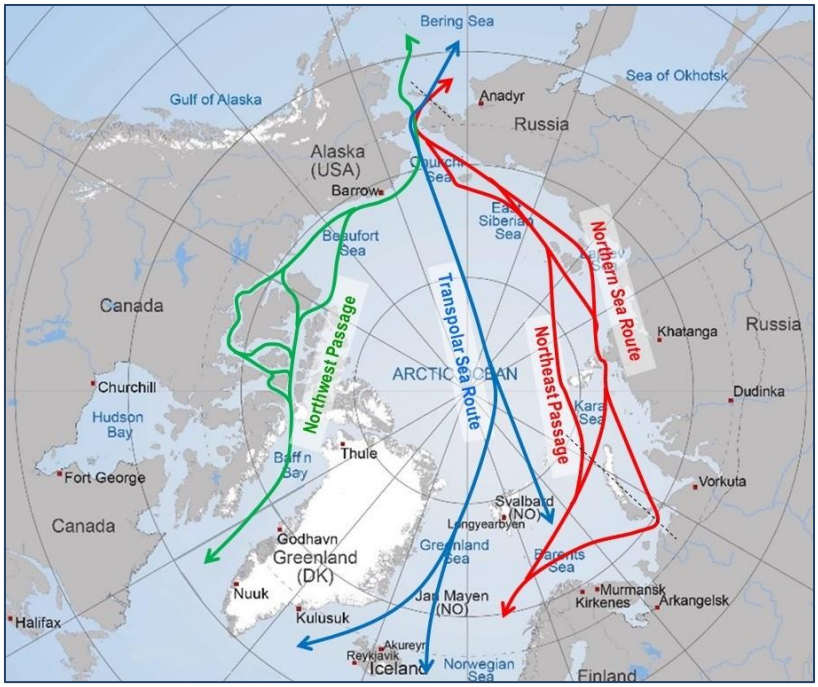


Fig. 6. The Northwest Passage, the Northeast Passage and the Northern Sea Route and the Transpolar Sea Route [own work]

The forecast of ice coverage made by the Institute of Arctic, which is illustrated in figure 5, is the basis for drawing conclusions about the move of shipping lanes along with the reduction of ice cover to the North Pole. At the end of this century, it will be likely to sail in close proximity to the now widely unavailable space for a surface navigation. Currently, the availability of these water is only for extremely powerful icebreakers, most often conducting scientific research, data acquisition and gathering experience for sailing in the highest geographical latitudes. The route leading through the North Pole will be the shortest route from the Pacific Ocean to

the Atlantic Ocean. Proposed name of the third passage through the Arctic Ocean, is the Trans-Arctic Route or the Transpolar Sea Route (TSR), which was illustrated in the figure 6. Feature of this transition will, of course, the shortest distance the shortest time of transition, the economic side, however, could not forget its only seasonality.

The greatest potential for a transit shipping is currently the Northern Sea Route/Northeast Passage, however, it should be noted that the route offers a shorter distance — compared to traditional routes through the Suez Canal and Panama Canal — only for specific starting ports and ports of destination (like the Northwest Passage). A significant decrease in distance takes place only between the northern ports of Europe, Asia and North America [10]

Alternative routes of transition from the Port of Hamburg to the ports of the Pacific Ocean are illustrated in table 1. The collected data in this table were calculated on the basis of navigation through the Northeast Passage.

Tab. 1. Alternative routes from Hamburg to the ports of the Pacific Ocean [6]

	Distance in nautical miles from the Port of Hamburg to:			
The route passes through:	Vancouver (Canada)	Yokohama (Japan)	Hong Kong	Singapore
The Northeast Passage (The Northern Sea Route)	**6635**	**6920**	**8370**	**9730**
The Suez Canal	15 377	11 073	9360	8377
The Cape Of Good Hope	18 846	14 542	13 109	11 846
The Panama Canal	8741	12 420	12 920	15 208

Analyzing collected data in table 1 relating to the distance to the ports of the Pacific Ocean (Vancouver, Yokohama, Hong Kong and Singapore), it should be noted that the length of all the routes from Hamburg by the Northeast Passage are possible, with the exception of one case to Singapore through the Suez Canal. This is the condition to obtain the most favorable economic performance on these routes. An important aspect of sailing through the Arctic Ocean is the safety of navigation provided by navigation systems based on land and satellite infrastructure, communications and safety and the ability to conduct search and rescue operations. According to a report by the Norwegian Fridtjof Nansen Institute (FNI) presenting, among other things, the state of navigation, communications and search and rescue infrastructure in the year 2000, were necessary to strengthen particular areas to ensure the safety of navigation, especially in view of the sailing of oil tankers transporting petroleum products and bulk carriers of metal ore. The current situation of shipping in the Arctic waters has significantly changed, but the environment for navigation has not changed radically [11].

POLAR CODE

Arctic waters navigation is not easy and safe for shipping. Data analysis published by the Loyd's List Intelligence Casualty Statistics (Data Analysis & Graphic Allianz Global Corporate & Specialty) says, that the Arctic waters are not area free of accidents, including the loss of the vessels. In the years 2006–2016 in the Arctic waters came to 470 marine accidents, and 18 ships were completely lost [17]. So far, the dynamic of accidents in the Arctic waters has been growing. In the year 2006 the number of accidents reached 8 and during the next years this number increased to 71 in the year 2015, but in 2016 is observed the reduce of accidents number to 55 [17]. Summary of the number of maritime accidents in the Arctic waters in the years 2006–2016 is illustrated in figure 7. In analyzing the above comparison, it can be concluded that in the years when the ice extent was historically the lowest, the accidents were relatively less. Examples are the years 2007 (about 4.4 million km^2) and 2012 (about 3.6 million km^2), when it recorded the lowest observed ice surface in the Arctic. The largest group of accidents defined by cause is related with the difficult climate conditions in the ice environment, low temperature, ice thickness and movement. The next group is grounding and hull damages in the cause of the lack of complete hydrographical information [17]. However, this situation can be changed due to the possibility of making the hydrographic work in in terms of the lack of ice during the summer in the North Hemisphere.

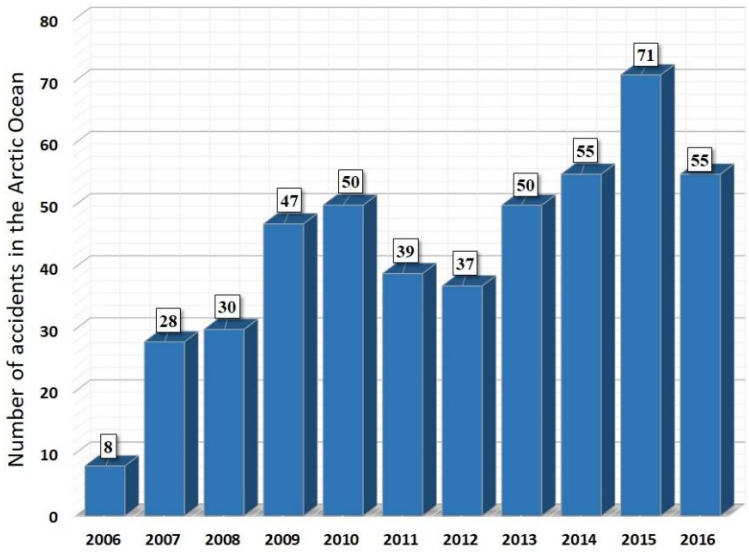


Fig. 7. Summary of the number of maritime accidents in the Arctic in the years 2006–2016 [17]

In order to improve the safety of shipping on the remote, vulnerable and difficult for navigation conditions of polar waters and to reduce the impact of this shipping on the environment of the polar regions, the International Maritime Organization's International Maritime Safety Committee established in July 2014 the *International Code for Ships Operating in Polar Waters* (*Polar Code*) [15]. The Committee considered the need for a mandatory framework for ships operating in polar waters, which would impose additional requirements on vessels, their systems and their operation, which go beyond the existing requirements of the Convention and other binding IMO documents. The Code was developed as a complement to existing documents. The *Polar Code* in the form of the new 14th Chapter of the SOLAS Convention will enter into force on 1st January, 2017. This marks an historic milestone in the IMO Organization's work to protect ships and people aboard them, both seafarers and passengers, in the harsh environment of the waters surrounding the two poles. The Code applies to the waters of the Arctic and Antarctic as well.

The difference between the waters of the Arctic and the Antarctic is that the Arctic Ocean is an ocean surrounded by continents, the Antarctica is a continent surrounded by an ocean. In waters around the Antarctic ice is scattered in summer on the South Hemisphere or is distracted by the ocean currents to the Weddell Sea and to the Ross Sea, while the Arctic ice during the summer in North Hemisphere is decreased as a result of the global warming and is also subject of the drift due to the impact of the winds on the ice.

The *Polar Code* covers the full range of design, construction, equipment, operational, training, search and rescue and environmental protection matters relevant to ships operating in the inhospitable arctic waters.

The chapters in the *Polar Code* each set out goals and functional requirements, to include those covering ship structure; stability and subdivision; watertight and weathertight integrity; machinery installations; operational safety; fire safety/protection; life-saving appliances and arrangements; safety of navigation; communications; voyage planning; manning and training; prevention of oil pollution; prevention of pollution form from noxious liquid substances from ships; prevention of pollution by sewage from ships; and prevention of pollution by discharge of garbage from ships [15].

The *Polar Code* [15] defined three category of ships which have the same meaning in SOLAS and MARPOL Conventions as follows:

1. Category A ship means a ship designed for operation in polar waters in at least medium first-year ice, which may include old ice inclusions.
2. Category B ship means a ship not included in category A, designed for operation in polar waters in at least thin first-year ice, which may include old ice inclusions.
3. Category C ship means a ship designed to operate in open water or in ice conditions less severe than those included in categories A and B.

The *Polar Code* includes mandatory measures covering safety part (part I-A) and pollution prevention (part II-A) and recommendatory provisions for both (parts I-B and II-B).

Ships operating in the Arctic waters are exposed to a number of unique risks as follows: poor weather conditions, the relative lack of good charts, communication systems and other navigational aids pose challenges for mariners. The remoteness of the areas makes rescue or cleanup operations difficult and costly. Cold temperatures may reduce the effectiveness of numerous components of the ship, ranging from deck machinery and emergency equipment to sea suctions. When ice is present, it can impose additional loads on the hull, propulsion system and appendages [18].

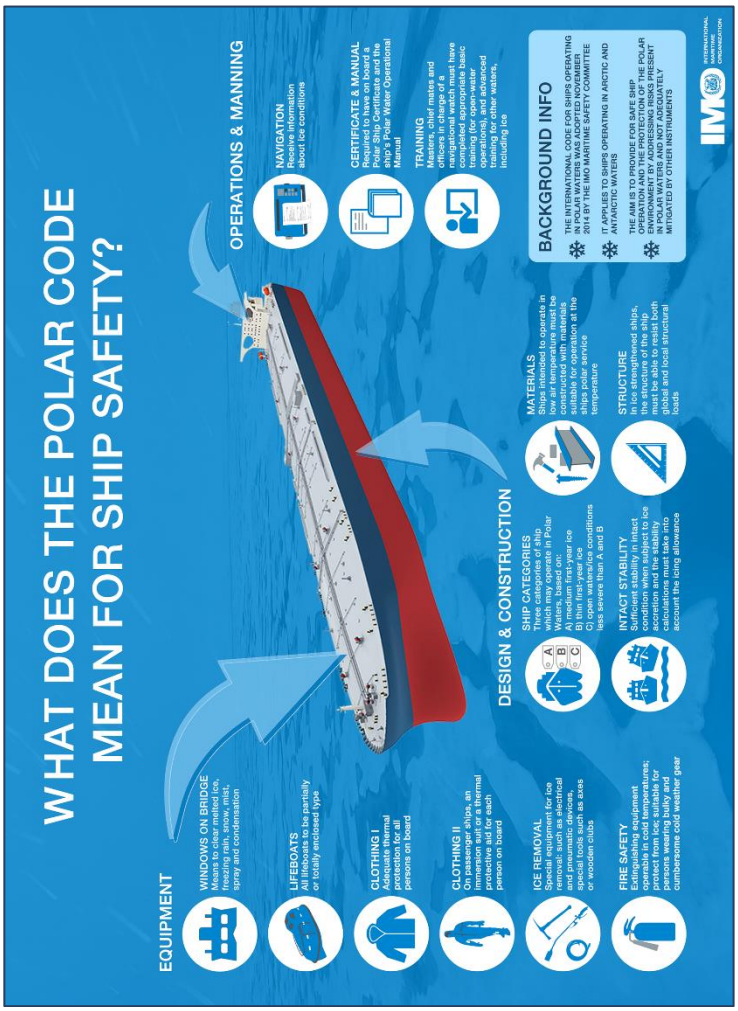


Fig. 8. 'What does the Polar Code mean for ship safety?' [18]

The primary goal of the *Polar Code* is to ensure the safety of shipping in the Polar waters. The most important for the safety of ships in those areas are: design and construction, operation and training of the crew. The importance of the *Polar Code* for ship safety is shown in figure 8 as the question: 'What does the Polar Code mean for ship safety?'.

DISCUSSION AND CONCLUSIONS

The melting ice cover opens up new opportunities for navigation and maritime transport in the Arctic. The increase in ship traffic has been moderate in recent years. According to different studies (such as the report of Arctic Marine Shipping Assessment from 2009), it is predominantly destinational traffic (to and from the Arctic) that holds the greatest promise for expansion in the medium-term perspective. Nonetheless, the potential to develop shorter sea routes between the world's major trade hubs is one of the basic factors impacting on the actions of countries and international cooperation in the region. Of key importance for cooperation in the Arctic are actions to implement the Arctic Council recommendations on navigation and marine environment protection, and the adoption of a mandatory *Polar Code* within the International Maritime Organisation. The purpose of the code is to improve navigation safety in the Arctic by permitting only specific categories of ships to operate in the region [10].

Ships operating in the Arctic and Antarctic environments are exposed to a number of unique risks. Poor weather conditions and the relative lack of good charts, communication systems and other navigational aids pose challenges for mariners. The remoteness of the areas makes rescue or clean-up operations difficult and costly. Cold temperatures may reduce the effectiveness of numerous components of the ship, ranging from deck machinery and emergency equipment to sea suctions. When ice is present, it can impose additional loads on the hull, propulsion system and appendages [18]. In the conclusion of the analysis were made the following generalizations:

1. Adopted by the IMO *The International Code for Ships Operating in Polar Waters* (*Polar Code*) in November 2014 during the 94th session of Maritime Safety Committee (MSC) and related amendments to the International Convention for the Safety of Life at Sea (SOLAS) make it mandatory. Polar Code marking an historic milestone in the Organization's work to protect ships and people aboard them, both seafarers and passengers, in the harsh environment of the waters surrounding the two poles.

2. Navigation to Arctic waters is still dangerous because of the lack of complete nautical information. This region is becoming an increasing focus of hydrographic work due to intensified activity in shipping and tourism as well as other activities. Arctic waters are a poorly recognized area in terms of batgraphy, however, due to the decreasing of sea ice extent, the size of the surveyed areas is systematically enlarged.
3. The presence of Polish vessels on Arctic waters and beyond the Northern Polar circle is mainly associated with scientific research, sailing and military training activities. Although the Arctic shipping does not belong to the Polish strategic interest, the Polish potential of shipping companies, shipbuilding, and port infrastructure can be used as part of the Poland's contribution in the safety of navigation and environmental protection in the Arctic.

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BEZPIECZEŃSTWO NAWIGACJI W ARKTYCE

STRESZCZENIE

W artykule przedstawiono wyniki badań opartych na analizie warunków występowania lodu na Morzu Arktycznym w ostatnich latach oraz konsekwencjach tych zmian. Zasięg lodu arktycznego zmienia się w związku z ociepleniem klimatu. Zmniejszanie powierzchni lodu prowadzi do intensyfikacji żeglugi na akwenie Morza Arktycznego skutkującej znacznym zmniejszeniem odległości

pomiędzy portami Europy i Wschodniej Azji oraz Ameryki Północnej i Ameryki Południowej. To zjawisko sprzyja otwarciu nowych szlaków żeglugowych prowadzących poprzez Morze Arktyczne. Po wejściu w życie 1 stycznia 2017 roku *The International Code for Ships Operating in Polar Waters* (*Polar Code*) oczekiwana jest poprawa bezpieczeństwa prowadzenia żeglugi na akwenach polarnych. Z przeprowadzonej analizy wypadków morskich na wodach Arktyki wynika, że liczba wypadków ma tendencję rosnącą, jednakże ostatni rok przynosi ich znaczny spadek.

Słowa kluczowe:
Arktyka, Morze Arktyczne, lód morski, zlodzenie, bezpieczeństwo nawigacji.