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Alterations of the heaviest ice conditions along Sabetta-Bering Strait route

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Abstract. AARI has unique archive of ice charts, which were made by recognition of satellite images, their composition and vectorization. The paper is considered methodology and preliminary results of computer processing of vector ice charts from the archive. The archive covers the period since 1997. The charts handling is processed in ArcGIS. The article presents some results of ice navigation conditions analysis within the standard route "Sabetta Port – the Bering Strait" for April and May, that is temporal interval of the heaviest conditions of ice navigation. There have been calculated conditional length of various ice age/age and form gradations for the route as a whole. For a homogeneous ice zone of the route the conditional length of an ice age gradation means result of multiplication of the gradation partial ice concentration at the zone length. The values were calculated for various ice forms (floe dimensions) of the ice age categories. The research revealed essential enhancement of the ice navigation conditions for the period 1998-2020. Nevertheless even complete disappearance of the old ice from the route does not mean absence of nip danger.

1. Introduction

Further opening up of the Arctic Ocean water area provides for intensification of oil and gas extraction from the Russian Arctic shelf, and cargo traffic by the Northern Sea Route (NSR), including through shipments and the hydrocarbons shipping from offshore oil and gas rigs and shore-based terminal. The opening up will be affected by changes of the Arctic climate. The impacts on the terrestrial fuel and energy complex infrastructure in the Russian Arctic probably will have negative consequences as a whole [1]. On the plus side, the Arctic warming provides new capabilities in the Russian Arctic related to oil, gas and ore minerals extraction, shipping by the Northern Sea Route, tourism, and fisheries [2]. On the minus side, the climatic changes can destroy the actual infrastructure, buildings, and power generation facilities and so on. There is an opinion, that "the climate change brings an increasing uncertainty" [3]. The paper declares that "ice loads for platforms in first-year ice environments are not predicted to significantly reduce". The authors recommend using trends of the climatic parameters changes with a high level of confidence. In addition, the authors give advice to take into account the climate evolution "both at the design stage and for operation of Arctic structures". We must accent that standards of safety in the petroleum and natural gas Arctic offshore structures were recently toughen up [4, 5]. Standard ISO 19906 (2019) pays a lot of attention to ice-structure interactions [6].



Decrease of the Arctic drift ice gives opportunities for trade between the Eastern Economies and the European Countries [7].

Dr. Alekseev points at an astronomical reason of the global warming that is orbital-forced increase of the solar insolation [8]. The Arctic warming in winter is connected with atmospheric circulation changes in the Northern Hemisphere due to effect of the sea surface temperature in tropical latitudes. The warming accelerated in the late 1990s. The main contribution into the warming gives the atmospheric and oceanic heat influx mainly from the Atlantic Ocean. The influx causes the decreases of thickness and area of distribution of the sea ice in the Arctic Ocean. Probably, the main reason of the decreases is not the anthropogenic global warming. It is possible, that the reason consists in natural cycles. Thus, there was observed cooling-down in the Arctic in the twentieth fifties and sixties after the warming in 1910 – 1940. Of course, anthropogenic impacts at the climate for the fifties and sixties were not less than in the first half of twentieth century. D.D. Bokuchava and V.A. Semenov [9] declare that the early 20th century warming in the Arctic can be explained by internal natural variability, external forcings such as solar and volcanic activity, positive feedbacks in the Arctic climate system, and anthropogenic factors. Qun Zhou and Wen Chen [10] note relationship between the Solar-Arctic Oscillation and the Arctic climate changes. B. Sherstyukov [11] points to the influence of large planets (Jupiter, Saturn, Uranus, and Neptune) location in the space toward the Sun at the climate fluctuations. According to his opinion, the changes in the moment of inertia of the barycentric movement of the Sun explain approximately 50% of water surface temperature inconstancy within the principal ocean currents. The inertia moment increasing is followed by the temperature raise in cold streams and by the decrease in warm ones. Computer experiments [12] detected existence of approximately 44-year periodicity property of heat content of the Atlantic water layer in the Arctic Ocean. There is heavy reliance of the longitudinal overturning circulation parameters and the mode of the cyclonic circulation in the Arctic. The reliance has essential time lag up to 20 years. Truly, there is significant decrease of the sea ice area in the Arctic Ocean: “the total area of the ices drifting in the Arctic Ocean at the end of winter was 5–8 % lower than the average values for many years” [13]. However, there is observed some slowdown of the Arctic warming [14]. With no doubt, the Arctic sea ice is a factor, which we must take into account for 21 century. Thus, computer simulation [15] demonstrates significant decrease of the ice spreading in the Barents Sea northern part by 2041-2050. Nevertheless, no complete disappearance of sea ice is expected until the end of the century. The Arctic warming is accompanied by increase of the weather change frequency. There is “increase of occurrence of meridional cold or warm air outbreaks under general warming” [16]. Changes of the marine cold air outbreaks frequency in the seas of the Russian Arctic “are likely connected with changes in dynamic and thermodynamic characteristics of the Arctic cyclone activity, and changes of air and sea surface temperature” [17]. Retreat of the sea ice plays the major role in the processes [17]. The decrease of the area of the sea ice spreading in the Arctic Ocean leads to decrease of the atmosphere static stability. The atmosphere non-stability creates conditions for genesis of cyclones, and the development of Arctic mesocyclones activity [18]. It is evident that the cyclones generation intensification leads to the hummocking one [19]. It means increase of ice compacting. The cyclones activation generates both zones of the drift sea ice compacting and ones of ice diverging. Frequent change of the ice navigation conditions along the shipping routes negatively influences the marine traffic management. Speaking about the ice navigation conditions, we must understand that the decrease of the level ice thickness can be recouped by increase of the hummock degree.

The complete disappearance of the ice cover along the Northern Sea Route is objectionable situation. The cyclones intensification leads to increase of storm frequency. It, in turn, when there is no the sea ice generates wind-generated sea waves. The high steep waves can be cause of a ship hull breakage. It is especially dangerous for the long vessels which carry oil and liquefied natural gas. The Arctic warming intensifies iceberg generation (calving) by glaciers of Franz Josef Land Archipelago, Novaya Zemlya and Severnaya Zemlya. The compacted sea ice cover prevents far spreading of the icebergs. It is necessary to underline that the most dangerous objects are bergy bits, which usually cannot be identified by an ice radar. A ship during her sailing within the exclusive economic zone of

Russia in the Arctic Ocean in concordance with the laws and regulations must pay duties for eventual icebreaker support. The Government of Russia has purpose to turn the Northern Sea Route into international shipping lane likewise the Suez Canal. The Russian profit is the icebreaking dues getting. If the water area will become ice free one, the profit will be impossible.

The length of the Shanghai-Rotterdam sea route through the Suez Canal is equal to 10590 nautical miles, and the length of marine transport system from Shanghai to Rotterdam by the Northern Sea Route is equal to 8900 nautical miles. The rate of fuel consumption decrease may give economy about 600 thousand US dollars per a sailing [20]. However, amount of the transit handling of freight by the Northern Sea Route is very low. Thus, number of transit vessels, which sailed by the Northern Sea Route in 2015 is equal to 18. As many vessels get over the Suez Canal for four and half hours! Which problems prevent the Northern Sea Route conversion in the international transit marine system? Firstly, a lead (channel in the ice) for big cargo vessels must have width in 50–60 meters. The main problem consists in the fact, that the actual international division of labour demands precise regularity of supply support. Therefore, a marine transport system must work like railway roads without failures in the sailing schedule. The Northern Sea Route must be in operation all year round to win the competition with the route through the Suez Canal. Nevertheless even vessel escort by the most powerful nuclear icebreaker cannot exclude probability of the vessel nip that is her occurrence within zone of drift ice compacting. The nip is possible when the total ice concentration is equal to 9 tenths or greater. Therefore, ice escort of a ship without ice reinforcing is impossible within close and compact floating ice. The heaviest ice conditions of the sailing are observed for April and May. If we propose cargo shipping along the Northern Sea Route, category of the vessels ice reinforcing is designated due to the ice conditions. The quick shrinkage of the sea ice spreading was advanced at turn of 21st century [15]. However the global warming then has slowed [14]. So there is necessity to examine the ice navigation conditions within the NSR after the end of twentieth century. The heaviest ice conditions take place along the eastern part of the Northern Sea Route from the Sabetta City (the Yamal Peninsula, Russia) up to the Bering Strait. The shipping of liquefied-gas from the natural gas liquefaction plant in the Sabetta City to countries of Eastern Asia is carried out along the leg of the Northern Sea Route.

2. Materials and methods

The Ice hydrometeorological information center of the AARI prepare ice charts in the format of ESRI shapefiles on the base of satellite images. The shapefiles then are posted on open source website of AARI. We has processed methodology of the vector ice charts usage for statistical analysis of ice navigation conditions along standard routes. The processing is realized in ArcGIS by means of specially processed computer Python programs. The processing includes: 1) Reprojecting of the initial shapefiles with ice information from geographical coordinate system in rectangular coordinate system; 2) Deleting of empty fields in attribute tables of the shapefiles with the ice information; 3) Merging of the reprojected shapefiles relating to separate Arctic seas; 4) Revealing the dominant ice gradation in each ice homogeneous zone, that is spatial object; 5) Overlay operation of intersection between the merged layer of ice information and layer of buffer zone around a navigation route. The buffer zone has width in 20 km that is 10 km in each direction. The overlay operation produces new layer of homogeneous ice areas within the buffer zone; 6) Deleting of all probable spatial duplicates in the result layer of intersection; 7) Dissolving of spatial objects in the layer with all identical ice characteristics; 8) Calculation of the layer spatial objects areas; 9) Calculation of ratios between areas of the spatial objects with various ice conditions within the buffer zone and total area of the buffer zone; 10) Production of the route length by the ratios. The results are average summarized lengths of legs of the route within ice cover with unique ice cover characteristics; 11) Calculation of partial concentrations of various age categories of sea ice; 12) Identification of ice forms (floes dimensions) for each age category of the ice; 13) Calculations of conditional lengths of various ice age gradations and ice forms (floe dimension) for each leg of the route. The conditional length of any ice age/age and form gradation means result of multiplication of the gradation partial ice concentration at the leg

length. For example, partial ice concentration of old ice within a route leg is equal to one tenth, and the leg length equals to 10 nautical miles. Therefore, the conditional length of old ice within the leg equals to one n.m. Let us assume that the forms of the old ice are big floes and medium floes. Therefore, the conditional lengths of the old ice big floes and the old ice medium floes are equal to 0.5 nautical mile. Then we summarize all conditional lengths of identical age/age and form gradations to get the conditional lengths for the route as a whole.

3. Results

The Figure 1 demonstrates spatial spreading of oldest age ice gradations in first third of May in 1998 and 2005, and Figure 2 – in 2012 and 2020 years.

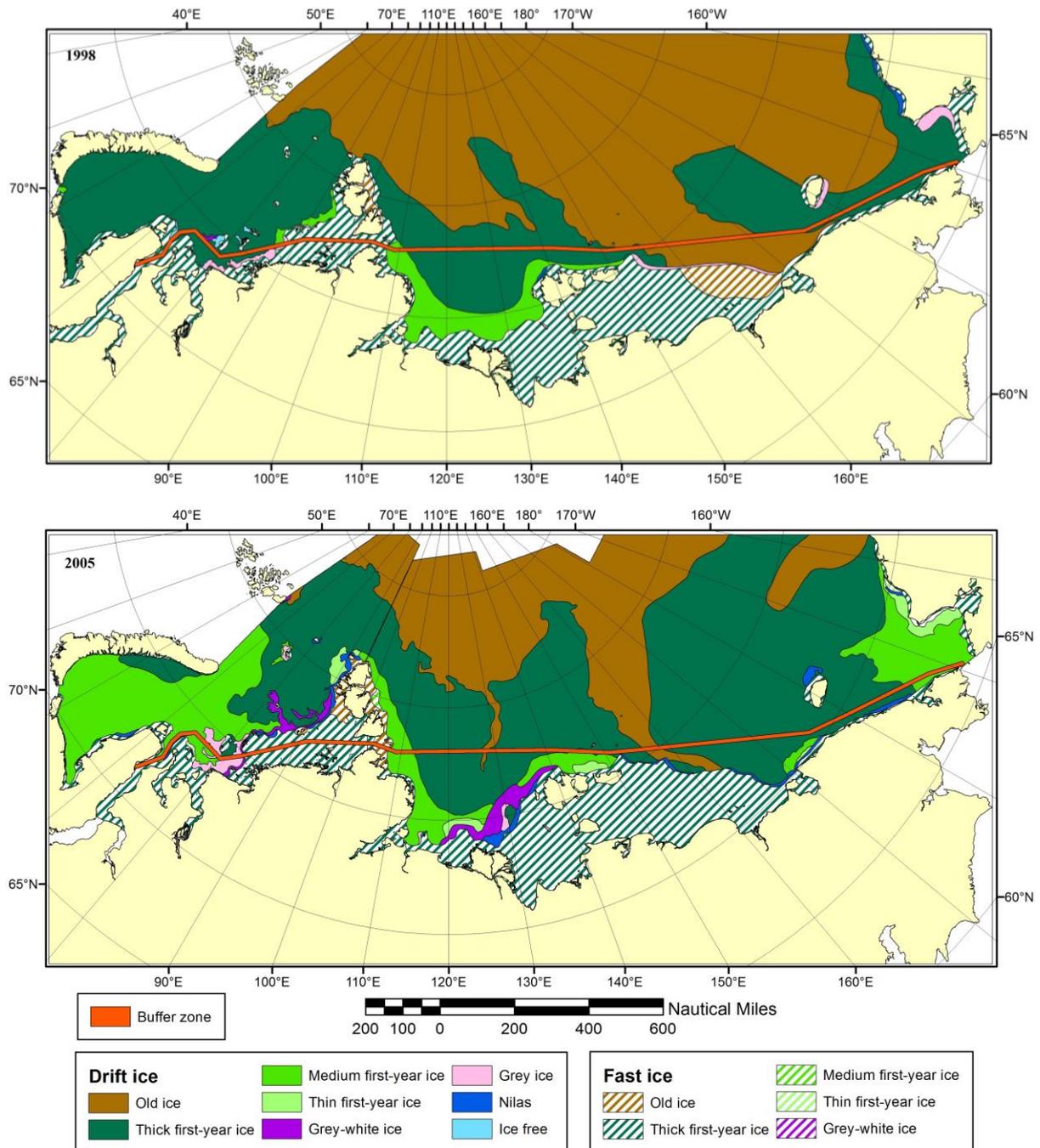


Figure 1. Spatial spreading of oldest age ice gradations in first third of May in 1998 and 2005

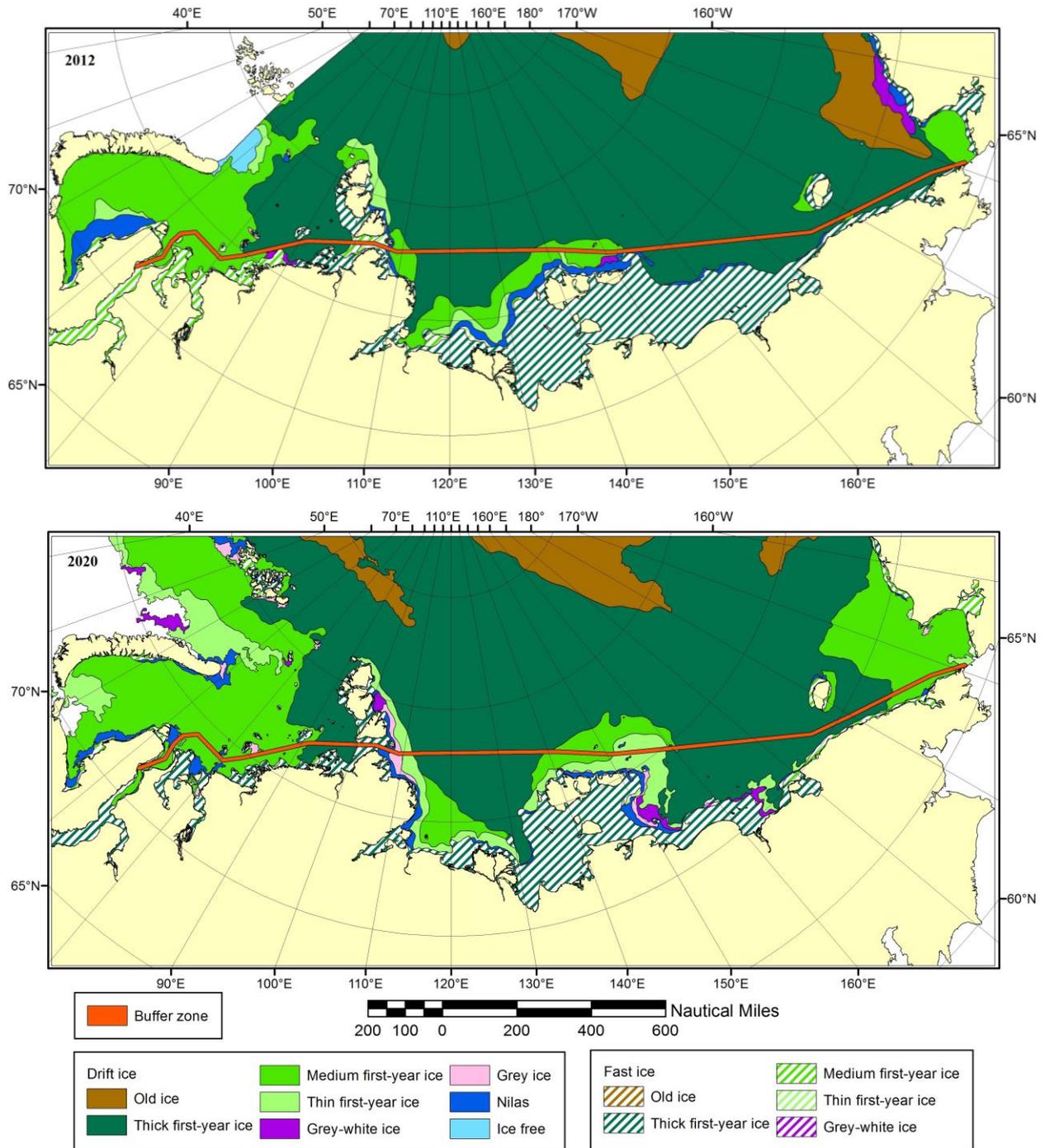


Figure 2. Spatial spreading of oldest age ice gradations in first third of May in 2012 and 2020

It is evident complete disappearance of the old ice from the route. Values of the conditional lengths of the old ice and the thick first-year ice as a percentage of the route length are presented in the Table 1. The table corroborates the disappearance of the old ice from the route “Sabetta Port – the Bering Strait” and some decrease of the thick first-year ice amount. Probably, the old ice disappearance may be explained by the increase of the cyclonic activity. The increase also may be the main reason of the

decrease of the thick first-year ice amount. The Table 2 demonstrates the total conditional lengths of the route legs within big and vast floes of the old ice and the thick first-year ice. The table shows significant decrease of amount of the vast and big floes of the old and thick first-year ice since 1998.

Table 1. Conditional lengths of the old ice and the thick first-year ice as a percentage of the route “Sabetta Port – Bering Strait” length

Years	1998		2005		2012		2020	
Month, ten-day interval	Old	Thick	Old	Thick	Old	Thick	Old	Thick
4_1	14.3	64.2	3.2	60.0	0.0	29.4	0.0	26.2
4_2	15.4	60.0	5.6	56.0	0.0	34.4	0.0	28.2
4_3	18.2	61.0	2.9	60.3	0.0	37.5	0.0	28.2
5_1	14.9	58.9	3.1	60.5	0.0	42.6	0.0	29.5
5_2	23.0	55.2	3.1	58.2	0.0	45.6	0.0	28.4
5_3	23.4	54.6	2.8	56.4	0.0	43.1	0.0	26.2

Table 2. Total conditional lengths of the route legs within big and vast floes of the old ice and the thick first-year ice as a percentage of the route “Sabetta Port – Bering Strait” length

Years	1998		2005		2012	2020
Month, ten-day interval	Old	Thick	Old	Thick	Thick	Thick
4_1	9.5	32.4	0.9	43.4	19.7	15.0
4_2	10.3	29.1	0.8	41.0	22.3	16.4
4_3	12.0	29.4	0.7	42.4	24.3	16.3
5_1	9.9	33.3	0.7	43.5	27.3	17.0
5_2	15.4	25.9	0.7	41.2	28.6	16.2
5_3	15.6	25.5	0.7	38.9	26.7	14.9

4. Discussion and conclusions

The improvement of the ice navigation conditions is evident. However, the Northern Sea Route cannot completely substitute the route between Eastern Asia and Europe through the Suez Canal because there is danger of the cargo vessels nips due to the drift ice compacting. It must be emphasized that the thick first-year ice has the same strength, as the old ice. The most dangerous sea ice objects are hummock ridges with consolidated layer. Therefore there is no significant difference between the risk from the old ice or the thick first-year ice. Any vessel on the Northern Sea Route must have high category of the ice reinforcing. The fact prevents the transformation of the Northern Sea Route in international marine transport system for vessels without the ice reinforcing. Probably, these vessels can sail along the route for August and September with icebreaker support, if the ice conditions allow it. It means that there is only very open floating ice along the route.

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