The Northern Sea Route under New Ice Conditions

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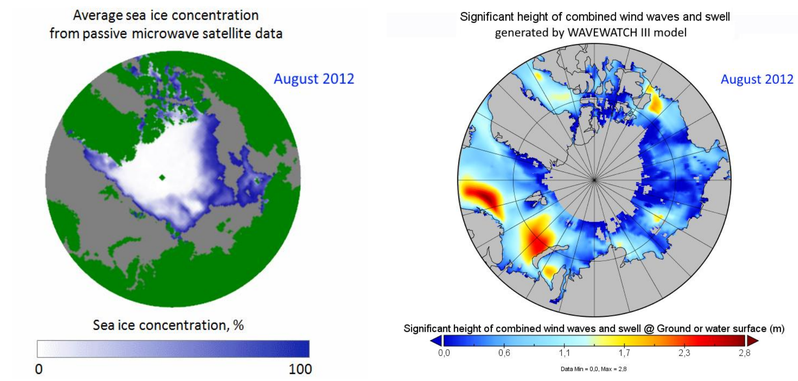
Introduction

One of the most strong signals of rapid change in the Arctic is the loss of summer sea ice during the last decades. The downward trend is supported by complex feedback mechanisms between thermodynamic and dynamic processes. The enlarged ice-free area results in increasing the effective fetch (Thomson and Rogers, 2014), and thus more energetic wave events may be expected in the marginal seas. Since waves can break up a thin ice cover in the marginal zone (Collins et al, 2015) it is also expected that wave-ice interaction will lead to some intensification of sea ice retreat.

Increased area of open waters releases new possibilities for navigation along the Northern Sea Route (NSR). On the other hand, possibility of generation of larger waves in the marginal seas make an area more dangerous to navigation. Here, we analyze changes in sea ice and wave conditions in the NSR over the last decade. The study is done for a standard navigation route suggested by NSR Advisory. Sea ice conditions are described basing on the satellite passive microwave observations. Wave conditions are described using NOAA wave model WAVEWATCH III (Tolman, 2009) simulations.

Data

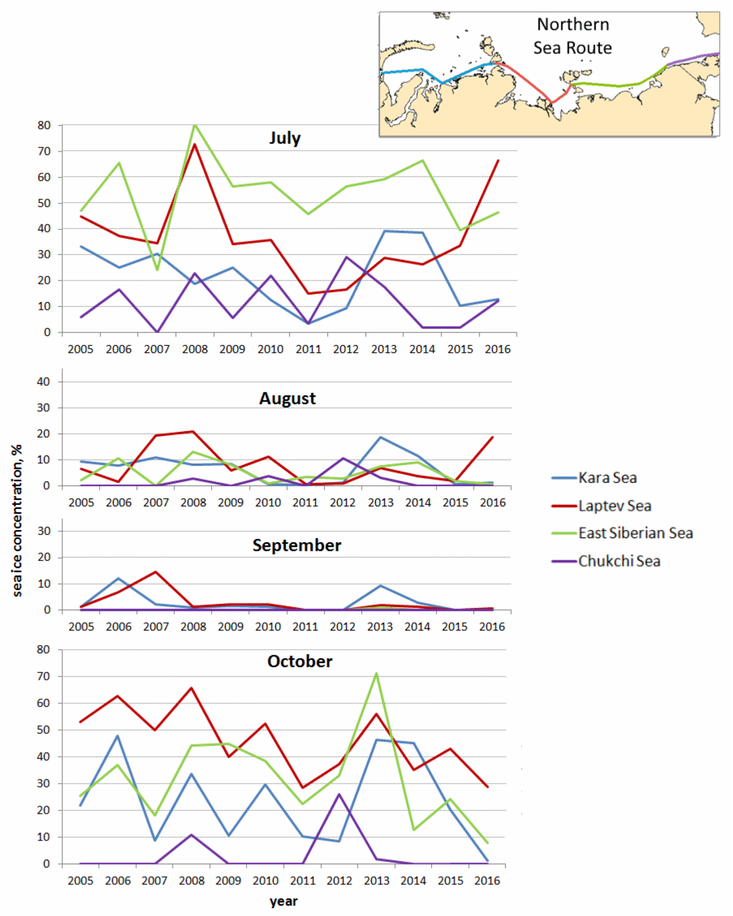


Examples of monthly averaged sea ice concentration and wave height products.

Sea ice concentrations are calculated using NORSEX algorithm.

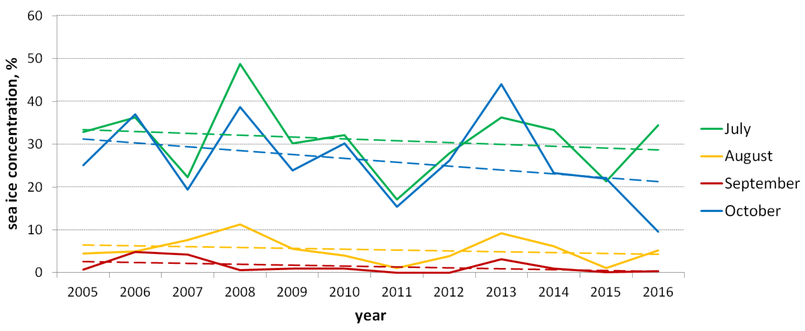
Wave heights are from the WAVEWATCH III numerical wave model calculations. The model is forced with the U.S. Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) wind fields and ice products derived from satellite passive microwave radiometers. Ice presence or absence is determined using a 25% threshold. Data are available from 2005-2017.

Sea ice concentration along the Northern Sea Route (NSR)



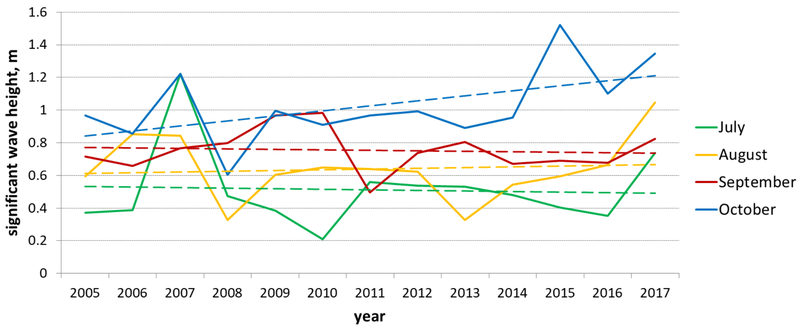
Monthly averaged sea ice concentration on different sections of the NSR.

Observations show that in September the NSR has been practically free of ice over the last nine years, except for 2013, when at the section in the Kara Sea the mean ice concentration increased to 9%. The latter situation is associated with the accumulation of ice in the northeastern part of the Kara Sea near the Vilkitsky Strait, which is known to be the bottleneck for shipping on the NSR. The highest ice concentrations are recorded (in July and October) in the Laptev and East Siberian seas. Significant level of variability can be illustrated by the range of standard deviation in July, which was from 27% in the East Siberian Sea up to 84% in the Chukchi Sea.



Monthly averaged sea ice concentration on the whole NSR.

Average sea ice concentration observed in July is 31.1 ± 8.3 %, in August 5.4 ± 2.9 %, in September 1.4 ± 1.6 %, in October 26.2 ± 9.9 %. Observed tendencies in ice concentrations are negative, from 0.9 to 0.19 % per year with low values of R^2.

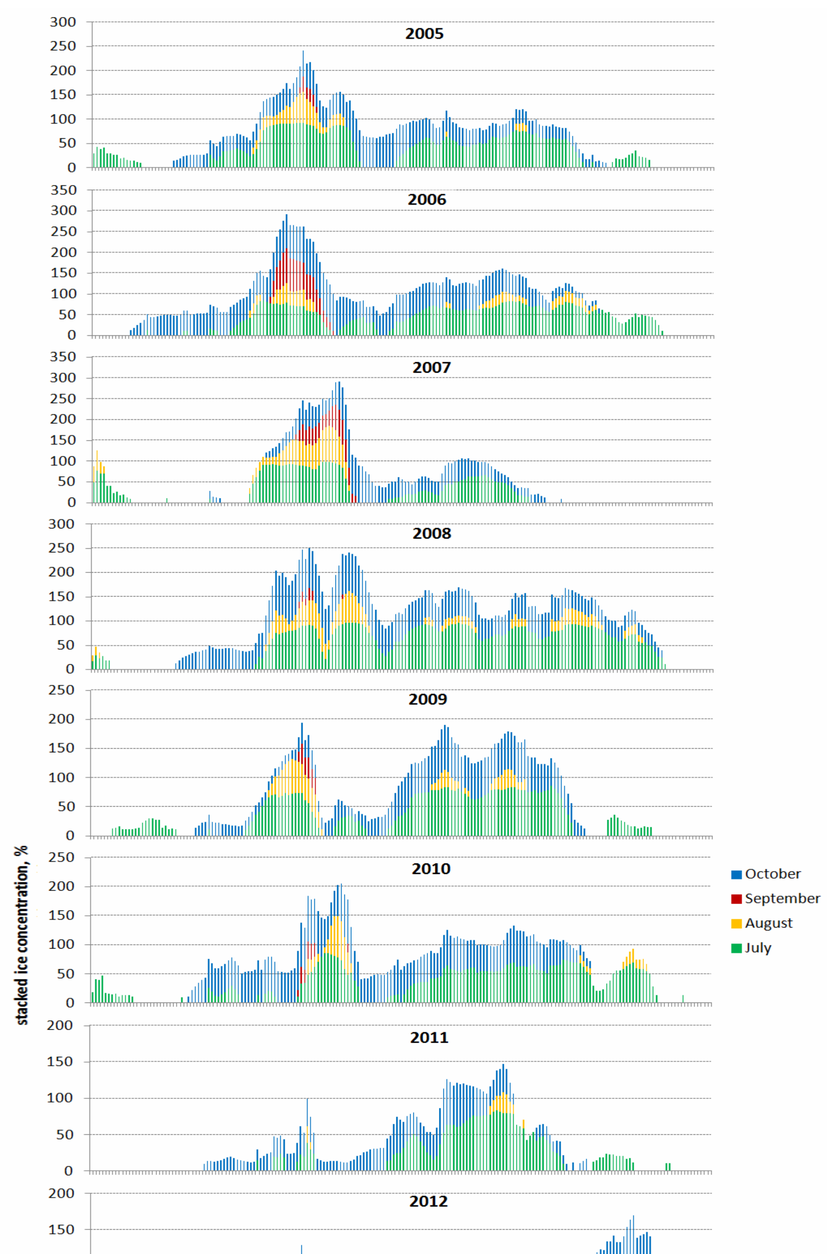


Monthly averaged WAVEWATCH III significant wave height along the NSR, 2005-2017.

Calculated monthly averages are the following: 0.55 ± 0.24 m in July, 0.63 ± 0.19 m in August, 0.75 ± 0.12 in September and 1.02 ± 0.22 in October. The positive linear tend in October is estimated as 0.03 m with the R^2 = 0.27. Other trends are insignificant.

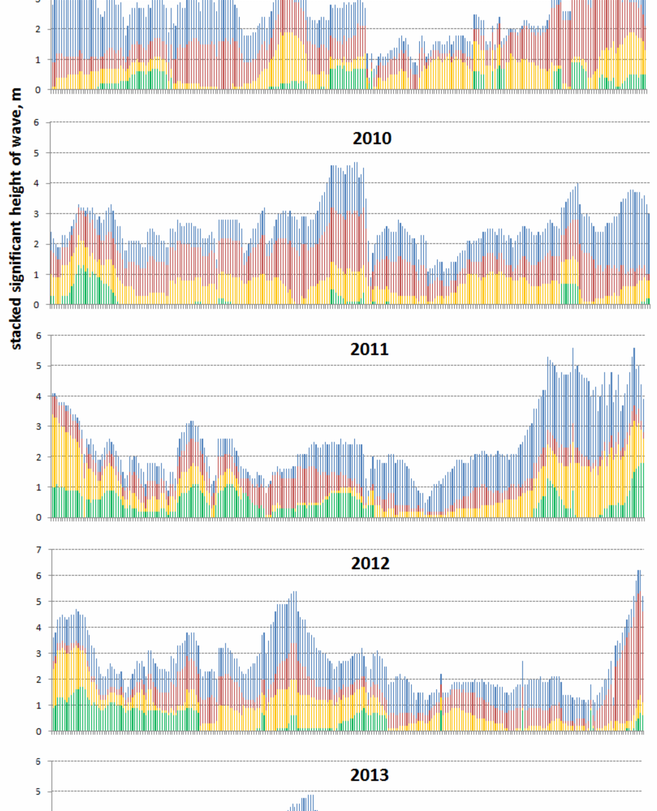
Correlation analysis of wave height and presence of ice on the route revealed a negative correlation with the coefficients of -0.35 in July, -0.48 in August, and -0.57 in October. In September correlation is insignificant, which is explained by virtual absence of sea ice on the route.

Sea ice concentration along the Northern Sea Route



Profiles of sea ice concentration along the NSR demonstrate that the major obstacle for navigation in August and September is the ice in the area around Vilkitsky Strait that connects the Kara and Laptev Seas. The ice can block the route staying in the Kara Sea or in the Laptev Sea as well.

Significant wave height simulated by the WAVEWATCH III model along the Northern Sea Route in July, August, September and October



The profiles of wave height along the NSR show that the highest waves are observed in October and with clearing the route from ice in 2005-2016 the waves become higher. The highest wave in October are observed in the Kara Sea.

References

Collins, C. O., W. E. Rogers, A. Marchenko, and A. V. Babanin, 2015: In situ measurements of an energetic wave event in the Arctic marginal ice zone. GRL, 42, 1863–1870, doi:https://doi.org/10.1002/2015GL063063

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