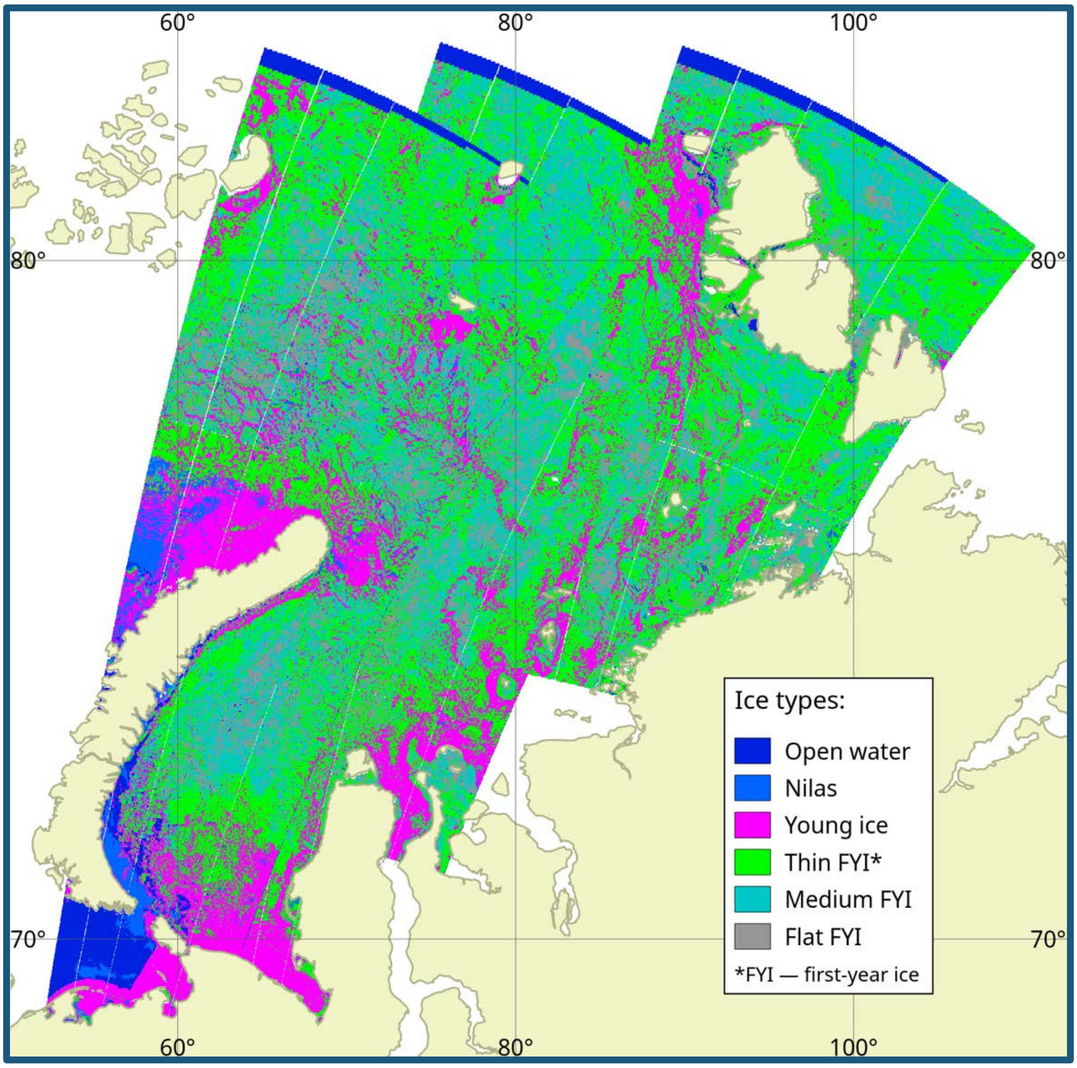
Annual Report 2019

Nansen International Environmental and Remote Sensing Centre

St. Petersburg, Russia

Non-profit international centre for environmental and climate research
Founded in 1992



Advanced satellite retrieval algorithms allow operational high resolution ice charting in the Arctic

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Cover page: Automated sea ice type classification in the Kara Sea on 25 April 2019 using Sentinel-1 SAR images and Support Vector Machine based technique (resolution of the map is about 300 meters).

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Vision

The Scientific Foundation "Nansen International Environmental and Remote Sensing Centre" (Nansen Centre, NIERSC) vision is to understand, monitor and predict climate and environmental changes in the high northern latitudes for serving the Society.

Scientific Research Groups

- Climate of High Northern Latitudes (*Head Dr. Leonid Bobylev)*
- Aquatic Ecosystems Under Global Warming (*Head Prof. Dmitry Pozdnyakov)*
- Applied Meteorological and Oceanographic Research (*Head Dr. Vladimir Volkov*)

Organization

NIERSC is an independent non-profit international research foundation established by Russian, Norwegian and German research organizations. NIERSC conducts basic and applied environmental and climate research funded by the national and international governmental agencies, research councils, space agencies and industry.

NIERSC was established in 1992 and re-registered at the St. Petersburg Administration Registration Chamber into a non-profit scientific foundation in 2001. The Centre got accreditation at the Ministry of Industry, Science and Technology of the Russian Federation as a scientific institution in 2002 and was re-registered in 2006 according to a new legislation on Non-Commercial Organizations of the Russian Federation.

NIERSC got a license for conducting meteorological and oceanographic observations from Roshydromet in 2006. In 2008 NIERSC received also a license from Roscosmos for conducting space-related research activities.

Staff

At the end of 2019 NIERSC staff incorporated 28 employees, 15 full-time and 13 part-time, comprising research and administrative personnel. Research personnel included one full Doctor of Science and 12 PhDs. 3 PhD-students and 2 master students were supervised and supported financially through the Nansen Fellowship Programme, all holding also part-time positions of Junior Scientists at NIERSC.

Scientific Production

In 2019, totally 38 publications were published including 9 papers in peer reviewed journals, 7 papers in other journals and 22 abstracts and brief papers in conference proceedings (see the list of main publications at the end of the report).

National and International Cooperation

NIERSC has a long-lasting cooperation with Russian organisations including St. Petersburg State University and institutions of the Russian Academy of Sciences, Federal Space Agency, Federal Service for Hydrometeorology and Environmental Monitoring among which are the Northern Water Problems Institute, Murmansk Marine Biological Institute, Scientific Research Centre for Ecological Safety, Obukhov Institute of Atmospheric Physics, Arctic and Antarctic Research Institute, Russian State Hydrometeorological University, Voeikov Main Geophysical Observatory and other.

Fruitful relations are established also with a number of foreign and international organizations, universities and institutions including Global Climate Forum, Climate Service Centre Germany (HZG-GERICS), Max-Planck Institute for Meteorology, Friedrich-Schiller-University (all Germany), Finnish Meteorological Institute and University of Helsinki (Finland), University of Sheffield (UK), Stockholm University (Sweden), Johanneum Research (Austria), Iskenderun Technical University, Turkey, Vlaamse Instelling voor Technologisch Onderzoek (VITO) & Royal Meteorological Institute of Belgium, Gent University (Belgium), Latvian Environment, Geology and Meteorology Centre, and especially with the NIERSC founders. Close cooperation is established with the Nansen Centre and the Nansen Scientific Society in Bergen, Norway.

Nansen Fellowship Programme

The main goal of the Nansen Fellowship Program (NFP) at NIERSC is to support PhD-students at the Russian educational and research institutions, including Russian State Hydrometeorological University, St. Petersburg State University, Arctic and Antarctic Research Institute, and other. The preferred research areas include climate and environmental changes in the Arctic, North Atlantic and Northern Eurasia, as well as methods and techniques of satellite remote sensing with focus on the Arctic and Sub-Arctic. NFP provides PhD-students with the Russian and international scientific supervision, financial fellowship, efficient working conditions at NIERSC, training and research visits to the international research institutions within the Nansen Group and beyond, involvement into international research projects. NFP is sponsored by the NIERSC, Nansen Scientific Society and Nansen Centre in Bergen, Norway. Postgraduate student activity is supervised by at least one Russian and one international senior scientist. All NFP PhD-students obliged to publish their scientific results in the international refereed journals and make presentations at the international scientific symposia and conferences.

Denis Demchev, the participant of the Nansen Fellowship Programme, has successfully defended his PhD Thesis "Methods of retrieval, analysis and monitoring of sea ice and iceberg drift using satellite radar data" on 17 June 2019 at the St. Petersburg State University. Thus, 30 Russian PhD-students have got their doctoral degrees under NFP since 1994.

Main Research Projects

INTAROS-Russia is the project complemented to the European Union's Horizon 2020 project INTAROS (Integrated Arctic Observation System) carried out by a consortium of 41 institutions. The main goal of INTAROS-Russia is development and application of Russian segment of the Integrated Arctic Observation System for providing Russian authority, organizations, stakeholders and public with the comprehensive and quality hydrometeorological and oceanographic information for the Arctic region. The partners of the INTAROS-Russia are: Research Institute for Hydro-meteorological Information (RIHMI), Obninsk; Nansen International Environmental and Remote Sensing Centre (NIERSC) and Arctic and Antarctic Research Institute (AARI), St. Petersburg. INTAROS-Russia is funded by the Ministry of Science and Higher Education of Russian Federation (Unique Project Identifier RFMEFI61618X0103, 2018-2020).

AFTER (Impacts of climate change and climate extremes on the agriculture and forestry in the Europe-Russia-Turkey Region) is the interdisciplinary project established in the framework of «ERA.Net RUS Plus Call 2017» program and incorporates the scientific groups of Russia, Germany, Belgium, Latvia and Turkey. AFTER aims at bridging the usability gap between state-of-the-art regional climate data and the demand for information at regional scale for climate change impact assessment and adaptation. The main objective of AFTER is to provide state-of-the-art climate information to assess: (i) impact of ongoing and projected global climate change and subsequent changes in climate extremes on the agriculture and forestry in selected regions of Europe, Russia and Turkey; and (ii) the level of contribution, which these changes in agriculture and forestry can provide to climate change mitigation and adaptation due to existing feedbacks. Project partners: NIERSC, St. Petersburg, Russia, coordinator; Ghent University, Gent, Belgium; Climate Service Centre Germany, Hamburg, Germany; Latvian Environment, Geology and Meteorology Centre, Riga, Latvia; Vlaamse Instelling voor Technologisch Onderzoek (VITO), Brussels, Belgium; Iskenderun Technical University, Iskenderun, Turkey. In Russia AFTER is funded by the Russian Fund for Basic Research (RFBR), Grant 18-55-76004, 2018-2020.

Assessment of calcifying phytoplankton role in CO_2 dynamics in the atmosphere-ocean system at subpolar and polar latitudes is the project aimed at the quantitative assessment of dynamics of (i) spatial extent and duration of blooms of *Emiliania huxleyi* as the major calcifying microalga in pelagic waters of the North, Norwegian, Labrador, Greenland, Barents and Bering seas, (ii) intensity of inorganic carbon production, and (iii) CO_2 partial pressure within blooms and in the atmospheric layer above them, as well as performance of projections of these parameters till the mid of the present century. The project is funded by the Russian Science Foundation (RSF), Grant No. 17-17-01117, 2017-2019.

Dynamics of deep oceanic convection in subpolar and polar oceanic regions under the climate change, its relation to freshwater and heat fluxes and its effect on the Atlantic Meridional Overturning Circulation (AMOC) is the project with the goal to assess interannual variability of intensity of deep convection in the Nordic seas and the Labrador-Irminger seas as an element of the global climate system. The first project stage is devoted to deriving interannual variations of convection intensity in the Greenland, Labrador and Irminger seas. The second stage aims to revealing interannual variations of the freshwater and heat fluxes to the regions of deep convection. A link between the interannual variations of convection intensity and the AMOC is investigated during the third stage of the project. This project is funded by the Russian Science Foundation (RSF), Grant No. 17-17-01151, 2017-2019, via St. Petersburg State University.

ARCONOR (Arctic cooperation between Norway, Russia, India, China and US in satellite Earth observation and Education) is the international project aimed at the sustaining long-term international partnership and cooperation between Norway, Russia, India, China and US in the area of satellite Earth observations for monitoring and forecasting the Arctic and support to Arctic shipping through advancing research, higher education and recruitment. ARCONOR is coordinated by the Nansen Environmental and Remote Sensing Centre (NERSC), Bergen, Norway, with partners: Nansen Scientific Society (NSS), Bergen, Norway; NIERSC, St. Petersburg, Russia; Nansen Environmental Research Center – India (NERCI), Kochin, India; Nansen-Zhu International Research Centre (NZC), Beijing, China; and the University of Connecticut, Storrs, USA. ARCONOR is funded by the Research Council of Norway; NIERSC participation is funded partly by grants from NERSC and NSS, 2017-2021.

Wind speed and wave field dynamics in polar lows and their impact on sea ice is the project devoted to studying distribution of surface wind speeds within polar lows in the Arctic, its influence on wind waves and swell generated by polar lows, and their combined impact on sea ice and marginal ice zone. This project is funded by the Russian Science Foundation (RSF), Grant No. 19-77-00092, 2019-2021.

ARCONOR Summer School 2019

The international interdisciplinary PhD and Post-Doc Summer School "Observing and modelling the Arctic environment – Climate processes, prediction and projection" has been held at the NIERSC premises in St. Petersburg on 8-13 September 2019 in the framework of the ARCONOR project (see photos at the report's back page). The Programme Committee of the School has been cochaired by Dr. M. Ravichandran, Director of the National Centre for Polar and Ocean Research (NCPOR), Goa, India, and Prof. Noel Keenlyside, University of Bergen/Nansen Centre, Bergen, Norway. The main goal of this school was to provide participating students with an overview of the state-of-the-art of research in the Arctic from observations through process understanding and model development to applications. NIERSC personnel took part in the Summer School as organisers, lecturers or participants.

Scientific Report

CLIMATE OF HIGH NORTHERN LATITUDES

Sea ice volume variability and water temperature in the Greenland Sea

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Dr. Igor Bashmachnikov, St. Petersburg State University (SPbSU)/NIERSC, St. Petersburg, Russia

Dr. Robert Ricker, Alfred-Wegener-Institut, Bremerhaven, Germany

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Dr. Leonid Bobylev, NIERSC, St. Petersburg, Russia

This study explores a link between the long-term variations in the integral sea ice volume (SIV) in the Greenland Sea and oceanic processes. Using the Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS, 1979–2016), we showed that the increasing sea ice volume flux through the Fram Strait goes in parallel with a decrease in SIV in the Greenland Sea (Fig. 1). The overall SIV loss in the Greenland Sea is 113 km^3 per decade, while the total SIV import through the Fram Strait increases by 115 km^3 per decade.

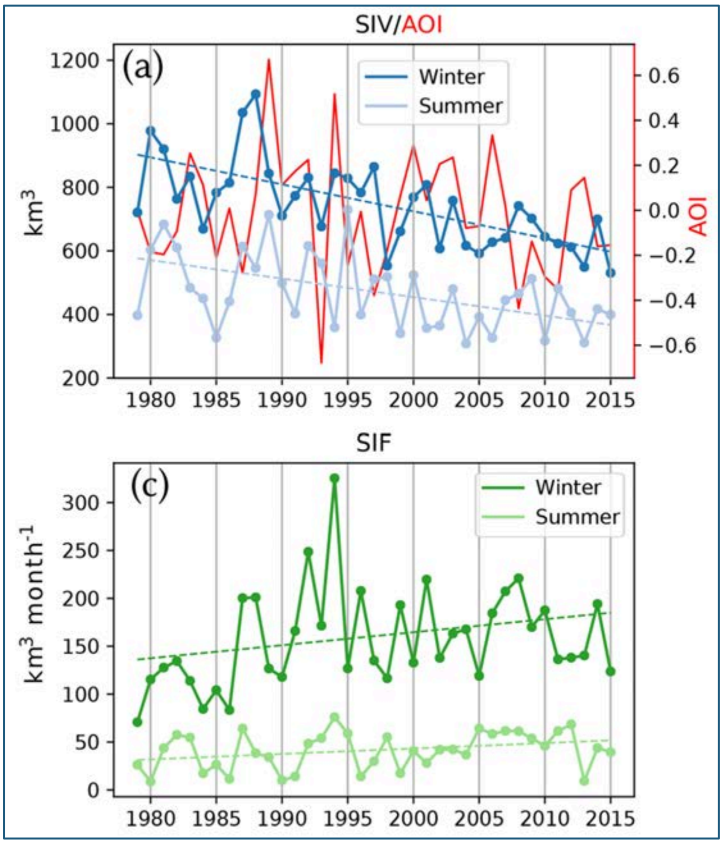

Figure 1. (**a**) Monthly mean PIOMAS sea ice volume (SIV, km^3) in the Greenland Sea and monthly summer Arctic Oscillation (AO) index (AOI); (**c**) monthly mean sea ice volume flux through Fram Strait (SIF, km^3/month).

An analysis of the ocean temperature and the mixed-layer depth (MLD) over the climatic mean area of the winter marginal sea ice zone (MIZ) revealed a doubling of the amount of the upper-ocean heat content available for the sea ice melt from 1993 to 2016. This increase alone can explain the SIV loss in the Greenland Sea over the 24-year study period, even when accounting for the increasing SIV flux from the Arctic. The increase in the oceanic heat content is found to be linked to an increase in temperature of the Atlantic Water along the main currents of the Nordic Seas, following an increase in the oceanic heat flux from the subtropical North Atlantic. We argue that the predominantly positive winter North Atlantic Oscillation (NAO) index during the 4 most recent decades, together with an intensification of the deep convection in the Greenland Sea, is responsible for the intensification of the cyclonic circulation pattern in the Nordic Seas, which results in the observed long-term variations in the SIV.

Acknowledgment: This study was conducted under the Russian Science Foundation support (project No. 7-17-01151).

Relevant publication: Selyuzhenok, V., Bashmachnikov, I., Ricker, R., Vesman, A. and Bobylev, L. (2020). Sea ice volume variability and water temperature in the Greenland Sea. The Cryosphere, 14, 477–495.

Positive feedback in the convergence of oceanic-atmospheric heat fluxes and ice cover in the Barents Sea

Katrina Kalavichchi, St. Petersburg State University (SPbSU), St. Petersburg, Russia

Dr. Igor Bashmachnikov, SPbSU/Nansen Centre (NIERSC), St. Petersburg, Russia

The heat transported by the ocean and atmosphere to the Barents Sea region play a significant role in the Arctic amplification. The heat fluxes govern ice conditions in the Barents Sea and affect the air temperature over the entire Eurasian sector of the Arctic. The variations of the oceanic heat flux into the Barents Sea and the resulting variations of the regional sea ice extent are thought to give origin to variations in the regional atmospheric circulation which further enhances heat fluxes.

In this study for deriving interannual variability of the convergence of oceanic and atmospheric advective heat fluxes, the gridded oceanic ARMOR-3D data-set and ERA-Interim atmospheric reanalysis were used from 1993 to 2014.

The mean oceanic heat flux over the study period is 102 TW (at the reference temperature of –1.8°C). It shows a significant positive linear trend of 2 TW per year. Over the same period, the mean atmospheric heat convergence into the Barents Sea is 225 TW. It shows small insignificant negative linear trend (Fig. 2). These results assume that the oceanic heat flux plays a leading role in the long-term reduction of sea ice extent in the Barents Sea. However, correlation analysis suggests that the convergence of the atmospheric heat fluxes are more important for the observed variations of the sea ice extent at the interannual time scales.

Analysis also showed that almost 70% of the linear trend in the oceanic heat flux in the Barents Sea is due to an increase in the current velocity. The contribution of increasing water temperature forms only around 30%. Given the confidence intervals, the contribution of each of the components varies within 2-4%. At interannual time scales, as well, the current velocity forms the major contribution to the variability of the oceanic heat flux: the correlation between the oceanic heat flux and the current velocity (over the year and for all seasons) is significant and reaches 0.8, with almost no correlation with the water temperature is found.

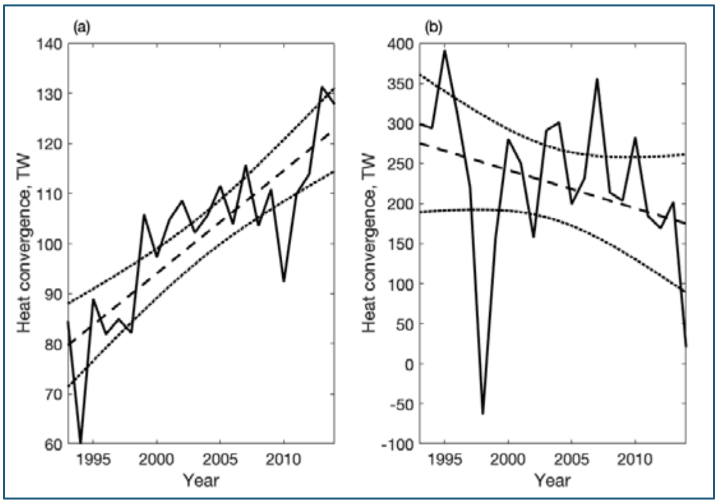

Figure 2. Interannual variability (the annual means) of convergence of (**a**) the oceanic and (**b**) the atmospheric (1000-850 hPa) heat fluxes (TW) integrated along the boundaries of the Barents Sea (solid lines); dashed lines present linear trends and dotted lines are their confidence intervals.

Among the three branches, passing through the Barents Sea Opening, the North Cape Current governs the interannual variability of the overall water transport. Transport by both, the North Cape and the Return current, increases with an increase in the convergence of Ekman transport. The latter is due to the increased gradient of the zonal component of wind velocity in the Barents Sea Opening. In turn, the variations of the atmospheric circulation are linked to the increased oceanic heat flux into the sea.

The results suggest a new mechanism of the positive feedback between variations in the oceanic heat flux into the Barents Sea, the area of the ice cover and the character of atmospheric circulation over the sea.

Acknowledgment: *This study was supported by the Russian Science Foundation project No. 17-17-01151.*

Relevant publication: *Kalavichchi, K.A., Bashmachnikov, I.L. (2019) Mechanism of a Positive Feedback in Long-Term Variations of the Convergence of Oceanic and Atmospheric Heat Fluxes and of the Ice Cover in the Barents Sea. Izv. Atmos. Ocean. Phys. 55, 640–649.*

The performance of global climate models in reproducing Arctic amplification

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Dr. Leonid Bobylev, NIERSC, St. Petersburg, Russia

Dr. Richard Davy, Nansen Centre (NERSC), Bergen, Norway

Arctic amplification is an inherent feature of the Earth's climate system. Nowadays, the rate of the surface air temperature (SAT) increase in the Arctic is about twice the global average rate. The assessment of the capability to reproduce the periods of Arctic amplification in the 20th and 21st centuries by the different datasets has been carried out. Four observational datasets have been used: GISTEMP v4, Berkeley Earth and NansenSAT combined with HadCRUT4. Also, the ERA-20C reanalysis data have been used as they cover the whole 20th century. However, a special focus was on the performance of the global climate models CMIP5, where two experiments were considered: historical and pre-industrial control runs. For the quantitative estimation of Arctic amplification, a metric based on the difference of average area-weighted SAT anomalies between the Arctic region and the whole Northern Hemisphere has been used.

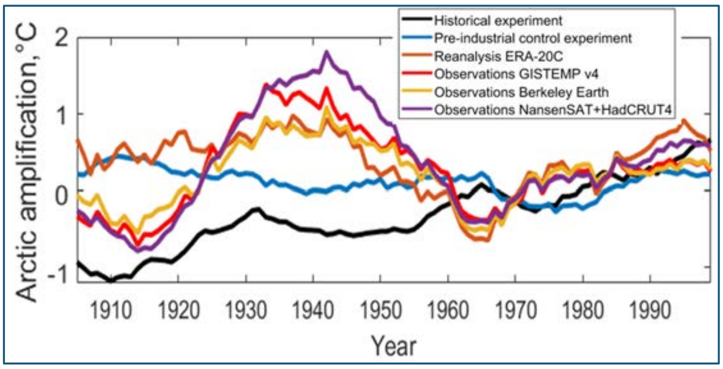

Figure 3. Arctic amplification (AA) in models (two CMIP5 experiments for winter season (January-March) with the averaging through the ensemble consisting of 9 models), ERA-20C reanalysis and observations (GISTEMP v4, Berkeley Earth and NansenSAT+HadCRUT4). AA is calculated for the region 70-90N relative Northern Hemisphere.

It is shown that all observational datasets reproduce the three periods of Arctic amplification in the 20th and 21st centuries: positive phase in 1920s-1940s, negative phase in 1960s-1970s and present positive one which has started at the beginning of the 1980s and is still ongoing. The reanalysis data ERA-20C significantly underestimate the early twentieth-century warming; however, they are in good agreement with observations for the other two periods. CMIP5 climate models in the historical experiment, which includes both natural and anthropogenic forcing, successfully show just the current period of amplification which, as thought, is the only one mainly effected by the external radiative forcing. Presumably, this is due to the fact that models cannot correctly reproduce some processes of natural long-term climate variability. In the CMIP5 pre-industrial control experiment, the Arctic amplification is absent as a phenomenon which confirms the importance of external forcing to trigger the current Arctic amplification. The results are summarized in Fig. 3.

Impact of extratropical cyclones and polar lows on sea ice cover: a winter 2016/2017 case study

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Arctic sea ice extent (SIE) in 2016/2017 winter season was the lowest in satellite record. In November and December 2016 this was mostly due to the situation in the Barents and Kara seas which were largely ice-free. Unlike this, in October 2016 when the SIE for the whole Arctic was also record-low, the ice cover in these seas was not extremely low. Then, an episode of steep SIE decline in the Barents and Kara seas occurred in November 2016, setting SIE lower than the previously observed lowest value by about 4×10^5 km^2 at its extreme (Fig. 4a). This was followed by a shorter but even steeper episode in December 2016 with a similar magnitude of SIE decline (Fig. 4a,b).

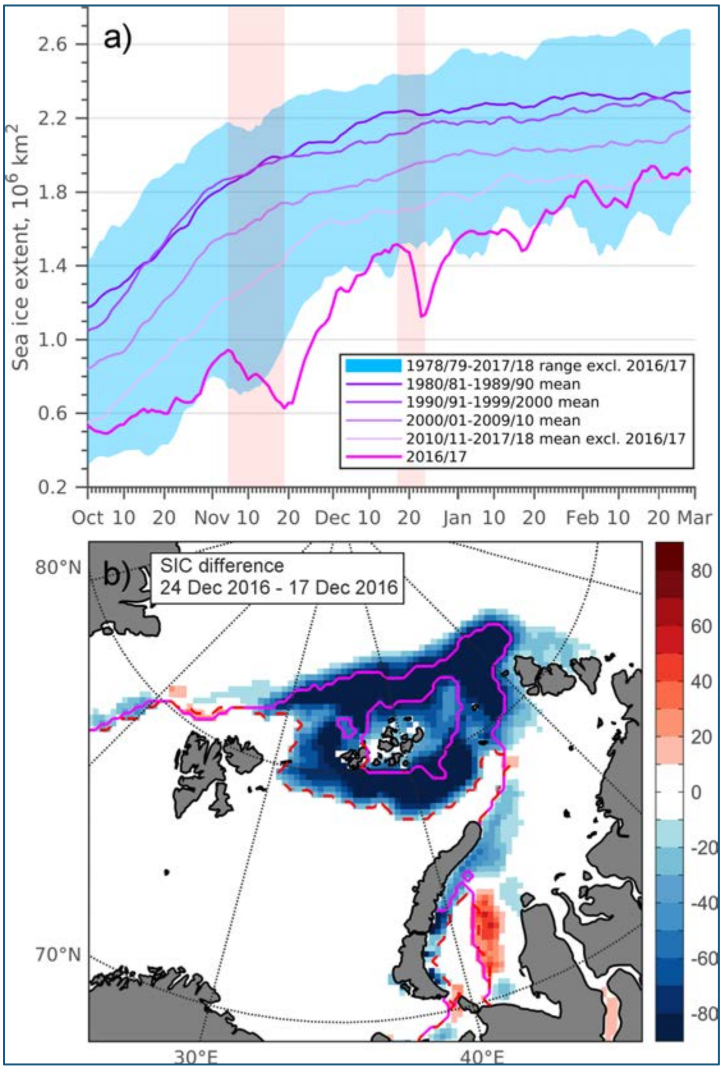

Figure 4. (**a**) Daily sea ice extent in the Barents and Kara seas from 1 October to 1 March for different periods. Pink shaded areas indicate the analysed periods of sea ice extent decrease in November and December 2016. (**b**) Difference in sea ice concentration (%) between 24 December 2016 and 17 December 2016. Magenta line indicates sea ice extent on 24 December 2016. Red dashed line indicates sea ice extent on 17 December 2016.

In this study we analysed meteorological and oceanographic conditions during these two episodes which largely caused the Arctic-wide record low SIE in November and December 2016. For this analysis we used satellite passive microwave and synthetic aperture radar (SAR), atmospheric reanalysis and model data. SAR data were used to obtain sea ice drift and deformation information. Such parameters as mean sea level pressure, air and sea surface temperature, wind speed, and significant wave height were analyzed along with sensible and latent heat fluxes and longwave radiation flux data, which were used for calculation of surface energy balance. As found, in both November and December 2016 the SIE decrease was induced by series of atmospheric cyclones. Most of these cyclones passed over the Fram Strait. All the data were combined to separately assess thermodynamic and dynamic impact of individual cyclones on sea ice cover.

Evaluation of regional climate models ALARO-0 and REMO over the CORDEX Central Asia domain

Participants of AFTER Project: Germany, Belgium, Latvia and Turkey
Dr. Leonid Bobylev, Nansen Centre (NIERSC), St. Petersburg, Russia
Dr. Natalia Gnatiuk, NIERSC, St. Petersburg, Russia

For climate impact studies on human and natural systems, high resolution climate information is needed. Over some parts of the world, plenty of regional climate simulations have been carried out, while in other regions hardly any high-resolution climate information is available. Our study aims at addressing one of these regional gaps by presenting an evaluation for two regional climate models (RCMs), REMO and ALARO-0, at a horizontal resolution of 0.22° (25 km) over the Central Asia.

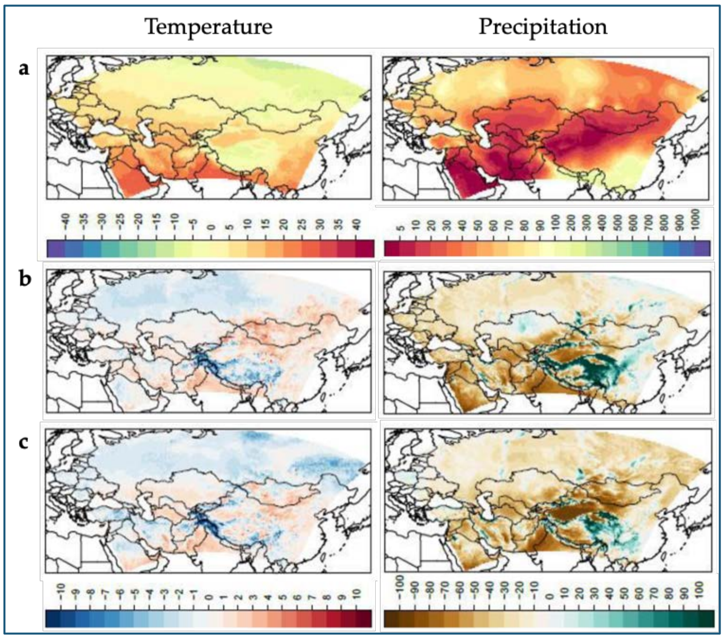

Figure 5. Left column: Annual mean air temperature (°C) at 2 m height over the CAS-CORDEX domain based on the observational CRU dataset for the period 1980-2017 (row a) and the difference between simulated and observed mean annual temperature for REMO (row b) and ALARO-0 (row c) models. **Right column:** Average annual precipitation (mm/month) over the CAS-CORDEX domain based on the observational CRU dataset over the 1980-2017 period (row a) and the difference between simulated and observed average precipitation for REMO (row b) and ALARO-0 (row c) models.

The output of the ERA-Interim driven RCMs is compared with different observational datasets over the 1980-2017 period. The choice of the observational dataset has an impact on the scores but in general one can conclude that both models reproduce reasonably well the spatio-temporal patterns for temperature and precipitation. The evaluation of minimum and maximum temperature demonstrate that both models underestimate the daily temperature range. More detailed studies of the annual cycle over subregions should be carried out to reveal whether this is due to an incorrect simulation in cloud cover, atmospheric circulation or heat and moisture fluxes.

In general, the REMO model scores better for temperature whereas the ALARO-0 model prevails for precipitation. This study demonstrates that the REMO and ALARO-0 RCMs can be used to perform climate projections over Central Asia which can be applied in impact modeling (Fig. 5).

Acknowledgment: *This study was supported by the ERA.Net RUS Plus programme in the framework of AFTER project (Russian Fund for Basic Research Grant 18-55-76004).*

Relevant publication: *Top, S., …, Bobylev, L., De Troch, R., Gnatiuk, N., et al. (2020). Evaluation of regional climate models ALARO-0 and REMO2015 at 0.22° resolution over the CORDEX Central Asia domain. Geosci. Model Dev. Discuss., in review process.*

Aquatic Ecosystems under Global Warming

An innovative algorithm for spaceborne identification of coccolithophore blooms in the world's oceans

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PhD-student Dmitry Kondrik, NIERSC, St. Petersburg, Russia

Svetlana Chepikova, NIERSC, St. Petersburg, Russia

Elizaveta Ignatieva, NIERSC, St. Petersburg, Russia

Unicellular marine algae Coccolithophores in general, and specifically one of their taxons *E. huxleyi*, are most widely distributed calcifying and photosynthesizing phytoplankton across the world's oceans, both in the southern and northern Hemispheres. They form gigantic blooming areas and, due to the calcification processes proceeding within their cells, are capable of significantly affect the balance of inorganic carbon both at the atmosphere-marine surface water interface and in marine surface water per se. Assessment of spatio-temporal dynamics in these processes across the world's oceans requires, as a first step, quantitative assessments of *E. huxleyi* bloom areas over a sufficiently long period, at least a couple of decades.

Earlier, an algorithm for delineation of *E. huxleyi* bloom zones was developed by us to automatically delineate *E. huxleyi* blooming areas in sub-Arctic and Arctic seas employing space observations. That algorithm exhibited efficient performance for the above marine areas. Nonetheless, our attempts to extend its applicability to marine environments at other latitudes, including the South Ocean, revealed the necessity to significantly improve it.

Thus, the principal aim of our work in 2019 became the development of a new ocean colour data based algorithm permitting to confidently perform *E. huxleyi* bloom contouring throughout the world's oceans. As input data, remote sensing reflectance (Rrs) values in six spectral channels (412, 443, 490, 531, 555 and 670 nm) at a resolution of 4 by 4 km and 8 days were taken from the GlobColour website (http://globcolour.info). Supporting information on *in-situ* measurements of Rrs spectra from *E. huxleyi* bloom zones was found at the free access database resource PANGEA (https://pangaea.de/). Then, using special procedure, the Rrs specific features were established for all marine environments throughout the world's oceans. The statistically sound set of features thus established constituted the base of the new algorithm for automated identification of *E. huxleyi* bloom zones. The new algorithm permits to exclude zones in the world's ocean, where Rrs spectra resemble those from genuinely *E. huxleyi* bloom zones, but in really originated from either shallow marine zones with bottoms covered by corals or coral sands or else marine waters heavily loaded with suspended matter of specific mineralogical composition. Thus, marine zones with depths under 50 m, and zones with confirmed coral reefs are automatically brushed away by the algorithm. These operational options permit to avoid Rrs misclassification and erroneous ascription of the aforementioned waters to *E. huxleyi* bloom zones. The algorithm application results in generation of binary masks visualizing *E. huxleyi* bloom localization at a time resolution of 8 days (Fig. 6).

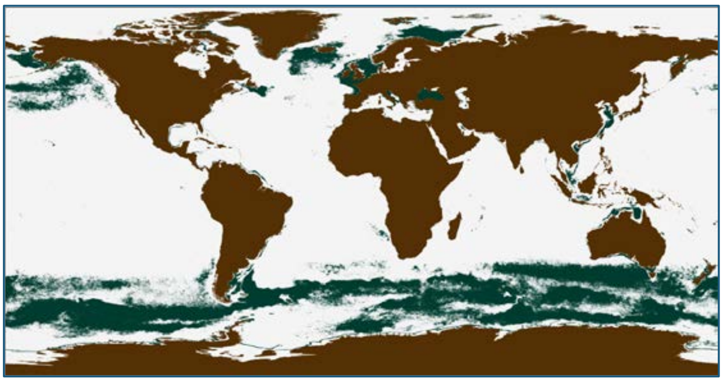

Figure 6. The summarized mask of coccolithophores bloom in the World Ocean for 1997-2019.

Analysis of the generated masks indicated that the developed algorithm confidently separates *E. huxleyi* bloom areas from both oligotrophic/low productivity marine zones and zones of mass development of algae of other phenological groups throughout the world's oceans.

Acknowledgment: *This study was conducted under the Russian Science Foundation support (project No. 1717-01117).*

Major factors determining *E. huxleyi* blooms

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The first part of this study was performed in 2018 and aimed at identifying the environmental vector factors predominantly controlling the growth of *E. huxleyi* blooming. The further advancement of this study was sought through the inclusion of a set of environmental scalar factors that, conjointly with the vector factors, determine the extent and rate of *E. huxleyi* blooming. The above set of factors included five indexes of large-scale atmospheric circulation viz. Arctic Oscillation (AO), North Atlantic Oscillation (NAO) Atlantic Multidecadal Oscillation (AMO), Pacific Decadal Oscillation (PDO), and Oceanic Niño Index (ONI), as well as sea ice cover characteristics relevant to the studied marine regions.

Of the five tested indexes of atmospheric circulations, solely AO, PDO and ONI proved to be more or less significant factors in the case of the North Atlantic and Arctic, although none of the time series of these three indexes evinced any statistically significant relationship with the intensity of *E. huxleyi* blooms. Changes in index phases, their mean and absolute maximal magnitudes undoubtedly affect the marine environment accommodating the inherent phytoplankton community and the competitive processes unfolding within it. Obviously, it proceeds primarily through modulation of water temperature of surface ocean/sea, the latter being one of the most strong factors controlling the growth of the algal taxon considered.

Specifically in the case of the Bering Sea, PDO and ONI proved to be relevant and are thought to act through modulation of surface marine currents driven in turn by modulations of Alaska Stream and intensification of water flow through Aleutian Arc into the zone where *E. huxleyi* blooms have been observed from space between 1998 and 2001. The North Pacific waters arriving at the above area condition not only the vector factors considered but also the concentration of nutrients, specifically iron. At that, the mechanism of PDO and ONI influence did not have a distinctly thermal nature.

Analyses of the ice-cover characteristics revealed no significant relation with *E. huxleyi* blooms, occurrence extent, duration and disappearance in all investigated seas. The highest correlation coefficient (r = 0.51) was evinced for the Barents Sea between the bloom onset date and the date of ice cover retreat. The reason why the ice-cover status affects most pronouncedly the *E. huxleyi* blooming phenomenon in the Barents Sea resides in the fact that, firstly, the North, Norwegian and Labrador seas do not freeze because of incoming warm Atlantic waters, and secondly, the Greenland Sea is ice-covered throughout winter. Finally, the ice cover in the Bering Sea within the area of *E. huxleyi* blooming is absent around the year due to strong wind action.

The results obtained constitute a base for the extension of this methodology over the world's oceans at other latitudinal zones in search of a deeper insight into the nature of multi-year variations in the phenomenon of *E. huxleyi* blooms.

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CMIP5 climate models validation and selection for simulating factors affecting *E. huxleyi* blooms in the Arctic and sub-Arctic seas

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Current climate models are used for performing future projections for various oceanographic, meteorological, and biochemical variables in the Arctic. However, individual models can have large biases when compared to historical observations. The goal of this study is the selection of subsets of climate models that most accurately reproduce the environmental variables that influence the coccolithophore *E. huxleyi* bloom over the historical period. We developed a novel approach for model selection and applied it to each of the Arctic and sub-Arctic seas in which *E. huxleyi* blooms have been observed. Once we have selected an optimal combination of climate models that most skilfully reproduce the factors which affect *E. huxleyi*, the projections of the future conditions in the Arctic from these models can be used to predict how *E. huxleyi* blooms will change in the future.

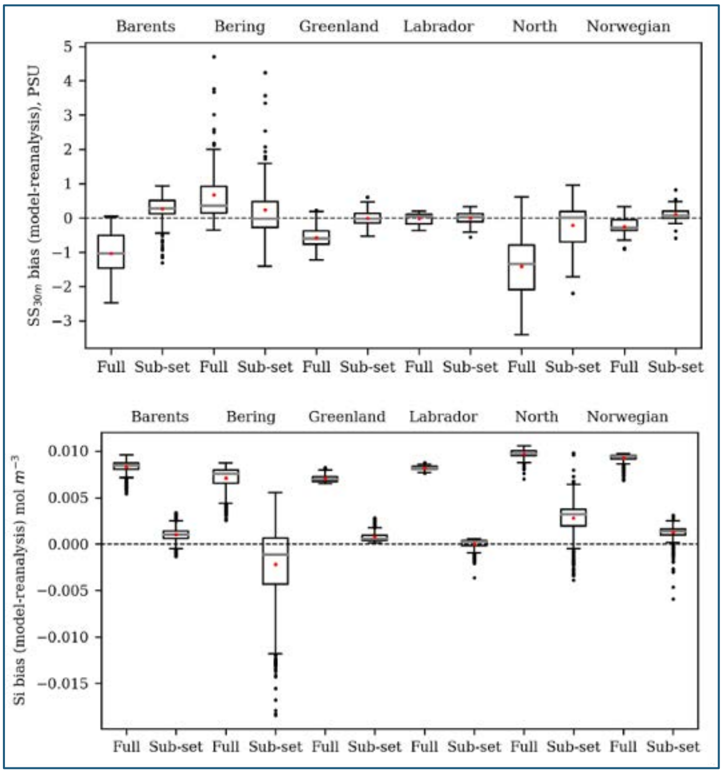

Figure 7. Boxplots of the spatial distribution of biases (difference between model and reanalysis) for sea salinity (top) and silicate (bottom) obtained with full-model ensemble ("Full") and selected model subsets ("Subset") in six Arctic and sub-Arctic seas.

We performed the validation of 34 CMIP5 atmosphere-ocean General Circulation Models (GCMs) over the historical period 1979-2005 using such statistical metrics as the correlation coefficient, difference between observed and model data standard deviations, root mean square error, and climate prediction index (the ratio of root mean square error to standard deviation of observational data). These metrics were used to analyse the seasonal cycle and interannual variability of the considered factors for the studied seas during the blooming season (June-September for the Barents Sea, January-December for the Bering Sea, June-August for the Greenland Sea, June-September for the Labrador Sea, May-July for the North Sea, May-August for the Norwegian Sea). Besides, spatial biases and trends for the blooming season were applied in the analysis using mean values and its amplitude (maximum-minimum) for six Arctic and sub-Arctic seas.

Furthermore, we proposed a procedure of ranking and selecting these models based on the model's skill in reproducing 10 important oceanographic, meteorological, and biochemical variables in the Arctic and sub-Arctic seas. These factors include the concentration of nutrients (NO_3, PO_4, and SI), dissolved CO_2 partial pressure, pH, sea surface temperature, salinity averaged over the top 30m, 10m wind and surface current speed, and surface downwelling shortwave radiation. The selection of CMIP5 models was performed in the study using the proposed percentile ranking approach. The distribution of values of a statistical measure for each model was divided into 4 groups: 25th percentile – very good models with the assigned score of 3, 50th percentile – good models with the assigned score of 2, 75th percentile – satisfied models with the assigned score of 1, and more than 75th percentile – unsatisfied models with score of 0. Further, the total score of each statistical measure was obtained individually for each climate model and used for the final ranking. Finally, the models were ranked with their total score and those GCMs which hit top 25% were selected.

In total, 60 combinations of models were selected for 10 variables over 6 study regions. The results show that there is no combination of models, nor is there one model, that has high skill in reproducing the regional climatic-relevant features of all combinations of the considered variables in target seas. Thereby, an individual subset of models was selected according to our model selection procedure for each combination of variable and Arctic/sub-Arctic sea. Following our selection procedure, the number of selected models in the individual subsets varied from 3 to 11. The selected subsets generally showed a better performance than the full-model ensemble (Fig. 7).

Acknowledgment: This study was conducted under the Russian Science Foundation support (project No. 1717-01117).

Relevant publication: Gnatiuk N., Radchenko I., Davy R., Morozov E., Bobylev L. (2020). Simulation of factors affecting E. huxleyi blooms in Arctic and sub-Arctic seas by CMIP5 climate models: model validation and selection. Biogeosciences, 17, 1199–1212, https://doi.org/10.5194/bg-17-1199-2020

Applied Meteorological and Oceanographic Research

Monitoring ice conditions in the southwestern part of the Kara Sea in 2019 during the period of intensive melting (new generation of ice charts)

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During 2017-2019, the MetOcean Group carried out research and development on the monitoring ice conditions in the Kara Sea within contracts with some commercial companies to ensure the safety navigation and offshore drilling. The work was carried out within the framework of the developed logistics model in accordance with the "System for Monitoring and Prediction of the Sea Ice Cover" (Patent No. 2672531, priority from May 17, 2017) providing scientific and operational information, products and services to users for planning of prospecting and drilling works and managing ice operations on the shelf of the Arctic seas for ensuring ice and environmental safety. The System used advanced methods for constructing an ice classification and sea ice drift maps including compression and rarefaction zones, which allow controlling ice processes during intense melting up to while the sea will be free of ice.

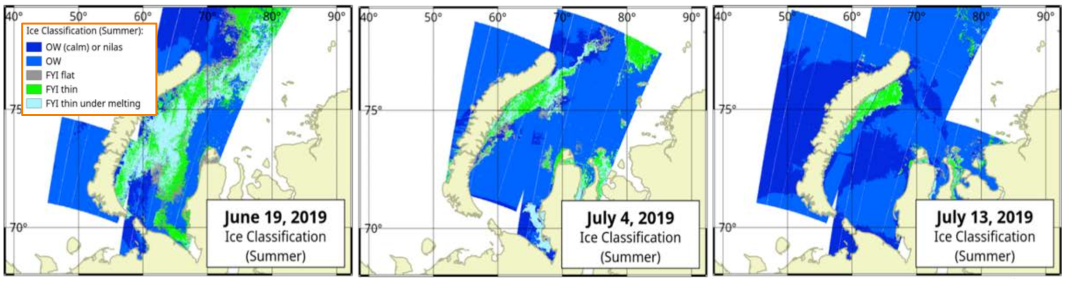

Figure 8. Change of ice conditions in the Kara Sea during intense melting in summer 2019.

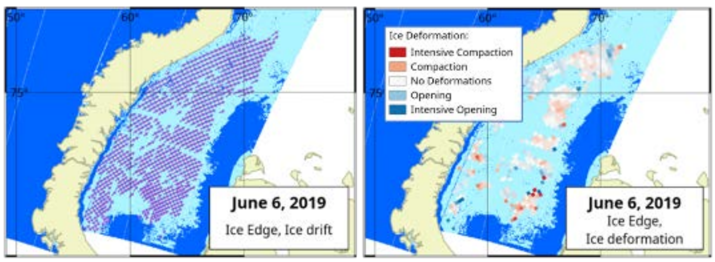

Figure 9. Ice drift-compacting-diverging fields.

The group's achievements in this area in 2019 permit to state that the obtained ice maps can be characterized as the "new generation ice maps" based on automated methods for processing satellite data, having high spatial and temporal resolution, and, as result, being "operational navigation maps". Fig. 8 and 9 show examples of maps describing the course of ice processes in June - July 2019, and charts of drift-compression-rarefaction fields.

Publications

Refereed Papers

1. *Alekseev G., Kuzmina S., Bobylev L., Urazgildeeva A., Gnatiuk N.* (2019). Impact of atmospheric heat and moisture transport on the Arctic warming. *Int. J. Climatol.*, 1-11, https://doi.org/10.1002/joc.6040

2. *Kalavichchi, K.A., Bashmachnikov I.L.* (2019). Mechanism of a Positive Feedback in Long-Term Variations of the Convergence of Oceanic and Atmospheric Heat Fluxes and the Ice Cover in the Barents Sea. *Izvestiya, Atmospheric and Oceanic Physics*, 55 (6), 640–649

3. *Bashmachnikov, I.L., Kovalevskiy D.V.* (2019). Stability analysis of single and multiple equilibria in a nonlinear model of open-ocean deep convection. *Discontinuity, Nonlinearity, and Complexity*, 8(2), 171-188, doi: 10.5890/DNC.2019.06.005

4. *Dukhovskoy D.S., I. Yashayaev, A. Proshutinsky, J.L. Bamber, I.L. Bashmachnikov, E.P. Chassignet, C.M. Lee, and A.J. Tedstone* (2019). Greenland Freshwater Flux Anomaly as a Possible Driver of the Recent Freshening in the Subpolar North Atlantic. *Journal of Geophysical Research: Oceans*, 10.1029/2018JC014686

5. *Kondrik, D., Kazakov, E., and Pozdnyakov, D.* (2019). A synthetic satellite dataset of the spatio-temporal distributoiopns of Emiliania Huxley blooms and their impacts on Arctic and sub-Arctic marine environments (1998-2016). *Earth System Science Data*, 11, 119-128, https://doi. Org.10.5194/essd/-11-119-2019

6. *Vihma, T., Uotila, P., Sandven, S., Pozdnyakov, D., et al.* (2019). Towards an advanced observation system for the marine Arctic in the framework of the Pan-Eurasian Experiment (PEEX). *Atmos. Chem. Phys*, 19, 1941–1970. doi: 10.5194/acp-19-1941-2019

7. *Volkov, V.A., A.V. Mushta, and D.M. Demchev* (2019). Regularities of the variability of large-scale sea ice drift structures in the Arctic Ocean (based on satellite data, 1978–2017). *Reports of Russian Academy of Sciences (Doklady Academii Nauk), Earth Sciences*, Vol. 488, Part 2, pp. 1190–1192 (*in Russian*)

8. *Zakhvatkina N., Smirnov V. and Bychkova I.* (2019). Satellite SAR Data-based Sea Ice Classification: An Overview. *Geosciences*, 9, 152, doi:10.3390/geosciences9040152

9. *Smirnov V.G., I.A. Bychkova, N.Yu. Zakhvatkina, Ye.U. Mironov, S.V. Klyachkin* (2019). Monitoring of the dangerous ice phenomena with the use of satellite imagery and model simulations. *Russian Meteorology and Hydrology*, 44 (1), 746-755

Other Papers

1. *Fedorov A.M., Bashmachnikov, I.L., Belonenko T.V.* (2019). Winter convection in the Lofoten Basin according to ARGO buoys and hydrodynamic modelling. Vestnik SPbSU (Gerald of St. Petersburg State University). Earth Sciences, 64(3), (in Russian), doi: https://doi.org/10.21638/spbu07.2019.308

2. *Iakovleva, D.A., Bashmachnikov, I.L.* (2019). Interannual variations of heat and freshwater contents in the cold water dome of the Labrador Sea. Vestnik SPbSU (Gerald of St. Petersburg State University). Earth Sciences, 64 (1), 136-158 (in Russian)

3. *Bashmachnikov, I.L., Fedorov A.M., Vesman A.V., Belonenko T.V., Dukhovskoy D.C.* (2019). The thermohaline convection in the subpolar seas of the North Atlantic from satellite and in situ observations. Part 2: indices of intensity of deep convection. Current problems in remote sensing of the Earth from space, 16 (1), 191–201

4. *Zhuravskiy, D.M., Prokhorova, UV., Ivanov, B.V., Yanjura, A.S., Kuprikov, N.M., Kurapov, M.V.* (2019). Field tests of photogrammetric evaluation technique of snow-glacial surface albedo. Earth Observation from Space, (4), 18-28 (in Russian).

5. *Morozov, E. A., Kondrik, D.V., Chepikova, S. S., and Pozdnyakov, D.V.* (2019). Atmospheric columnar CO2 enhancement over E. huxleyi blooms: case studies in the North Atlantic and Arctic waters Transactions of the Karelian Research Centre of the Russian Academy of Sciences, Limnologoia i Oceanologia series, 3, 28-33. doi: 10.17076/lim989 (in Russian)

6. *Kondrik, D.V., Kazakov, E.E., Pozdnyakov, D.V., Johannessen, O.M.* (2019). Satellite evidence for enhancement of the column mixing ratio of atmospheric CO2 over E. huxleyi blooms. Transactions of the Karelian Research Centre of the Russian Academy of Sciences, Limnologoia i Oceanologia series, 9, 125-135. doi: 10/17076/lim1107 (in Russian)

7. *Volkov V.A., Zakhvatkina N.Yu., Demchev D.M., Zubkov S.A., Salman A.L.* (2019). Ice maps of a new type: theory and applications. MurmanshelfInfo Information and Analytical Magazine (in Russian and English)

Participants of the international interdisciplinary PhD and Post-Doc Summer School "Observing and modelling the Arctic environment – Climate processes, prediction and projection" held at the NIERSC premises in St. Petersburg on 8-13 September 2019 in the framework of the ARCONOR project (top: near the entrance to the Nansen Centre premises; bottom left: at the legendary Icebreaker Krasin; bottom right: at the Peter the Great Monument)

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