Biannual Report 2024-2025

NANSEN INTERNATIONAL ENVIRONMENTAL AND REMOTE SENSING CENTRE

(NIERSC), The Nansen Centre, St. Peresburg

Russia

ABOUT THE NANSEN CENTRE

The Nansen Centre is an independent non- profit international research foundation. It conducts basic and applied environmental and climate related research focusing on the Arctic and Northern Eurasia as well as globally for serving the Society. The Nansen Centre is a project- based organisation funded from the Russian research agencies and indystry.

NIERSC was established in 1992 as a commercial company 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 the Non-commercial Organizations of the Russian Federation. The center has extensive national and international collaboration. Aditionally the centre contributes to the training of master and PhD-srtudents within the special Nansen Fellowship Programme (NFP) established in 1994. The goal of the Nansen Fellowship Programme is to support master and PhD- students at the Russian educational and research institutions including such as Russian State Hydrometeorological University , St. Petersburg State University, Arctic and Antarctic Research Institute, Institute of Atmospheric Physics of the Russian Academy of Science and other instituitions. The preferred research areas include current and future climate and environmental changes in the high northern latitudes, as well as methods and techniques of satellite remote sensing with the focus on sea ice and Polar lows in the Arctic. NFP provides master and PhD- students with the Russian and international scientific supervision, financial fellowship, efficient working conditions at the centre, involvement into international and national research projects. All NFP PhD- students obliged to publish their scientific results in the national and international refereed journals and make presentations at the national and international scientific symposia and conferences. Totally 33 Russian PhD- students have got their doctoral degrees under NFP since 1994.

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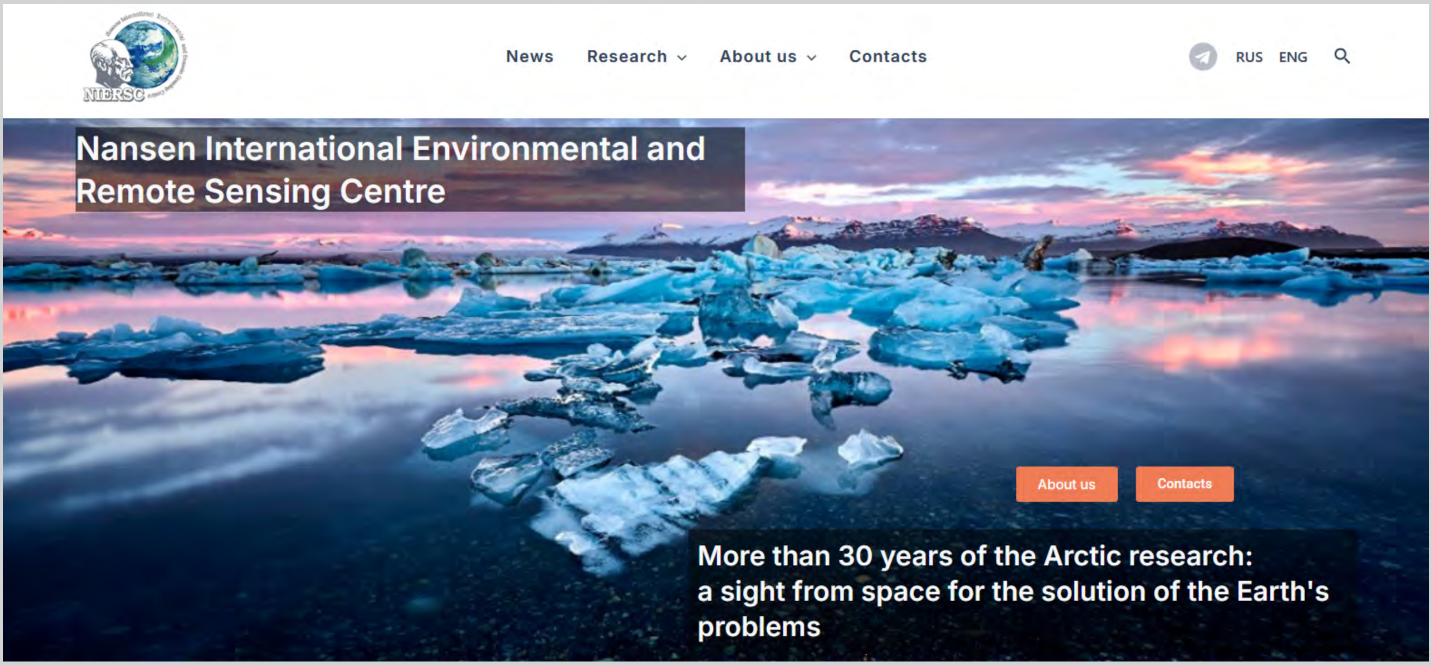


ACIVITIES & ACHIEVEMENTS

RESEARH AREAS

Climate variability and change

- Arctic amplification of global warming
- Atlantic impact on Arctic warming
- Projections of future Arctic climate based on modern models of ocean-ice-atmosphere
- Changes of sea ice conditions on the Northern Sea Route in the past, present and future
- Variability and change of deep water convection in the ocean
- Ocean eddies dynamics and impact on sea ice edge and heat transport to the Arctic

Meso-scale dynamical structures

- Detection and parameter retrieval of polar lows and meso-scale cyclones using satellite and model data
- Regional high-resolution forecast of atmospheric conditions and wind waves based on WRF and WAVEWATCH models
- Automatic satellite multispectral detection of ocean eddies using neural networks

Operational analysis and forecast of sea ice conditions using satellite data and neural networks

- Sea ice classification of high resolution
- Estimation of sea ice drift speed
- Detection of sea ice hummocks, convergence and divergence zones
- Iceberg identification

State of marine and lake ecosystems

- Assessing marine primary production and absorption/emission of CO_2 based on satellite data
- Trophic state of lakes and water storage basins under climate change and anthropogenic impact
- Detection of regions of mass algae blooms using satellite data

Weather and climate extreme events

- Detection/identification, analysis and attribution of extreme events
- Teleconnections between Arctic amplified warming and extreme events in the northern midlatitudes

PROJECTS

	2024	2025
PROJECTS COMPLITED	0	5
ONGOING PROJECTS	4	3
NEW PROJECTS STARTED	1	0
TOTAL	**5**	**8**

List of Projects:

Iceberg distribution in the Arctic seas. *Funded by Arctic Research Centre /Rosneft, 2022-2025*

Ice regime charts for the Arctic seas. *Funded by Arctic Research Centre/ Rosneft, 2022-2025*

Impact of atmospheric heat fluxes on Arctic climate feedbacks and amplification/ Grant to M. Latonin. *Funded by the Russian Science Foundation (RSF), 2023-2025*

Arctic Amplification and extremely cold winters in Siberia/ Grant to N. Gnatiuk. *Funded by RSF, 2023-2025*

The study of three- dimensional circulation in the Lofoten vortex according to hydrodynamic modelling data/ Grant to E .Novoselova. *Funded by RSF, 2024-2026*

Developing technique for sea ice parameter retrieval using radar images of compact hardware module. *Funded by Moscow Physical- Technical Institute (MPTI), 2025*

Co- variability in extreme drought/ flood events between China and Russia and the roles of the mid- high latitude ocean- sea ice- atmosphere interaction/ Russia- China Joint project. *Funded by RSF, 2024-2027*

Trends in sea ice conditions changes in the Vilkitsky Strait as a part of the Northern Sea Route/ Grant to E. Shalina. *Funded by RSF, 2024-2026*

DISSERTATIONS

Igor Bashmachnikov defended Doctor Degree at the St. Petersburg State University on 5 February 2025.

Topic: Subsurface mesoscale eddies and their manifestations at the sea surface

Diana Iakovleva defended dissertation at the St. Petersburg State University on 3 July 2025.

Topic: "Influence of oceanic advection on the formation of the thermohaline structure of the Norwegian, Irminger, Labrador seas and on the development of deep convection".

AWARD

Mikhail Latonin, research fellow at the Foundation "Nansen-Centre", was awarded the RAS medal for his work titled:

"Study of the Mechanisms of Arctic Amplification of Global Warming."

PUBLICATIONS & PRESENTATIONS WITH RESEARCH RESULTS

	2024	2025
PAPERS IN PEER-REVIEWED SCIENTIFIC JOURNALS	6	10
OTHER PAPERS	0	1
CONFERENCE PROCEEDINGS, POSTER & SCIENTIFIC PRESENTATIONS	10	5
TOTAL	16	16

Refereed Papers:

1. *Chen, Y., Yan, Q., Bashmachnikov, I., Huang, K., Mu, F., Zhang, Z., Xu, M., Zhao, J.* (2024). MFDA: Unified Multi- Task Architecture for Cross- Scene Sea Ice Classification. *IEEE Transactions on Geoscience and Remote Sensing,* 62, 4303221, 1-21, doi: 10.1109/TGRS.2024.3491190 (Q1).

2. *Hu, H., Zhao, J., Ma, J., Bashmachnikov, I., Gnatiuk*, N., Hui,F .(2024). The sudden ocean warming and its potential influences on early -frozen landfast ice in the Prydz Bay, East Antarctica. *Acta Oceanologica Sinica,* 43 (5), 65-77, doi: 10.1007/s13131-024-2326-7

3. *Kolyada V.S., Golubkin P.A., Smirnova J.E.* (2024). Influence of the four- dimensional data assimilation on the reproduction of polar low wind speed field. *Journal of Hydrometeorology and Ecology*. 76, 422- 436, doi: 0.33933/2713-3001-2024-76-422-436 (in Russian).

4. *Latonin, M., Bashmachnikov, I,, Radchenko, Iu.,Gnatiuk, N., Bobylev, L.P., Pettersson, L.H.* (2024). Meridional oceanic and atmospheric heat fluxes at the entrance to the Atlantic sector of the Arctic: verification of CMIP6 models and climate projections based on the selected sub- ensembles. *Russian Journal of Earth Sciences*, 24 (4), ES4007, https:// doi. org/ 10. 2205/ 2024ES000917

5. *Moreno- Ibáñez, M., Casado, M., Gremion, ... Latonin, M., et al* . (2024). Engagement of Early Career Researchers in Collaborative Assessments of IPCC Reports: Achievements and Insights. *Frontiers in Climate*, 6, 1395040, https:// doi. org/ 10. 3389/fclim.2024.1395040 (Q1).

6. *Latonin, M.M., Demchenko, A.Yu.* (2024). A robust stepwise jump in the Arctic wintertime warming in 2005 coherent with the increased clear -sky downward longwave radiation flux. *Dynamics of Atmospheres and Oceans*, 108, 101503, https:// doi . org/ 10. 1016/ j.dynatmoce. 2024. 101503

7. *Latonin, M.M., Bashmachnikov, I.L., Semenov, V.A.* (2025). Enhanced Wintertime Convergence of Atmospheric and Oceanic Heat Transports in the Barents Sea Region under Present Climate Warming. *Russian Journal of Earth Sciences*, 25 (2), ES2008, https://doi.org/10.2205/2025ES000967

8. Bashmachnikov I.L., Priakhin S.S., Kozlov I.E., Wekerle C., Zhong W., Shliapin S.A., Kaledina A.S. (2025). Eddies stabilize the sea-ice margin along the East Greenland Current. Journal of Geophysical Research - Oceans (Q1).

9. *Tuchinskaya V.I., Bashmachnikov I.L., Zakhvatkina N.Yu., Kozlov I.E., Iakovleva D.A.* (2025). Automatic identification of ocean eddies in SAR using U-Net convolutional neural network. *Russian Journal of Earth Sciences* (in press).

10. *Demchenko A.Yu, Budiansky M.V., Bashmachnikov I.L., Udalov A.A.* (2025). Lagrangian analysis of fast-transported recirculating Atlantic Water in Fram Strait. Oceanology (in press).

11. *Bashmachnikov, I.L.* (2025). The manifestation of deep underwater eddies in the sea level and sea surface temperature using the example of meddies. Part 1: Observations. *Hydrometeorology and Ecology*, 79, 207-225, doi: 10.33933/2713-3001-2025-79-207-225

12. *Bashmachnikov, I.L.* (2025). The manifestation of deep underwater eddies in the sea level and sea surface temperature using the example of meddies. Part 2: Theory. *Hydrometeorology and Ecology*, 80, 484-509, doi: 10.33933/2713-3001-2025-80-484-509

13. *Shalina, E., Radchenko, I., Gnatiuk, N., Kolyada V.* (2025). Ice-Free Conditions in the Arctic Projected by Score-Based Selected Models and Models' Spread Analysis. *Earth Syst Environment*.https://doi.org/10.1007/s41748-025-00856-z (Q1).

14. *Golubkin, P.A., Kolyada, V.S., Smirnova, J.E.* (2025). Antarctic polar mesoscale cyclones based on ERA5 reanalysis data. *Journal of Hydrometeorology and Ecology*. 78, 7-19, doi: 10.33933/2713-3001-2025-78-7-19 (in Russian).

15. *Gnatiuk, N.V., Radchenko, I.V., Davy, R., Zhao, J., Bobylev, L.P.* (2025). Which climate model evaluation methods can consistently select skillful models from the CMIP6 ensemble? *Geography, Environment, Sustainability*, 18(2), 125-149. https://doi.org/10.24057/2071-9388-2025-3694

16. *Kalashnikova, O.Y., Radchenko, I., & Kretova, Z.* (2025). Mudflow and flood hazard risk evaluation in Kyrgyzstan using hydrological modeling and CMIP6 models. *Earth Systems and Environment*,1-28. https://doi.org/10.1007/s41748-025-00769-x

NANSEN CENTRE - SCIENTIFIC SCHOOL

Nansen Centre is acknowledged as being the reference in St. Petersburg for research in area of "Climate of High Northern Latitudes"

Research leader of Scientific School: **Leonid Bobylev**

Theme: Understanding of recent and present variability of the Arctic climate system and assessing the impact of climate change in the northern high-latitude regions, with an emphasis on the territory of Russia

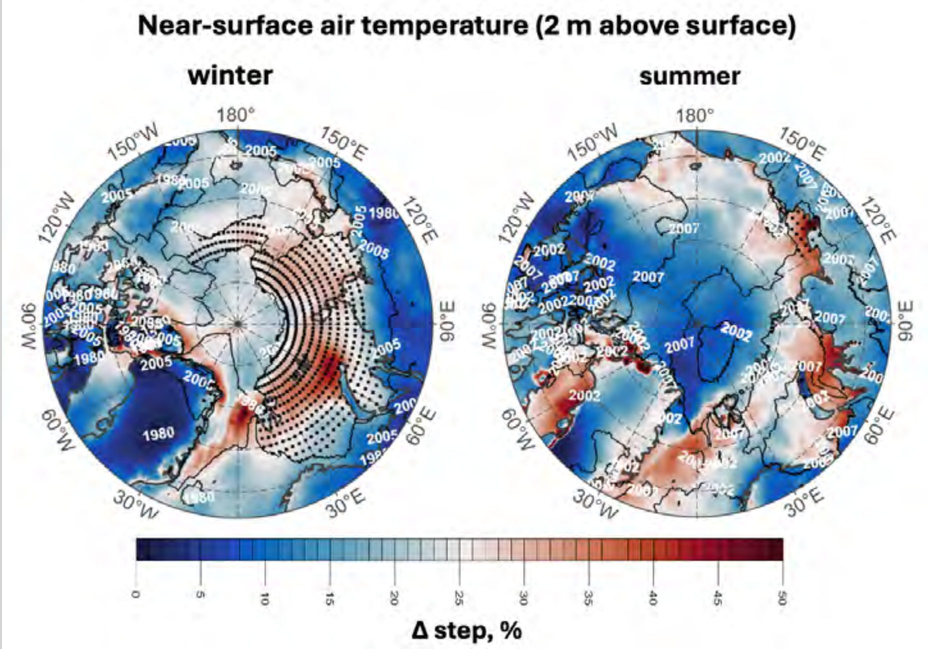
Thematic sections:

- Arctic sea ice
- Evaluation of the quality of existing CMIP model products
- Polar cyclone research
- The interaction of the atmosphere and the ocean, including the areas of deep ocean convection
- Aquatic ecosystems and their response to global changes

CLIMATE VARIABILITY AND CHANGE

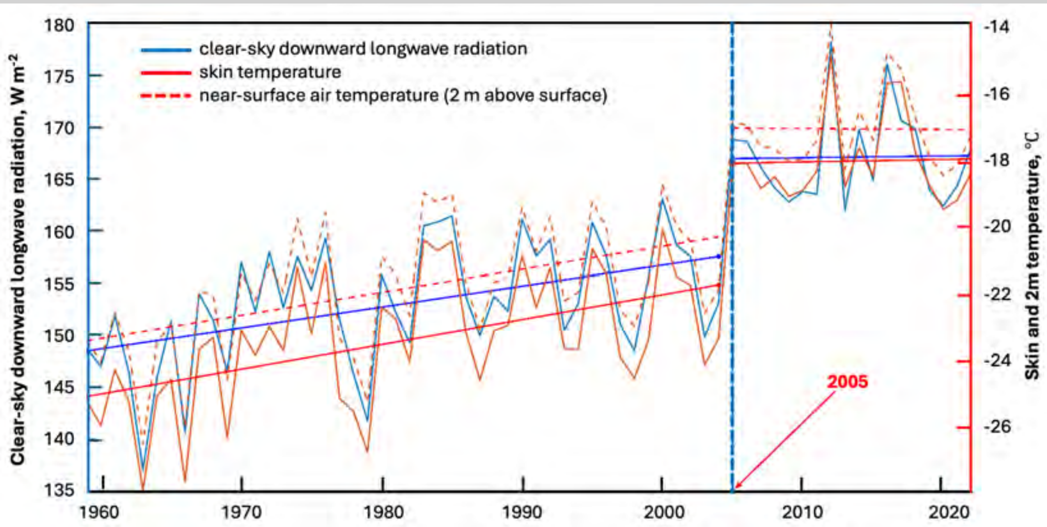
A robust stepwise jump in the Arctic wintertime warming in 2005 coherent with increased clear- sky downward longwave radiation flux

Mikhail Latonin



Near- surface air temperature in the Arctic. The shaded areas with the respective colorbar are relative errors denoted as Δ step, representing the effectiveness of the stepwise model. Contours show two most frequent years of stepwise changes. Black dots delineate the regions where the model of stepwise changes is statistically significant according to the Fisher criterion at the 5 % significance level for the year 2005 in the winter season and for the year 2007 in the summer season (winter season defined as December, January, February and March and the summer season defined as June, July, August and September).

In some areas of the Arctic, the Earth' s surface and near- surface air temperatures are rising faster than in other areas. The purpose of our study was to identify, based on the ERA5 reanalysis data, the spatiotemporal structure of climatic changes in the Arctic during 1959– 2022. The main emphasis was put on the three parameters: mean surface clear- sky downward longwave radiation flux, near- surface air temperature, and skin temperature. A statistical model of stepwise changes was applied to the time series of the studied characteristics at each grid point of the entire Arctic (67-90°N). The results obtained indicate a close relationship between all parameters in the winter season. The dominant year of stepwise changes was 2005. Moreover, it was precisely this transition from one state of the climate system to another that was statistically significant over a large territory, which is located mainly in the Eastern Hemisphere (see top figure). The time series averaged over the identified areas are highly correlated with each other, and the year 2005 characterizes the change from a sharp increase in values to their variability without a pronounced trend (see bottom figure). The available satellite observations fully confirm the temporal structure of the stepwise changes for the studied parameters and largely confirm its spatial structure. Thus, the clear- sky downward longwave radiation flux is one of the leading factors in the formation of the thermal regime of the Arctic.



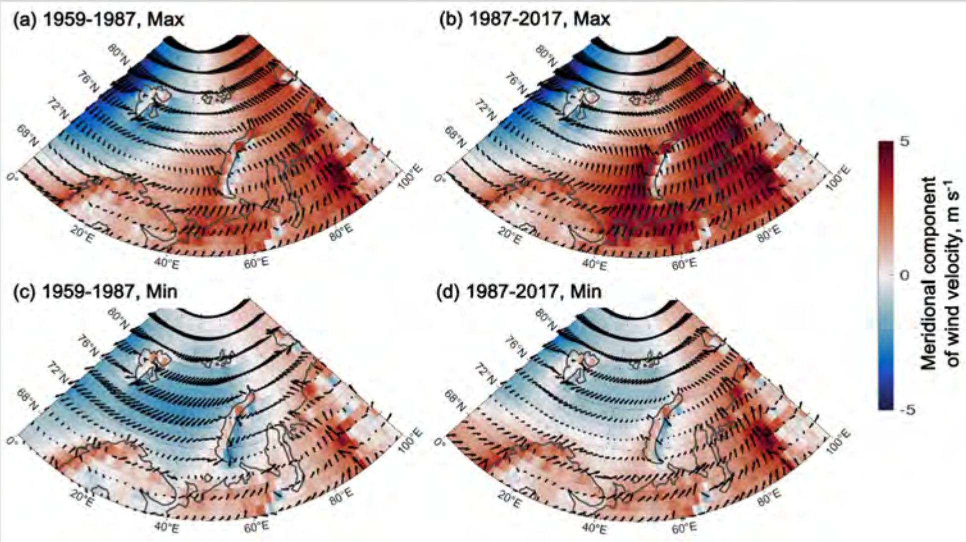
Time series of clear- sky downward longwave radiation, skin temperature and near- surface air temperature (2m above surface), averaged over the regions of significance for the winter season, and their llinear trends . Reference line is plotted at 2005 , which is the year of stepwise changes.

Publication: Latonin, M. M., Demchenko, A.Yu. (2024). A robust stepwise jump in the Arctic wintertime warming in 2005 coherent with the increased clear- sky downward longwave radiation flux. *Dynamics of Atmospheres and Oceans*, 108, 101503. https:// doi. org/ 10. 1016/ j.dynatmoce. 2024. 101503.

Acknowledgements: This study was funded by the Russian Science Foundation (RSF), grant number 23 – 77– 01046 (https:// rscf. ru/ en/ project/23-77-01046/)

Enhanced wintertime convergence of atmospheric and oceanic heat transports in the Barents Sea region under present climate warming

Mikhail Latonin

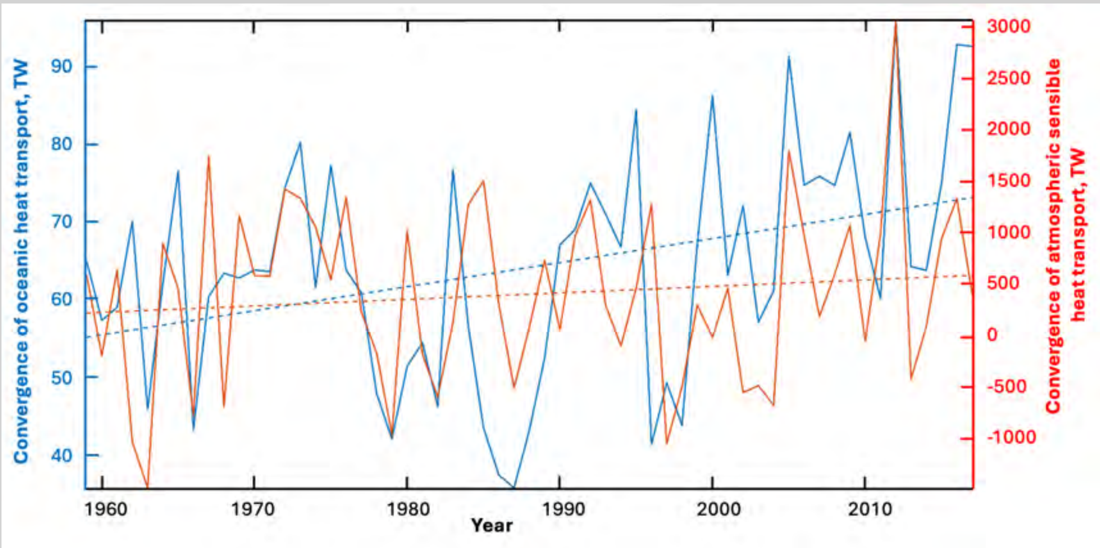


Mean wind velocity values (black arrows) at a height of 10 m in the years with the maximum values of the oceanic heat transport at the entrance to the Barents Sea (a, b) and in the years with the minimum values of the oceanic heat transport at the entrance to the Barents Sea (c, d). The colors show the values of the meridional component of the wind velocity; positive values correspond to the northward direction.

A distinctive feature of the Barents Sea climate system is a suggested positive feedback in the ocean– sea ice– atmosphere system that can enhance regional climate variations. The objective of this study is to assess the effectiveness of this positive feedback for the advective heat fluxes in the winter season using the ORAS4 ocean reanalysis and ERA5 atmospheric reanalysis data for the period 1959 – 2017. Based on the signs of the linear trends of the oceanic heat transport, two periods were identified for the analysis: 1959 – 1987 and 1987– 2017. Composite maps of surface wind fields indicate an increase in the effectiveness of the positive feedback in the Barents Sea region during the present period relative to the previous one. This is manifested in the strengthening of the southern winds over the southeastern part of the sea in years with the maximum oceanic heat transport and in the weakening of the northern winds over the northwestern part of the sea in years with the minimum oceanic heat transport (top figure). The convergence of the atmospheric sensible heat transport over the Barents Sea has a maximum in the lower troposphere, 1000– 900 hPa. An increasing synchronization of the convergence of atmospheric and oceanic heat transports in the Barents Sea region, derived in this this study, contributes to an acceleration of the local warming (bottom figure).

Publication: Latonin, M. M., Bashmachnikov, I.L., Semenov, V A. (2025). Enhanced wintertime convergence of atmospheric and oceanic heat transports in the Barents Sea region under present climate warming. *Russian Journal of Earth Sciences*, 25, ES2008. https:// doi. org/ 10. 2205/ 2025ES000967.

Acknowledgements: This study was funded by the Russian Science Foundation (RSF), grant number 23– 77– 01046 (https:// rscf.ru/en/ project/23-77-01046/).

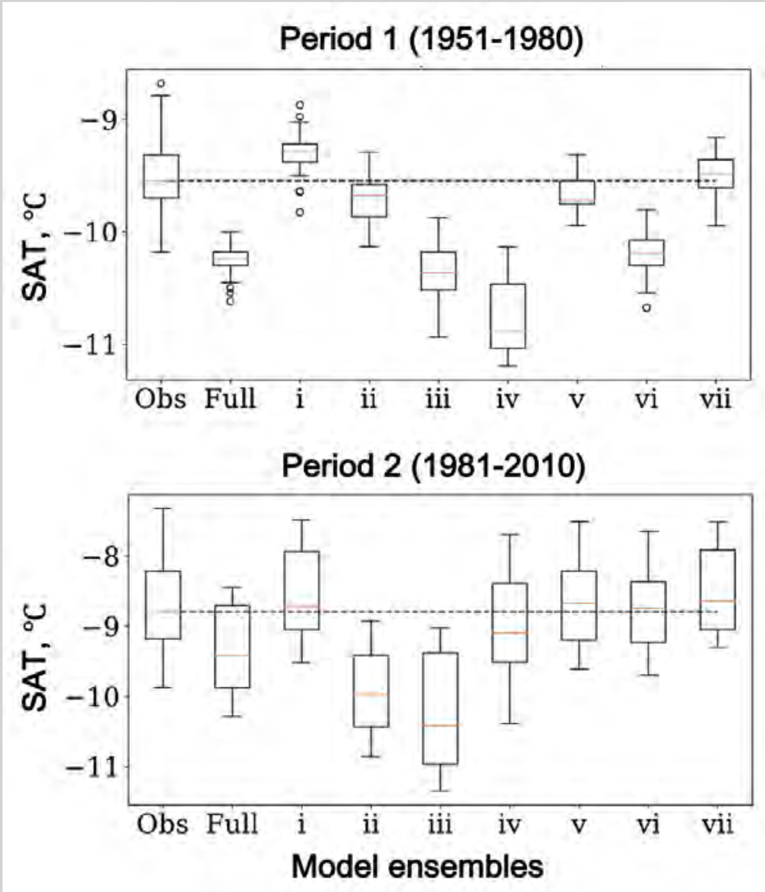


Convergence of oceanic and atmospheric heat transports in the Barents Sea region. 1 TW = 1012 W. Dashed lines show linear trends.

Comparison of evaluation methods for selecting most skillful climate models for modelling arctic surface air temperature

Natalia
Gnatiuk
Iuliia Raddchenko
Richard Davy
Jiechen Zhao
Leonid Bobylev

In order to determine which method for evaluating and selecting climate models is the most robust for assessing model skill, seven widely used methods were tested using surface air temperature data from 25 CMIP6 models in the Arctic region. The examined methods included: a single statistical metric – (i) root mean square error, and (ii) spatial trend analysis; a single skill score – (iii) the Taylor skill score, and (iv) probability density function comparison; a combination of several statistical metrics – (v) the Taylor diagram with interannual variability skill score, and (vi) the Taylor diagram, biases and trends; and a multiple statistical criteria method – (vi) a percentile- based approach. To evaluate their consistency, each method was applied to two periods: 1951- 1980 and 1981- 2010. For each method, the models were ranked and classified into three quality groups: very good, satisfactory, and unsatisfactory. An optimal subset of models, corresponding to the top 25%, was selected based on each method' s ranking. Results are visually summarized in Figure, which presents boxplots of the annual surface air temperature for the observations, the full ensemble, and the method- specific sub- ensembles for the two periods. The results suggest a preference for the percentile-based approach, with a consistency of 72%. In contrast, the consistency of the other methods ranges from 40 to 60%.



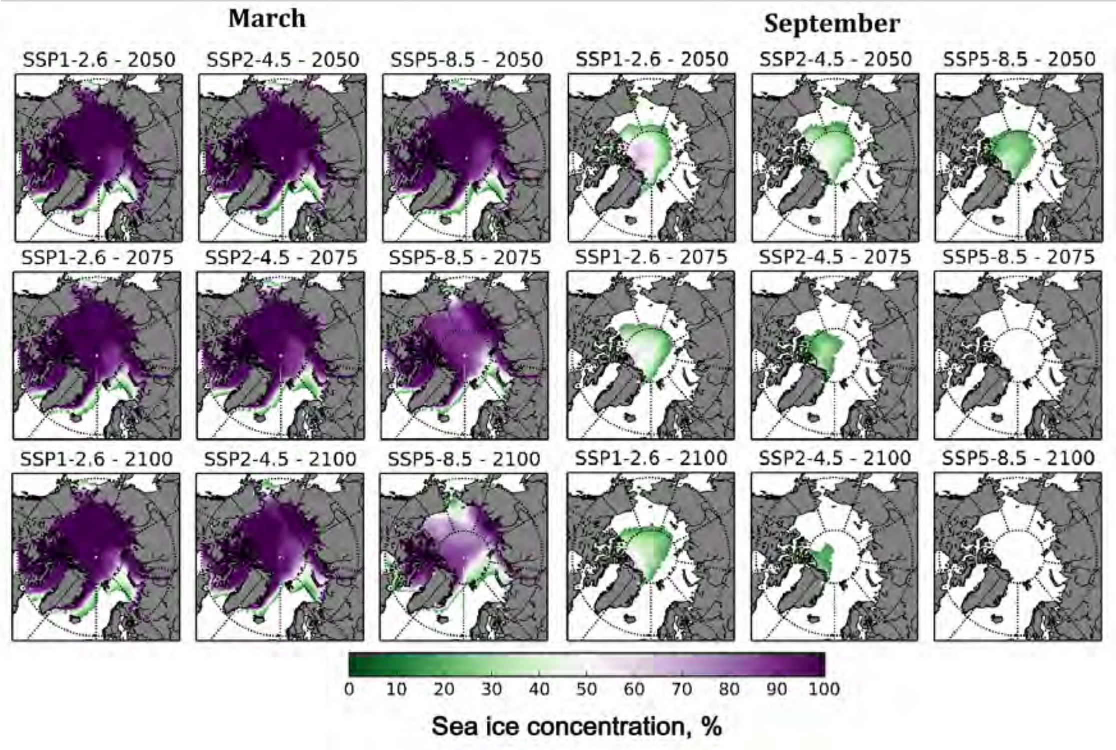
Boxplots of the annual surface air temperature over Arctic for observations, the full 25-model ensemble, and sub-ensembles selected based on the seven model assessment methods, for 1951-1980 and 1981-2010.

Publication: Gnatiuk N.V., Radchenko I.V., Davy R., Zhao J., Bobylev L.P. (2025). Which climate model evaluation methods can consistently select skillful models from the CMIP6 ensemble? Geography, Environment, Sustainability, 2 (18), 126-149 https://doi.org/10.24057/2071-9388-2025-3694.

Acknowledgements: This study was funded by the Russian Science Foundation (RSF) grant No. 23-77-01106, https:// rscf. ru/ en/project/23-77-01106/.

Projected Ice- Free Conditions in the Arctic in the 21st century

Elena Shalina
Iuliia Raddchenko
Natalia Gnatiuk
Vsevolod Kolyada



Projected evolution of the ensemble-mean March (left) and September (right) pan-Arctic sea ice concentration (%) for 2050, 2075 and 2100 under the SSP1-2.6, SSP2-4.5, and SSP 5-8. 5 scenarios.

Given the pivotal role of sea ice within the climate system, there is a considerable interest in its future changes. We have estimated the change in sea ice area (SIA) in the Arctic for the period 2020- 2100 under three future scenarios: SSP1- 2. 6, SSP2- 4. 5, and SSP5- 8. 5. These projections are based on the ensemble of nine selected CMIP6 models (representing the top 25 %) that best match the observed interannual variability, seasonal cycle, and spatial distribution of biases and trends in sea ice concentration over the historical period of 1979– 2014. Between 2020 and 2100, the March SIA is projected to decrease by 5%, 11 %, and 32 % under SSP1- 2. 6, SSP2- 4. 5, and SSP5- 8. 5, correspondingly . The respective reductions in September SIA are 65%, 92%, and 100 % (see Figure). Our results suggest that an ice- free Arctic is unlikely under the SSP1- 2.6 scenario. The SSP2-4.5 scenario predicts ice-free conditions in September by the early 2060s, and in August by the mid- 2070s. The high- emission SSP5- 8. 5 scenario projects more rapid and extensive ice loss. Under this scenario, the September ice cover could disappear as early as the late 2040s, followed by the August ice cover in the mid- 2050s, the July ice cover in the early 2080s , the October ice cover in the mid- 2060s and the November ice cover in the mid- 2080s. Under the SSP5- 8. 5 scenario, the entire Arctic will be ice-free in September, meaning that only first- year ice will be present during the cold period.

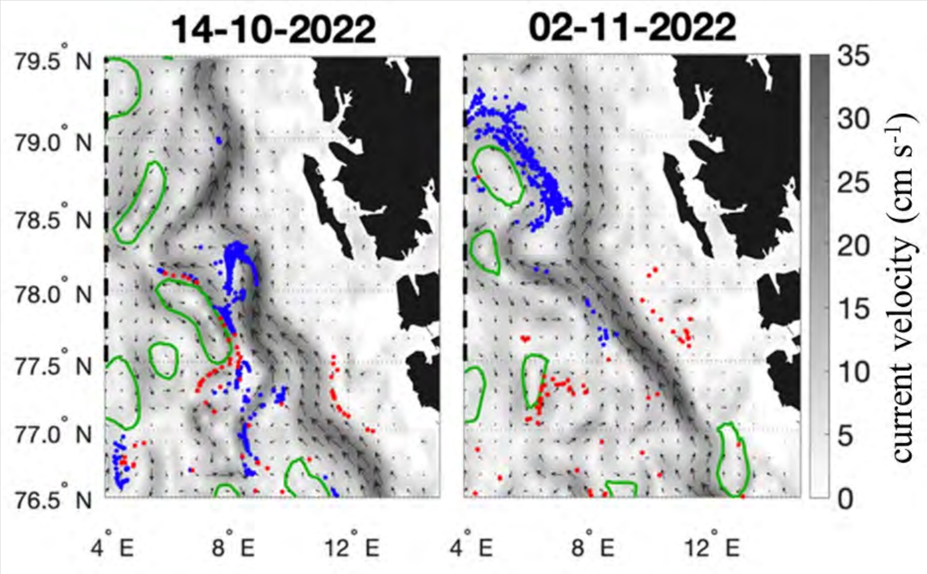
Publication: Shalina, E., Radchenko, I., Gnatiuk, N., Kolyada, V. (2025). Ice- Free Conditions in the Arctic Projected by Score- Based Selected Models and Models' Spread Analysis. *Earth Systems and Environment.*
https:// doi. org/ 10. 1007/ s41748- 025- 00856-z

MESO-SCALE DYNAMICAL STRUCTURES

Fast-transported recirculating Atlantic Water in Fram Strait

Anna Demchenko
Igor Bashmachnikov
et al.

Characteristics of the Recirculating Atlantic Water in the Fram Strait were investigated by examining behavior of Lagrangian particles as they moved westward from the West Spitsbergen Current. It was found that two distinct mechanisms of particle movement exist: (1) one linked to a fast transport by both current and eddies, and (2) another one linked to slow eddy diffusion. Fast particles are advected by the mean current or skirt the peripheries of eddies aligned in a sort of a chain. The slow transport of the particles occurs when the particles



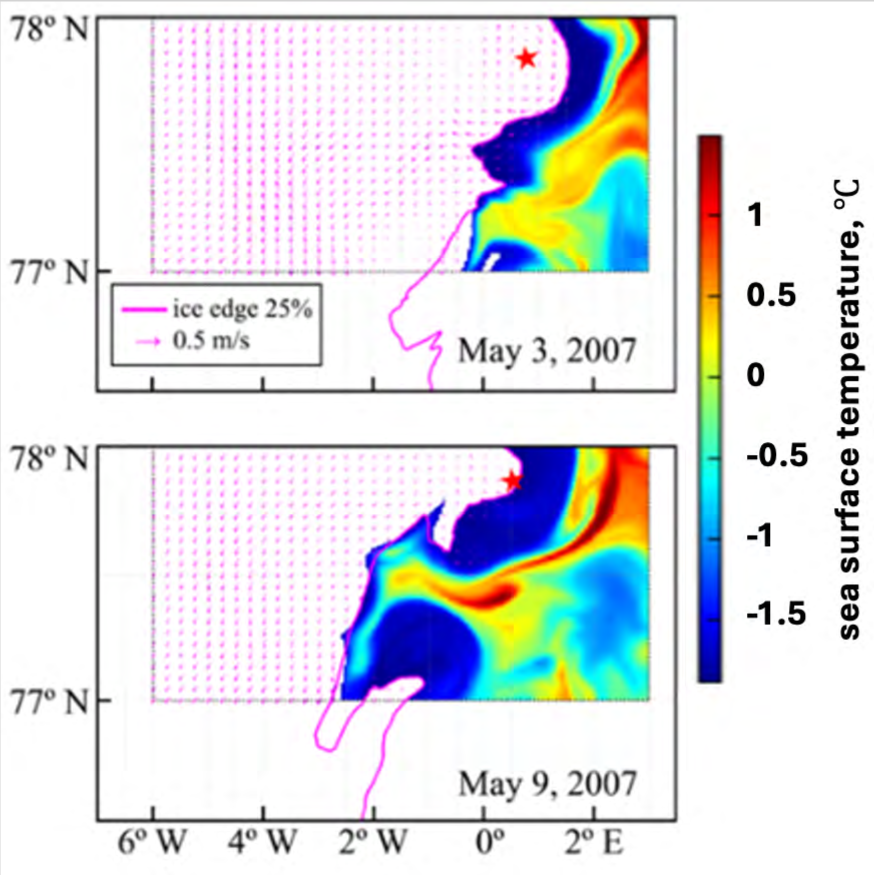
Velocity in the area of the West Spitsbergen Current at 100 m depth derived from GLORYS12V1 reanalysis (black vectors). Markers indicate the pulls of "slow" (red) and "fast" (blue) particle, respectively, on 10. 14. 2022 (left) and 11. 02. 2022 (right). All the markers start their trajectories at the southern boundary of the study region on 09. 23. 2022 and classified by the time needed to reache the western boundary of the region. Eddy boundaries are marked with green contours.

are trapped by eddy cores. In this case, the particles 78.5 – 79.5°N move to the west either along with the moving eddies or are transmitted from one eddy to the other making several turnovers around their cores. In the Fram Strait main transport corridors have been identified, which represents the most likely pathways for the particles to recirculate from the West Spitsbergen Current. The arrival of the westward recirculating fast particles in portions is associated with an episodic formation of a recirculation branch from the West Spitsbergen Current between 78.5 –79.5 °N.

Publication: Demchenko A.Yu., Budyansky M.V., Bashmachnikov I.L., Udalov A.A., 2025. Lagrangian analysis of fast-transported recirculating Atlantic Water in Fram Strait. Oceanology (in press)

Sea-ice retreat by eddies in the marginal ice zone of the East Greenland Current

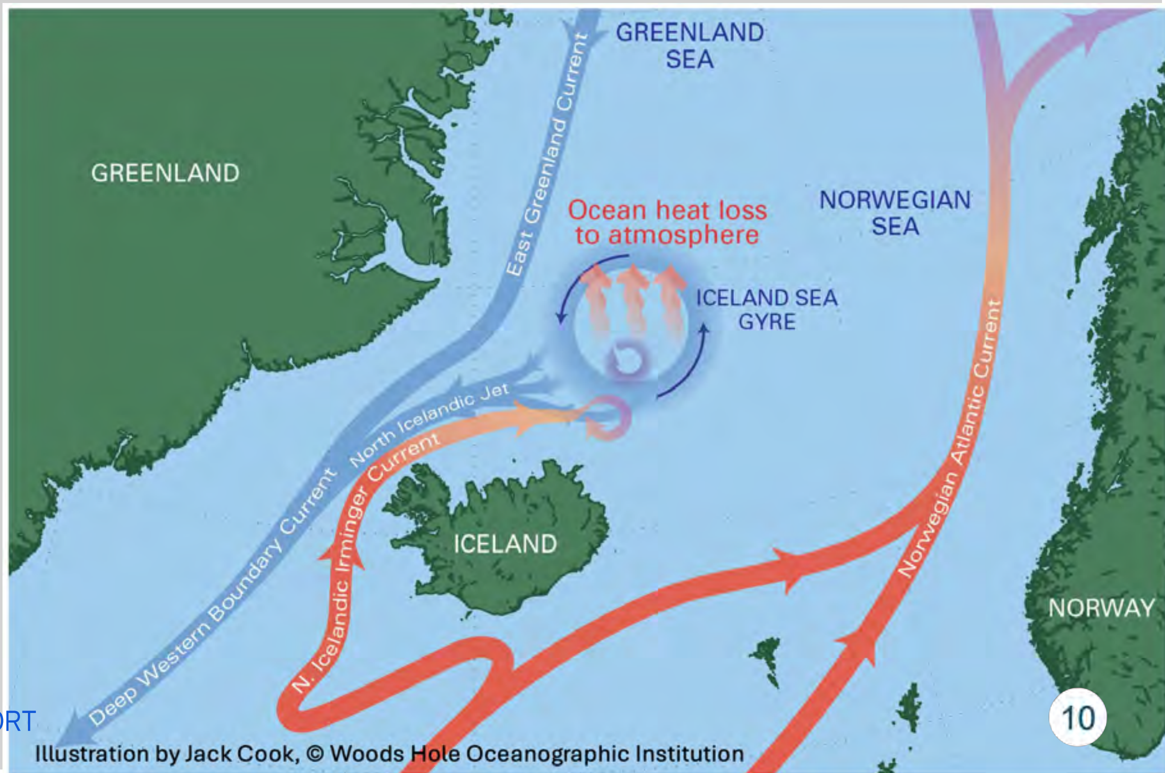
Igor Bashmachnikov
Anastasia Kaledina
et al.



Entrainment of warm water by an anticyclonic eddy, center of which is marked with red star. The magenta vectors are sea- ice drift velocities (m s $^{-1}$), magenta line marks the sea- ice edge at 25 % ice concentration. FESOM model data.

Ocean mesoscale eddies are assumed to be an important factor of ice retreat of the sea- ice margin, especially in the regions where sea surface temperature gradients are large. One of such areas is the northern Greenland Sea, where a strong discharge of Polar Water and sea- ice from the Arctic meets with the warm Atlantic Water inflow from the Norwegian Current. The effect of eddies on the Marginal Ice Zone of the East Greenland Current is studied using an eddy- resolving FESOM1. 4 ocean model with 1 km spatial resolution. It is found that the horizontal mixing with ocean eddies can effectively decrease ice area, resulting in a local retreat of the ice-edge by 3- 8 km per day. However, such sea- ice retreats are quickly restored, counterbalanced by the sea- ice convergence in the East Greenland Current. This balance of the sea- ice fluxes is the reason for the relatively stable position of the ice margin throughout almost the entire year, with the exception of the 1- 2 summer months (August- September), when an increase in the air temperature leads to a short but rapid westwards retreat of the ice edge.

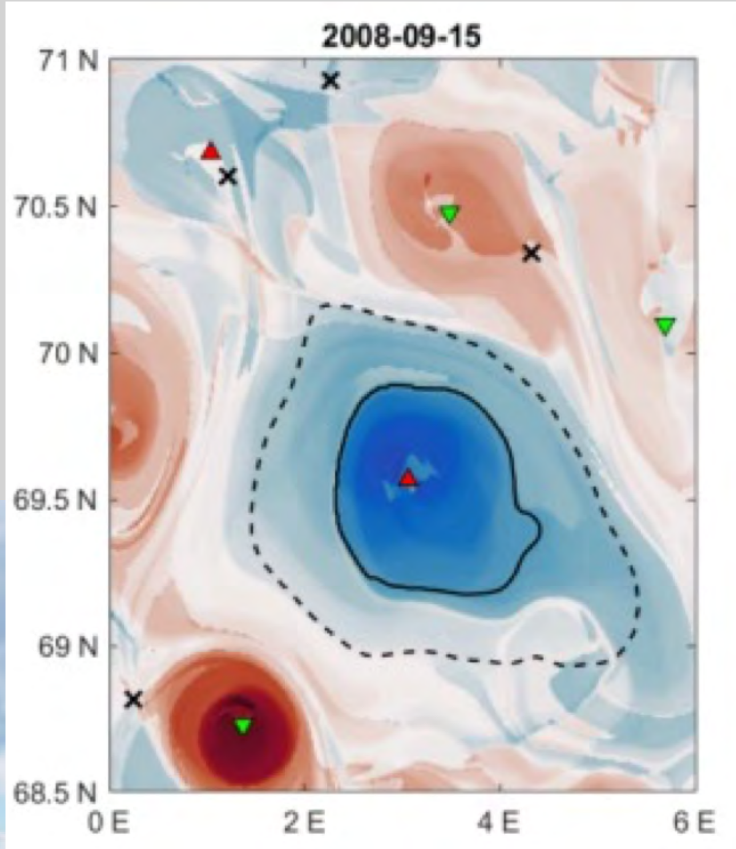
Publication: Bashmachnikov, I. L., Pryakhin, S. S., Kozlov, I. E., Wekerle, C., Zhong, W., Shliapin, S. A., & Kaledina, A. S. (2025). Sea - ice retreat by eddies in the marginal ice zone of the East Greenland Current. *Journal of Geophysical Research: Oceans*, 130(11), e2025JC022330, https:// doi. org/ 10. 1029/ 2025JC022330



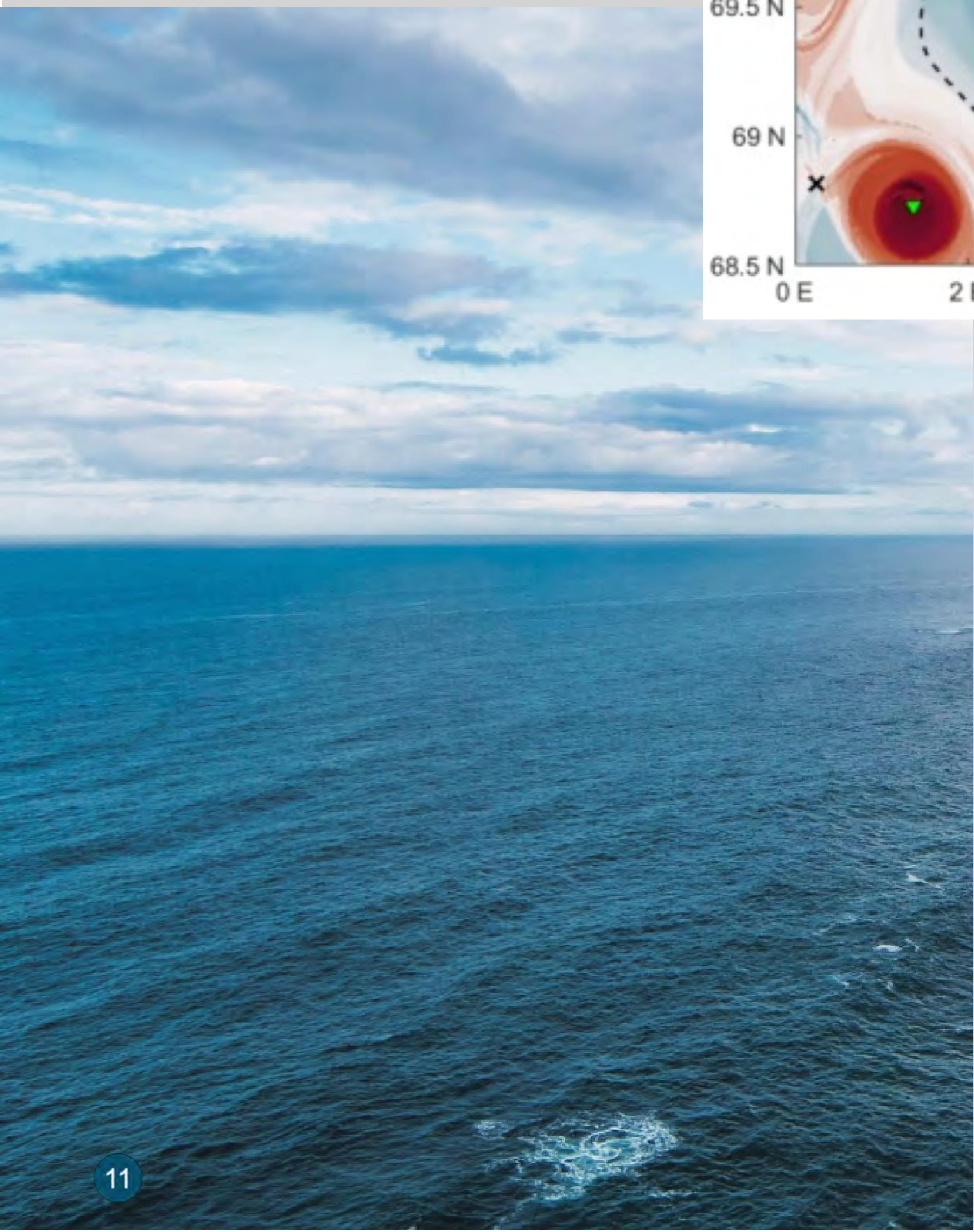
Determination of horizontal boundaries of mesoscale quasi- stationary eddies

Elena Novoselova

A new Lagrangian algorithm, the Lagrangian Eddy Boundary Delineation Algorithm (LEBDA), has been developed, designed to determine the horizontal boundaries of mesoscale quasi- stationary eddies. In contrast to traditional Eulerian methods employed for similar tasks, LEBDA minimizes abrupt boundary changes, a critical advantage particularly relevant for the analysis of long- lived structures. A key feature of the algorithm is the use of passive tracer trajectories, enabling accurate identification of both the eddy core and its periphery, while effectively filtering out transient perturbations. A comparison with the Automated Mesoscale Eddy Detection Algorithm (AMEDA), using



Eddy boundaries determined by the LEBDA method (solid contour) and the AMEDA method (dashed contour).

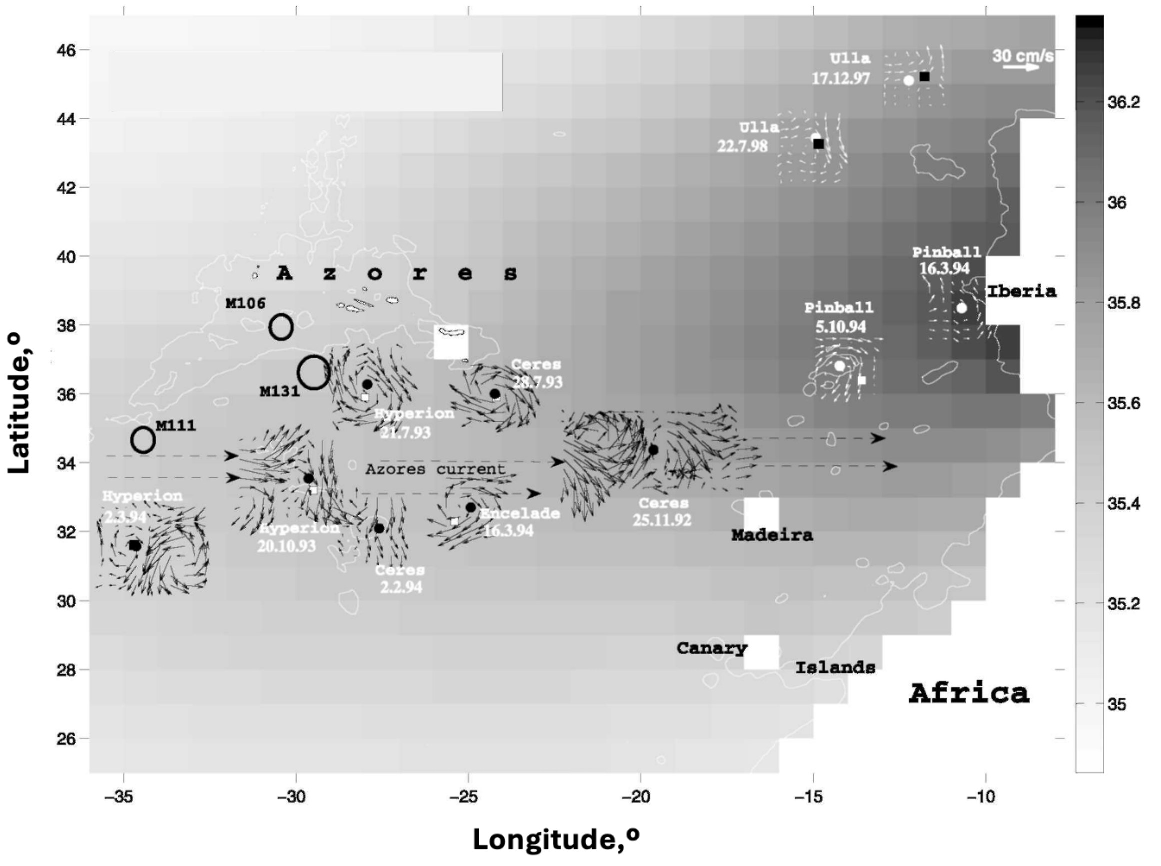


the Lofoten Vortex as a case study, demonstrated that LEBDA provides a more physically consistent and temporally smooth delineation of the eddy boundary (see Figure). Unlike AMEDA, which tends to overestimate eddy sizes (by up to 1. 5 times), LEBDA exhibits a gradual and realistic evolution of boundaries.

Acknowledgements: This study was funded by the Russian Science Foundation (RSF).

Manifestation of deep underwater eddies in the sea level and sea surface temperature

Igor Bashmachnikov



Salinity at a depth of 1000 m (color) The small black/white squares are the positions of the meddy centers on the trajectories of the RAFOS floats on the specified dates; the black and white arrows represent geostrophic currents from altimetry data for the same period; the black/white circles represent the centers of anticyclonic meddy signals on the sea surface closest to the centers of meddies. The horizontal dashed arrows show the average position of the Azores current. The black circles are the positions of the three meddies (M131, M111 and M106) observed during the cruise of RV Archipelago in August 2005. The white line is an isobath of 2000 m

Theoretical advances in manifestations of dynamic of subsurface eddies on the sea surface are described. The Mediterranean water eddies in the Atlantic - meddies, are taken as an example. However, the results are applicable to other mesoscale eddies with deep cores. The results showed that the intensity of meddy surface signals depend on the meddy characteristics (the potential vorticity anomaly of meddy cores and the ratio of the core radius to core depth) and on the background conditions (the ratio of the Coriolis parameter to the mean water stratification above the meddy and the velocity of the background current). It is shown that only meddies with dynamic radii over 15 – 20 km can be detected using AVISO altimetry observations. Naturally, for eddies with shallower cores, the critical radius is smaller. The meridional change in the f/N ratio in the study area determines the overall 6-fold north-to-south decrease in the relative vorticity of the meddy sea-surface signals, which goes together with a simultaneous increase in its radius relative to the radius of the generating meddy. The seasonal variability in the intensity of meddy sea-surface signals is linked to the seasonal variability of the upper ocean stratification. Comparison of the theoretical and observed meddy signals allows, in particular, identifying the episodes of partial disintegration of merger of meddy cores.

A comparison with observations has shown that the meddy sea-surface signal may be significantly increased during its interaction with the background current. Locally, such interactions can also lead to a rapid attenuation or complete loss of the signal on the sea surface.

Publication: The manifestation of deep underwater eddies in the sea level and sea surface temperature using the example of meddies. Part 2: Theory. *Hydrometeorology and Ecology*. 80, 484-509, doi: 10.33933/2713-3001-2025-80-484-509

Climatology of polar mesoscale cyclones around Antarctica over 2000–2020

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Vsevolod Kolyada
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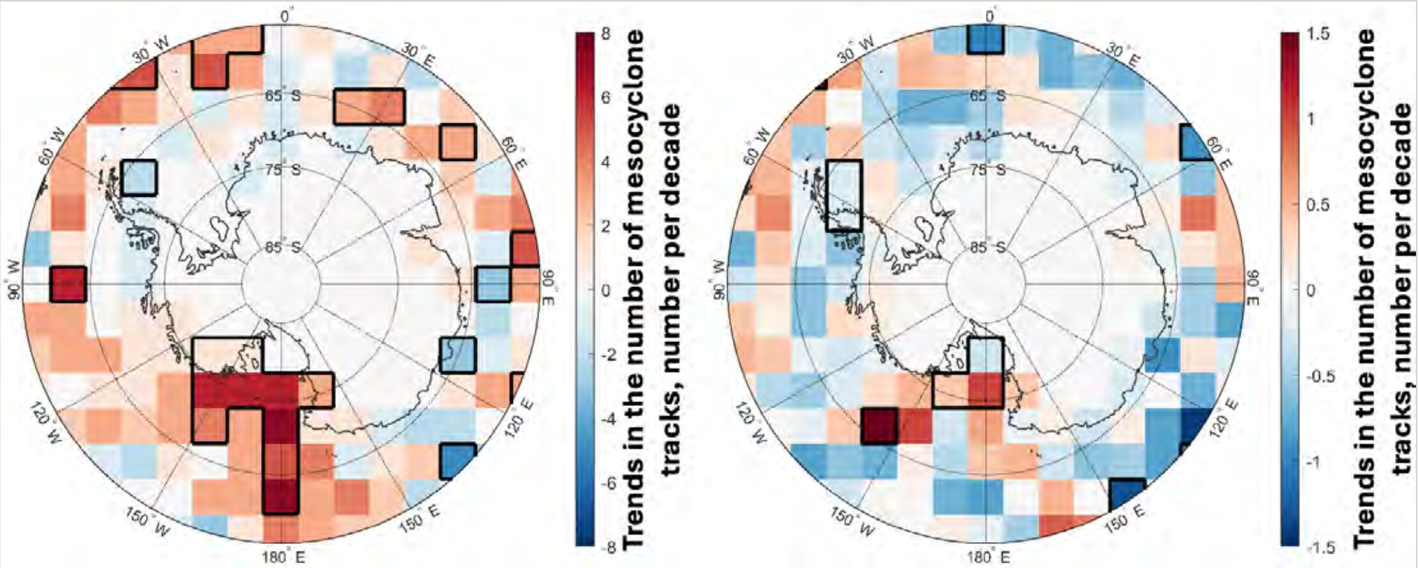

Trends in the number mesocyclone tracks (number per decade) crossing 500×500 grid cells. Left panel – for all cases; right panel – for most intense cyclones. Framed grid cells represent statistically significant trends with a level exceeding 95 %.

Polar mesoscale cyclones are atmospheric vortices observed in the high latitudes of both hemispheres. The most intense of these vortices, known as polar lows, are hazardous phenomena that can threaten maritime activities and coastal infrastructure due to the strong winds and high waves they generate. Furthermore these relatively small atmospheric systems play a crucial role in the exchange of heat and moisture between the ocean and the atmosphere in the polar regions, which are critical for the global climate.

To assess the frequency, primary regions of occurrence, and key characteristics of polar mesoscale cyclones around Antarctic, ERA5 atmospheric reanalysis data were utilized. Using a specially configured automatic cyclone identification and tracking algorithm, a detailed climatology of these cyclones was created for 2000–2020.

The analysis identified over 34 000 cyclones, of which 2 650 were classified as the most intense. The results show that the interannual variability in the total number of cyclones is about 10 %, whereas the number of the most intense vortices fluctuates much more strongly — up to 40 %. Most cyclones form in summer and autumn, which is facilitated by the extensive area of ice-free ocean. In contrast, the most intense vortices more frequently form in winter, which is explained by the stronger temperature contrast between the ocean and the cold air, which serves as an energy source for cyclone development. The main regions of cyclonic activity are the Bellingshausen and Amundsen seas. Another important result is the identification of a statistically significant positive trend in the number of cyclones over the Ross Sea.

The average lifetime of the identified cyclones is about 16 hours, and the mean distance traveled is 487 km. More intense cyclones, on average, exist longer (28 hours) and travel greater distances (869 km).

Publication: Golubkin P. A., Kolyada V. S., Smirnova J. E. 2025. Antarctic polar mesoscale cyclones based on ERA5 reanalysis data. *Gidrometeorologiya i Ekologiya (Hydrometeorology and Ecology)*, 78, 7—19, doi: 10.33933/2713-3001-2025-78-7-19. (In Russian).

WEATHER AND CLIMTE EXTREME EVENTS

Changes in the area affected by severe droughts in Russia

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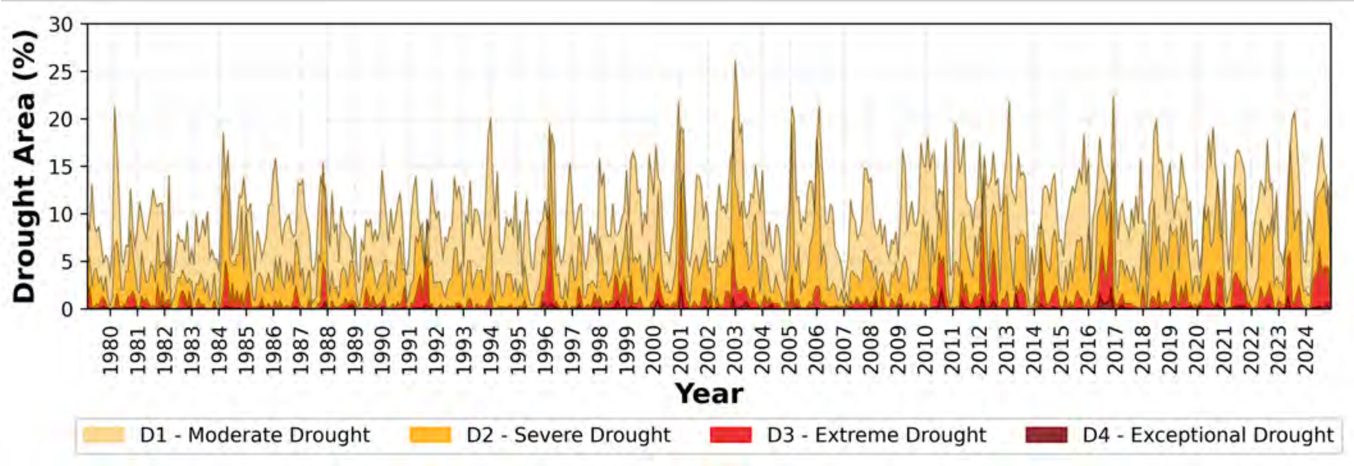

Changes in the area affected by severe droughts in Russia.

An analysis of changes in the extent of droughts of varying intensity in Russia was conducted for the first time for the period from 1979 to 2024. The drought-affected area and its intensity were assessed using the Standardized Precipitation-Evapotranspiration Index (SPEI). The index was calculated on a three-month timescale (SPEI-3), which reflects the agrometeorological type of droughts by considering the water balance over the previous three months.

Overall, the frequency of widespread droughts has increased (see Fig). Over the past two decades, the area affected by severe to extreme droughts has grown substantially – nearly doubled. The area experiencing moderate drought exceeded 25% of the Russian territory in 2003 and was above 20% in 1980, 2001, 2002, 2006, 2013, 2017, and 2023. Severe droughts affected nearly 20% of the area in 2001, 2003, and 2005, with notable peaks also observed in 1984, 1996, 2006, 2020, and 2023. Very severe and extreme droughts impacted over 10% of the area in 1996, 2001, and 2016, and more than 5% in 2003, 2010, 2012, 2014, and 2023.

OPERATIONAL ANALYSIS AND FORECAST OF SEA ICE CONDITIONS

Iceberg detection algorithm in Sentinel-1 medium-resolution SAR data using neural networks

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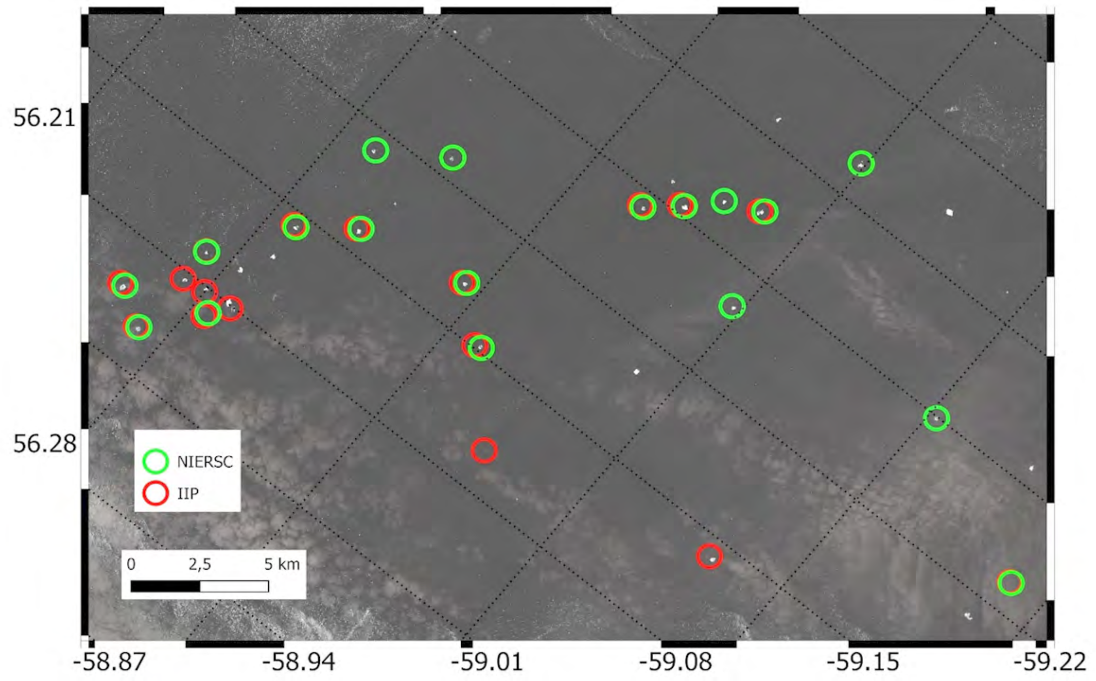
Igor Bashmachnikov
Natalya Zahvatkina
Denis Demchev
Anna Demchenko

The new computationally effective algorithm is developed that combines the blob detection technique with a unified architecture of the Gated Residual (GRN) and Variable Selection Network (VSN). The method makes it possible to identify relatively small icebergs of about 100 long in Sentinel- 1 Extra Wide (EW) Swath images of medium spatial resolution. The Sentinel- 1 EW data provide the most comprehensive coverage of the Arctic. Validation of the results using an independent sample in the Labrador Sea demonstrated that this method achieves accuracy (more than 90 %) and recall (90 %), comparable or higher to the results of International Ice Patrol (IIP) for the Sentinel- 1 EW images (see Figure).



Example of icebergs automatically detected by International Ice Patrol (red markers) and NIERSC (green markers) overlaid on optical image 6 hours apart for the EW SAR image of 6th of June 2019. White dots represent icebergs in the optical data. Drifting ice has completely melted by the time of the survey.

A number of the relatively small icebergs, detected with the suggested algorithm, and, that are common in the Arctic, as well as in the Subpolar Gyre, often are not detected by the IIP algorithm. The developed time-efficient automatic algorithm for iceberg detection will reduce their high danger for navigation.

An automatic algorithm for recognition of sea ice cover types from UAV SAR Data

(jointly with the Scientific and Technical Centre for Ecology and Environmental Monitoring at Moscow Institute of Physics and Technology (MIPT))

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Vladimir Kozlov
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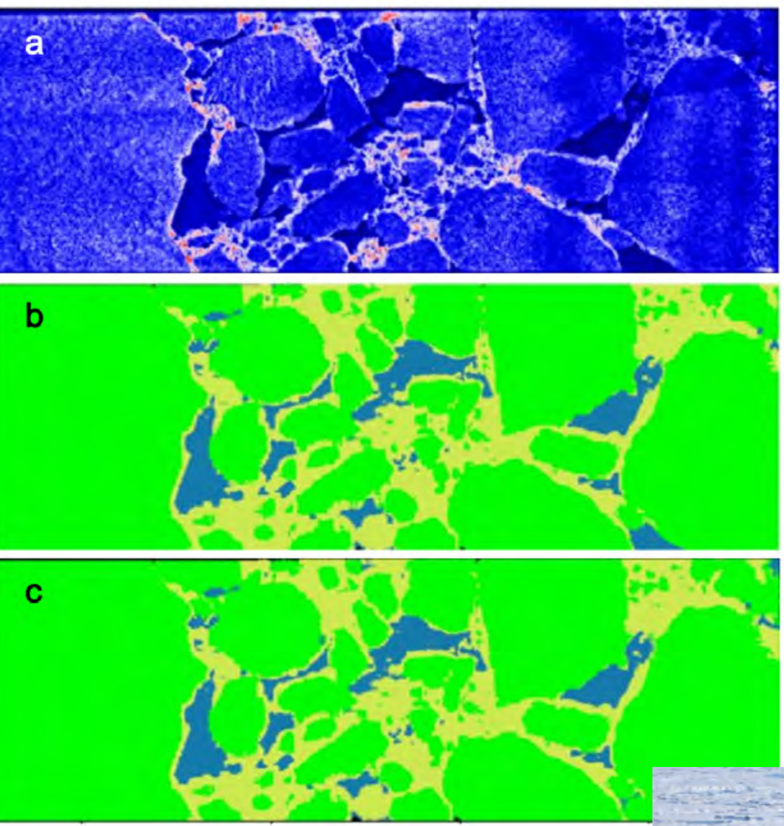
Operational monitoring of the Arctic ice conditions is of critical importance for safe navigation, especially given the increased utilization of the Northern Sea Route. Existing satellite systems, despite their broad coverage , suffer from limited imaging revisit rates, which is insufficient for real-time vessel support. Synthetic Aperture Radar (SAR) data from Unmanned Aerial Vehicles (UAVs) present a promising alternative, offering high spatial resolution and flexibility. However, their use is challenged by high noise levels and limited polarization information, which complicates automatic classification. This study presents an integrated method for sea ice segmentation from single-polarization (VV) X- band SAR data acquired with a UAV in the Gulf of Ob (the Kara Sea). The combination of adaptive filtering with a semantic segmentation on the basis of a modified Swin- Unet neural network architecture helped to compensate for the hardware limitations and demonstrates its high efficacy in addressing the task of automatic segmentation for noisy single- polarization UAV SAR data (see left Figure). The segmentation quality in terms of the F1 -score was: 0. 94 for class " Ice", 0. 93 for class " Broken Ice" and 0. 79 for class "Water". The obtained results have a practical applicability for operational ice classification using a developed graphical user interface for the software package.



An example of an automatic segmentation of a UAV SAR image using Swin- Unet: a) original data; b) expert mask; c) segmentation result (green – fast ice and ice floes, yellow – broken ice, blue – water)

The Russian nuclear icebreaker Yamal breaking through sea ice in the Arctic. Photograph: Sue Flood/ Alamy (The Guardian, Thu 15 Jan 2026)

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