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INFORMATION

Cruise 93 of the R/V *Akademik Mstislav Keldysh*: Geosystems of the Western Eurasian Arctic Shelves in the Season of Active Autumn–Winter Convection and Polar Night

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Abstract—Multidisciplinary studies of the bottom sediments–water column–atmospheric water layer system in the Barents and Pechora seas and Baydaratskaya Bay of the Kara Sea were carried out on the expedition European Arctic–2023: Geological Record of Environmental and Climate Change during the season of polar night and active development of autumn–winter thermal convection. Fundamentally new data on a number of areas of oceanology were obtained in the cruise.

Keywords: sedimentation, biogeochemistry, climate, methane, paleoceanography, Arctic

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The expedition European Arctic–2023: Geological Record of Environmental and Climate Change was carried out within the program of the Shirshov Institute of Oceanology, Russian Academy of Sciences (IO RAS), to study sedimentation, climate fluctuations, and regional features of methane emissions in the contact zone between cold Arctic and warm Atlantic waters [6]. The European Arctic, including the Barents Sea and the Fram Strait, is a key region of the global ocean conveyor, the processes in which determined the climate and environmental conditions throughout the "Arctic Mediterranean" and the Northern Hemisphere in the Pleistocene and, particularly expressively, in the last 16–17 ka during the transition from the Last Glaciation of the Pleistocene to the modern interglacial of the Holocene. Reduction of ice cover and melting of glaciers on Arctic islands in the 21st century can be considered the modern period of the regional periglacial [6], an analogue of repeatedly occurring periods of warming in the Holocene [2].

The research was carried out during the polar night from November 8 to December 7, 2023, in the Barents and Pechora seas and Baydaratskaya Bay of the Kara Sea (Fig. 1) along the entire route of the vessel, some 4000 nautical miles, and at 124 integrated oceanological stations. Cumulative research of bottom sediments, the water column, and atmospheric surface layer was achieved through the efforts of a multidisciplinary team, e.g., to solve the problems of creating a monitoring system for climate change and climate-active substances in accordance with Order of the Russian Federation Government no. 3240-r of October 29, 2022 [1, 5]. We present only a few important and fundamentally new results.

For the first time, using the chamber method, 273 gas flow measurements at the water–atmosphere interface were carried out with a Picarro G4301 $CO_2/CH_4/H_2O$ gas analyzer [10] at 79 stations. The expedition recorded atmospheric methane emission via to molecular diffusion with an intensity on the order of several hundred $\mu gCH_4\ m^{-2}\ h^{-1}$ in waters of Baydaratskaya Bay, locally reaching several $mg\ m^{-2}\ h^{-1}$ due to the ascent of gas bubbles on the Yamal shelf as a result of fluid unloading of methane from bottom sediments. The highest methane concentrations in the water column and sediments were determined in Baydaratskaya Bay and the Pechora Sea. In this area, the methane concentration in the surface atmospheric layer reached 2118 ppb. Background methane concentrations exceeded 2018 ppb according to continuous minute measurements with two gas analyzers: a Picarro G2132-I [4] at a height of 19 m above the water line and a Picarro G4301 [10] at 9 m above the water

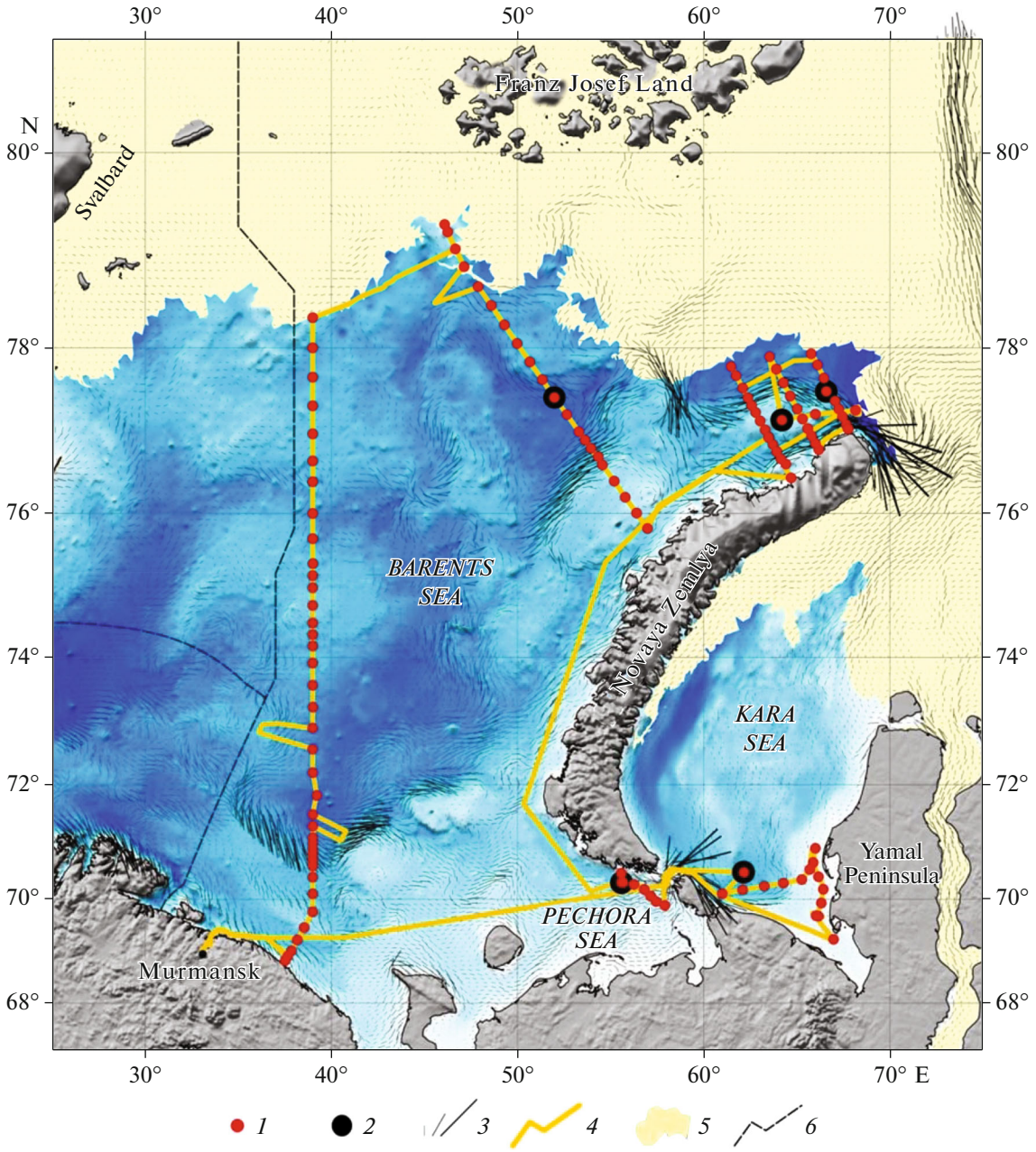

Fig. 1. Map of expedition route and oceanographic stations in Russian part of Western Arctic shelf of Eurasia, November–December 2023: (*1*) integrated stations; (*2*) integrated stations with sampling of sediment columns using large-diameter geological gravity corer; (*3*) current vectors; (*4*) vessel route; (*5*) ice cover; (*6*) borders of economic zones of Russian Federation and Norway and fishery protection zone of Svalbard. Current vectors were constructed from reanalysis (http://bulletin.mercator-ocean.fr/en/PSY4#3/75.50/-51.33) and are presented after [9]. Position of the edge of ice cover is shown as of date of study in this part of the water area according to the Norwegian Meteorological Institute, https://cryo.met.no. GEBCO bathymetric base, https://www.gebco.net.

line, respectively. A steady flux of carbon dioxide from the atmosphere onto the water surface was recorded throughout the studied region in the range from 15 to 160 mgCO_2 m^{-2} h^{-1}.

For the first time, the structure of the Western Novaya Zemlya Current at the Barents–Kara boundary has been studied in detail; the vertical and lateral matter fluxes in this current, which transports warm North Atlantic water towards the Kara Sea at a speed of up to 70 cm/s, have been assessed. The merging of two branches of the current was revealed near the northern tip of Novaya Zemlya.

A detailed hydrological survey was carried out in the central Barents Sea on a meridional transect along 39° E, an analogue of secular standard transect no. 6 "Kola Meridian" [8]. For different landforms, differ-

ent stages of convection have been identified in the areas of the cores of the three main branches of the North Cape Current and Murmansk Coastal Current.

The winter reserve of nutrients in the photic zone was calculated. Nutrients that limit primary production in spring have been identified: primarily mineral forms of nitrogen in Baydaratskaya Bay and dissolved silicon in the Barents Sea. Local sources of oil slick formation on the water surface of the Barents Sea have been identified. The concentration of hydrocarbons in ice and subglacial water is shown, mainly in suspension.

In areas where methane-bearing fluids are discharged, a rich collection of benthic fauna has been recovered (10 types and 107 morphospecies; 43 species identifications have been made so far), including two large groups of sedentary animals: brachiopods and bryozoans (Bryozoa). Bryozoans are widely represented, with 22 species. Currently, there is no information in the literature on the response of bryozoans to methane input from sediments. The composition and distribution patterns of meiofauna have been studied in detail in order to identify indicator species of methane discharge. The first information on the bioaccumulative potential (heavy metals, rare earth elements) of benthic fauna in these areas has been obtained.

Five sediment sections promising for detailed sedimentation and paleoclimate reconstruction over the past 10–15 ka were obtained in order to understand the further development of the natural environment under conditions of modern global warming. A rare mineral, ikaite, was discovered in a core from a contourite drift of the South Novaya Zemlya Trench at a depth of 4.4 m, a paleomarker of the sedimentation environment and discharge of methane-bearing fluids. In the Pechora Sea water column, new acoustic anomalies were recorded, formed by the release of gas from the sedimentary layer. Studies of previously known gas manifestation points were carried out based on materials from recent geological-geophysical and geomorphological expeditions of the Institute of Oceanography of the Russian Academy of Sciences [3]. On the northeastern slope of the Litke Plateau (Barents Sea), a pockmark with a diameter of ~250 m and a depth of 10–12 m was studied; as it formed, material was ejected to the north due to the explosive release of gas. Thus, the accumulation and release of significant volumes of methane from sedimentary strata in the Arctic [7] accompanied the change in glacial and interglacial climatic events.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This work does not contain any studies involving human and animal subjects.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

REFERENCES

1. S. K. Gulev, "Global climate change and the World Ocean," Probl. Prognozir., No. 6, 25–36 (2023).
2. G. G. Matishov and L. G. Pavlova, "Salinity under oceanic periglacial conditions in the Arctic seas," Dokl. Ross. Akad. Nauk **367** (1), 115–116 (1999).
3. S. L. Nikiforov, N. O. Sorokhtin, R. A. Ananyev, et al., "Research in Barents and Kara Seas during cruise 52 of the R/V *Akademik Nikolaj Strakhov*," Oceanology **62** (3), 433–434 (2022).
4. N. V. Pankratova, I. B. Belikov, V. A. Belousov, et al., "Observations of methane, ozone, black carbon, nitrogen oxides, carbon dioxide, and $\delta^{13}C$-CH_4 over the Russian Arctic seas from the research vessel in summer and autumn 2018," Okeanologiya **60** (5), 685–695 (2020).
5. M. G. Reshetnikov, "Climate policy in Russia: Science, technology, economy," Probl. Prognozir., No. 6, 6–10 (2023).
6. *The Barents Sea System*, Ed. by A. P. Lisitsyn (GEOS, Moscow, 2021) [in Russian].
7. T. Himmler, D. Sahy, T. Martma, et al., "A 160,000-year-old history of tectonically controlled methane seepage in the Arctic," Sci. Adv. **5** (8), 1450 (2019).
8. V. V. Ivanov, I. E. Frolov, and K. V. Filchuk, "Transformation of Atlantic water in the north-eastern Barents Sea in winter," Arctic Antarctic Res. **66** (3), 242–262 (2020).
9. V. V. Ivanov and F. K. Tuzov, "Formation of dense water dome over the Central Bank under conditions of reduced ice cover in the Barents Sea," Deep Sea Res. I: Oceanogr. Res. Pap. 103590 (2021).
10. D. A. Pestunov, A. M. Shamrin, V. P. Shmargunov, and M. V. Panchenko, "Gas-analytic measurement complexes of Baikal atmospheric-limnological observatory," in *Proc. SPIE 9680, 21st Int. Symp. Atmosph. Ocean Optics: Atmos. Phys.* (2015). https://doi.org/10.1117/12.2205538