
INFORMATION

Study of Oceanographic Conditions in the Area of the Avachinskiy Bay, Kamchatka, in Winter during an Expedition on the R/V *Akademik Oparin* (Cruise 65)

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Abstract—During cruise 65 of the R/V *Akademik Oparin* from November 26 to December 29, 2022, research was continued in the area of Avachinskiy Bay, Kamchatka, to study the possible factors that caused the mass mortality of marine organisms in fall 2020, and perform integrated hydrographic and hydrochemical surveys on the northeastern shelf of Sakhalin Island to monitor the environmental situation in areas of oil and gas production and in the southern Sea of Okhotsk. According to data from two autonomous moorings deployed in the coastal zone of Avachinskiy Bay with an exposure of 169 days, relatively calm water dynamics in the bay were noted throughout the entire summer–fall season of 2022, which contributed to enrichment of waters in nutrients necessary for plankton development. No noticeable decrease in oxygen content was recorded. A survey of the southern part of the East Kamchatka Current was carried out, the evolution and the structure of the anticyclonic eddy of Avachinskiy Bay at the time of its splitting was traced. Studies have been carried out on the hydrochemical characteristics of coastal bays and rivers during the freeze-up period. Samples of plankton and bottom sediments were taken for special analyses in the laboratories of the Pacific Institute of Bioorganic Chemistry and National Center for Marine Biology, Far Eastern Branch, Russian Academy of Sciences.

Keywords: Kamchatka Peninsula, Avachinskiy Bay, Sea of Okhotsk, Sakhalin shelf, mesoscale eddies, hydrography, biogeochemistry

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The main objectives of the expedition of cruise 65 on the R/V *Akademik Oparin*, organized by the Il'ichev Pacific Oceanological Institute, from November 26 to December 29, 2022, were a continuation of studies we began in summer 2022 (cruise 80 of the R/V *Professor Gagarinskiy*) on abiotic environmental factors that could have contributed to the mass death of marine organisms in Avachinskiy Bay, Kamchatka, in 2020, as well as an assessment of other possible environmental risks in the coastal waters of the Kamchatka Peninsula associated with climate change and other natural factors. At the beginning of the winter period, comprehensive hydrographic and hydrochemical surveys were carried out in the Pacific Ocean adjacent to the southeastern part of Kamchatka (Fig. 1), which will make it possible to identify large-scale interannual changes occurring in the western Subarctic of the Pacific Ocean and assess regional processes associated with the mesoscale water dynamics, as well as local impacts caused by the influence of continental runoff. Studies of biogeochemical processes in the

marine coastal zone were repeated in Vilyucha and Avacha bights.

In total, the expedition made 118 stations with CTD sounding, 89 with sampling for dissolved oxygen, pH, alkalinity; 83 with water sampling for nutrients. There were also 21 stations with bottom sediment sampling, 38 stations with sampling for phytoplankton, and 43 for zooplankton. A total of 471 samples were analyzed for standard hydrochemical parameters: dissolved oxygen, alkalinity, pH (pH), and 439 samples were analyzed for nutrients (phosphates, nitrates, nitrites, and silicates).

Radioisotope studies were carried out: 104 water samples were taken for ³H, and 46 samples for ⁷Be, ²²⁶Ra, ²²⁸Ra and ¹³⁷Cs. In addition to the surface layer of the ocean, water samples were taken at nine stations from different depths down to the bottom layer of the sea. The total volume of water sampled was 6029 L. In addition, five samples of snow and bottom sediments were collected.

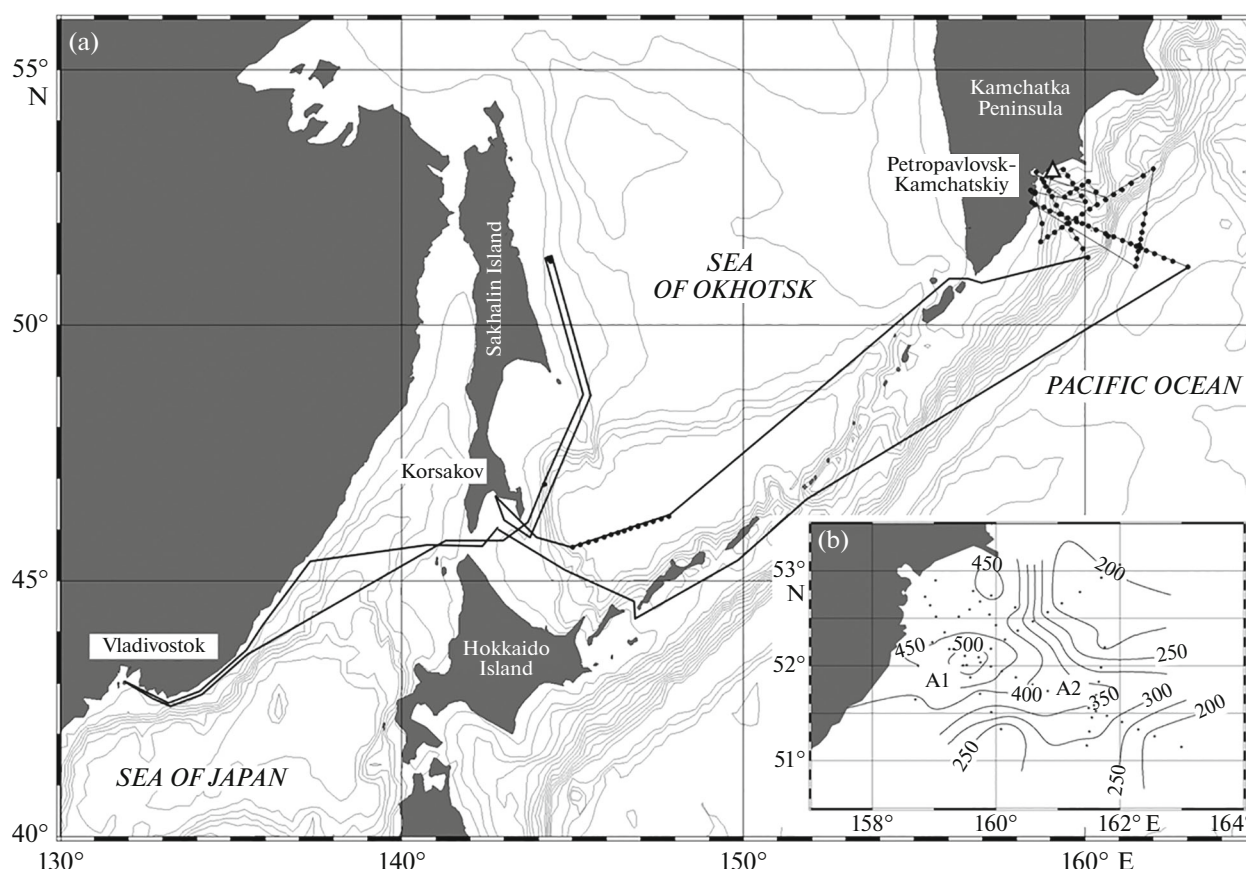


Fig. 1. Scheme of work of POI FEB RAS expedition on the R/V *Akademik Oparin* (cruise 65) November 26–December 29, 2022 (a) and depth distribution of isopycnal surface 26.8 in Avachinskiy Bay area of Kamchatka. A1 and A2, positions of cores of detaching anticyclonic eddy. Dots show position of oceanographic stations; triangle, position of moorings in Avachinskiy Bay.

Two autonomous mooring stations (ABS) were recovered, deployed in June 2022 at a depth of 22 and 57 m near Khalaktyrsky beach to study the short-period variability of oceanological characteristics and worked for 169 days.

The preliminary results of the expedition are as follows:

(1) A detailed survey of Avachinskiy Bay, Kamchatka, and adjacent waters of the Pacific Ocean was completed at the beginning of the winter season, the results of which, in addition to those of an earlier summer survey (June–July 2022), will make it possible to refine the specific features of the hydrographic and hydrochemical regimes of this area, and assess the impacts of climate change and regional dynamics of water and continental runoff on biogeochemical processes in the ocean, which is necessary for studying abiotic environmental factors affecting the state of ecosystems and dynamics of harmful algal blooms (HABs) in the coastal waters of Kamchatka and adjacent waters of the Pacific Ocean and analyzing possible mechanisms behind the environmental disaster of September 2020.

(2) Long-term observations of the variability of currents and other oceanographic parameters (tem-

perature, salinity, turbidity, oxygen and chlorophyll *a* content) were carried out using bottom measuring stations deployed in the coastal zone of Avachinskiy Bay, in the area of Khalaktyrsky Beach. Analysis of a 6-month series of data showed that the coastal zone, in general, is characterized by relatively calm water dynamics, facilitating the formation of fields enriched with nutrients necessary for the development of plankton. Sharp changes in oceanographic characteristics are associated with the advection of water by submesoscale eddies and jets. No significant decrease in oxygen content was recorded throughout the summer-autumn season of 2022.

(3) The structure of the southern part of the East Kamchatka Current has been studied, the dominant role of mesoscale eddies in the formation of its meanders, the deviation of the flow from the shelf, and the transport of coastal waters far into the open ocean has been established. A detailed survey was carried out on a long-lived anticyclonic eddy in the area of Avachinskiy Bay, discovered from satellite altimetry data in May and tracked until the end of 2022. During both summer and winter surveys, the eddy splitted: the detached part moved east, crossing the Kuril–Kamchatka Trench and transporting trapped coastal water in

the core, forming a current meander that was abnormally elongated in the zonal direction.

(4) During the freeze-up period, research has been carried out on biogeochemical processes in the estuaries of rivers flowing into Avachinskiy Bay: the Avacha River, which is partially subjected to anthropogenic impact, and the Vilyucha River, which is almost completely isolated from it. In the waters of the latter, increased concentrations of nitrate ions of about 30 $\mu\text{mol/L}$ were found, as well as extremely high concentrations of silicates up to 227 $\mu\text{mol/L}$, which can be explained by the influence of ground- and hydrothermal waters. In the river–sea mixing zone in the Vilyucha River estuary, in the winter season the waters are sharply undersaturated with carbon dioxide in relation to the atmosphere, as indicated by the increased pH value. The bottom waters in Vilyucha and Avacha bights are supersaturated with carbon dioxide relative to the atmosphere. In lows in the relief of these bays, both in summer and winter, reduced silts with a pungent odor of hydrogen sulfide were found throughout the entire sediment thickness of about 1 m. Comparison of the chemical composition of the Vilyucha and Avacha waters will make it possible to assess the impact of anthropogenic and natural eutrophication on the state of the coastal and marine waters of Kamchatka.

(5) The results of tritium measurements in samples collected during the cruise correspond to the background values of the studied water areas. The average tritium concentration in the Sea of Japan was 1.11 tritium units (TU corresponds to 0.119 Bq/L) and varied from 0.77 to 1.39 TU; in the Sea of Okhotsk, the average concentration of 1.29 TU varied from 0.65 to 1.9 TU. In samples taken east of the Kuril Islands and Kamchatka Peninsula, the average tritium concentration of 0.6 TU varied from 0.34 to 0.95 TU. The results are important for subsequent work related to studying the radioecological consequences of tritium-contaminated water discharged from the Fukushima-1 nuclear power plant for the Northwest Pacific.

(6) Special surveys were carried out on the shelf of Sakhalin Island and in the southern part of the Kuril Basin to study winter water exchange processes in the Sea of Okhotsk. A comprehensive complex transect was conducted to study the structure of waters of the anticyclonic eddy of the Kuril Basin, the formation mechanism of which is associated with the interaction of water flows of the Soya and East Sakhalin currents, which differ in their thermohaline characteristics. Integrated

measurements (hydrology, hydrochemistry, and plankton) were carried out here for the first time.

(7) Samples of phytoplankton and bottom sediments were taken for special analyses in the laboratories of the V.I. Il'ichev Pacific Oceanological Institute (POI) FEB RAS, the Pacific Institute of Bioorganic Chemistry (PIBOC) FEB RAS, and the National Scientific Center of Marine Biology FEB RAS, necessary for the implementation of scientific research plans of the integrated interdepartmental program “Ecological Safety of Kamchatka: Study and Monitoring of Hazardous Natural Phenomena and Anthropogenic Impacts”; in particular, more than 40 samples were taken for isolation of strains of marine bacteria and metagenomic studies at the PIBOC.

In addition to personnel of POI, representatives of PIBOC and students and undergraduates of Far Eastern Federal University took part in the expeditions.

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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.

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