CARTOGRAPHIC REPRESENTATION OF RESEARCH ACTIVITIES IN THE RUSSIAN ARCTIC IN THE PERIOD FROM 1950 UP TO THE PRESENT DAY

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Abstract
The paper presents maps and a text covering the contents and status of research in the unique Arctic region throughout two stages: the stage of the Arctic lands development by the Soviet Union (1950 – 1991) and the stage of the Russian Arctic development from 1991 to the present day. The texts to the maps show that studying the Arctic basin has always been aimed at deepening the geographical knowledge about the region’s nature, economy and ecology, including improving transport links. The organization and development of the Arctic region research are discussed within a framework of the country’s economic and political situation. The article features its most important scientific results.

The maps cover the whole territory of the Russian Arctic, and contain information about the polar stations and their research profile, air, and sea expeditions and “Severny Polyus” (“North Pole”) drifting stations, the Northern Sea Route with the standard routes characteristics and the area of all the navigation routes. Map scales are: 1:25 000 000 and 1:16 000 000. A larger scale – 1: 16 000 000 shows in more detail the ecological-biological centers and centers for integrated research – "Mys Baranova" (“Cape Baranov”) Ice base and the Russian research center in the Svalbard archipelago. Drifting stations, namely, the drift routes of each of the stations, the drift beginning and end, are depicted to same scale in more detail. Drifting stations are shown by specific inset maps. The paper is illustrated with map and legend fragments, the report gives the maps in full.

INTRODUCTION

The Arctic is a unique area with harsh natural conditions and high development potential.

The Arctic has always attracted people. Its development began centuries ago and has been continuing to this day. The revival of interest to the Arctic in recent years has been due to current and expected climatic changes, their impacts on the economic activities and ecological status.

Russia has made a great contribution to the study of the region, accompanied by the presentation of these results in a completed and visual cartographic way.

When creating maps, it is of great importance to generalize and systematize information obtained from a variety of sources. In our work, it was analyzed for the period from 1950 up to the present day.

OBSERVATION CENTERS AND NETWORKS

Exploration surveys in the Russian Arctic throughout the period from the 1950s to the present, are divided into two stages which correspond to two thematic maps.

Throughout the time under examination, the study of the Arctic basin, as in all other years, has been aimed at deepening of the geographical knowledge about nature, the economy, the ecology of the region, including improving transport links and communications.

The base for research at all stages of exploring this unique region has been the establishment of the Arctic drifting stations, air and sea expeditions, centers for integrated research within the entire region. It was these networks for observations and field investigations that became the main objects of mapping (studying). The Northern Sea Route played an important role both in the organization of this work and in obtaining factual data. Let us consider the stages of the region exploration surveys in more detail.

The stage of the development of the Arctic lands by the Soviet State (1950 – 1991)

In the postwar years the Arctic navigation was actively developed, thanks to the commissioning of new classes of icebreakers, including the "Lenin" and "Arctic" nuclear-powered ships. The Northern Sea Route was used for...
procurement of new buildings, provision of geological surveys of oil, gas and other natural resources of the North. The period of Arctic navigation expanded in connection with the application of new scientific methods for studying the Arctic, carrying out meteorological research, ice reconnaissance.

On the territory of the Arctic zone, there were many hydro-meteorological and meteorological stations. They monitored the regime for the oceans, seas, rivers, lakes, marshes and weather condition as a whole. From 1957, 103 polar stations worked, of which 38 in addition to the regular program made aerological and actinometric measurements. The scope of observations performed increased. Air reconnaissance of ice conditions started to be held regularly. [2]

In the late 60-ies of the 20th century, there was created a special space system of several meteorological artificial Earth satellites, which allowed to obtain information about clouds and snow cover, distribution of ice, the temperature of the underlying surface, and other characteristics.

To monitor the status of the environment in the Arctic, there were set drifting automatic radio meteorological stations (DARMS) — remote units for measurement and transmission by radio in coded form the values of air temperature, atmospheric pressure, the speed and direction of the wind, as well as for obtaining data on the deflection angles of the station from the vertical position in the drift process.[4]

Due to the increase of flights over the endless expanse of the North, on the mainland there were established aviation-meteorological stations (offices affiliated with airports), which were to perform meteorological observations, gather information on weather, compile and analyze synoptic maps, advise of and forecast weather for flight support.

From 1950 to 1991 there were set up 30 "Severny Polyus" (SP) ("North Pole") drifting stations. They conducted a wide range of research, and in 1954, there were established two drifting stations in the Arctic zone, and from this time on, simultaneous operation of several stations became a common practice. [2]

The working group of SP-2 was disembarked on the floating ice of the Arctic on April 2, 1950, it becoming the second station in the history of Soviet stations. It drifted in the Arctic Ocean for more than a year. The station team was then evacuated because of some swift ice twitch and split, but the expedition equipment wandered the expanses of the Arctic for several years. Being in the field of view during the observations, the remnants of the equipment contributed to a real scientific discovery - the existence in the Arctic of two relatively independent systems of the general ice drift. The first one was a trans-Arctic system from East to West, from the Chukchi Sea to the Greenland Sea, and the other one — along the anticyclonic ring in the Western Canadian sector of the Arctic, it was discovered from the movements of the SP-2 camp remnants; the time of a full circulation of this system was estimated to be four years. [2]

In general, the trajectory of the drift of all 30 SP stations, beginning with that of SP-2 (1950) and ending with the last station SP-31 (1988), can be divided into three groups: 1 — the stations, drifting across the pole or near it in the Greenland sea; 2 — the stations involved in the anticyclonic circulation of ice in the Western Arctic; 3 — the stations, the drift of which was unusual and different from that of the first two "standard" options. [2]

Every year the amount of work conducted at the drifting stations, became more diverse. In addition to observations on meteorology, aerology, actinometry, oceanography, the state of the ionosphere, the drift and rotation of ice floes, they began to study the issues associated with the regime for ice, the physics of the interaction of the upper ocean and ice to identify new regularities and properties of the nature of the Arctic.

The Program of Work of the North Pole-5 drifting station was greatly expanded compared to that of the previous ones. In addition to regular oceanographic and hydrobiological stations, there were added remote stations onboard the Mi-4 helicopter. [2]

Automatic recorders continuously registered water currents in different horizons. Ice studies included the study of thermals of both ice and snow, with semiconductor thermometers. Aerometeorological observations included temperature and wind sounding of the atmosphere through daily sending aloft of weather balloons to a maximum altitude. To explore the physical features of the atmospheric processes, two times per month there were practiced series of frequent sending of radiosondes and pilot-balloons aloft, actinometric, magnetic, and special observations of the condition of the ionosphere, observations of radio waves propagation.

Exploration of the Arctic by aviation is marked by the "Sever" ("North") Arctic high-altitude air expeditions (VVE), to hold ice and oceanographic studies of drifting ice. The objectives of the expeditions included the installation of radiometric stations and radio buoys, preparation of ice-hydrological forecasts and other observations related to the support of the navigation of vessels along the Northern Sea Route.[5]
The “North” High-latitude air expeditions usually worked two seasons a year. In autumn (November — December) they supplied the SP drifting stations with materials, equipment and food. In spring (March — May), research units of the expeditions performed comprehensive monitoring at scheduled points in the Arctic basin or on the shelf of the Arctic seas. These units were usually called "jumping", as they after making observations at one point, immediately flew to another one, then the next, etc. At each point of landing, the scientific staff together with the crews of airplanes or helicopters deployed a temporary camp on the ice, the existence of which was from several hours to several days, depending on the work program.

Each "North" expedition consisted of a combined aviation detachment, the VVE headquarters, two or three scientific groups, a group of logistic support, shore bases and the so-called "hops" — temporary bases on the ice to support "North Pole" stations located at a considerable distance from the shore.

The unit of high-latitude expedition "North-25" at the beginning of 1973 was destined to start performing unique oceanographic surveys associated with obtaining in situ data on the state of the ocean and the atmosphere at numerous points of the Arctic Ocean. SP stations were used as the base for building up on the huge high-latitude space. Using SP-21 as the source database, the "North-25" expedition performed deep-sea oceanographic and meteorological observations at 182 points in the ocean. [5]

It was supposed, from the results of the work of the expedition, to improve methods for long-term and short-term weather forecasts and ice-hydrological processes for high and temperate latitudes, to measure the depth of the ocean, the direction and speed of underwater currents at as many points as it was possible. There were addressed issues related to the possibility of the year-round navigation and the development of new high-latitude routes. It was planned to compile an Atlas of the bottom topography and currents of the Arctic Ocean.

Arctic sea expeditions continued to work as well. Icebreakers were applied to research activities and, later, so did nuclear submarines. During expeditions, integrated investigations were dedicated to the study of the ocean bottom topography, atmospheric phenomena and interaction of all natural systems.

The expedition, which began in 1948 and continued until 1954, helped detail the bathymetric map of the Polar basin and the outline of the Lomonosov Ridge with a length of about 1,800 km. [1]

In 1955, the legendary expedition aboard the ice-cutter "Fyodor Litke" identified the deepest point of the Arctic Ocean — 5449 m. It drilled the bottom of the ocean to gather geological samples. The "Fedor Litke" ice-cutter reached 83° 21’ North latitude, setting the record for freewheeling in the Arctic ocean.[3]

In the period from 1956 to 1957 under the leadership of George A. Baskakov, the participant and leader of expeditions in different seas, chief of the first expedition for the survey of the currents of the Arctic seas, conducted the expedition covering a vast area of the Kara, White and Barents seas. The main objective of the research was surveying of currents. The expedition worked aboard three vessels: the ice-cutter "Fyodor Litke", and two schooners: "Aktyubinsk" and "Buyo" in 1956; "Astra" and "Tuyvak" — in 1957. In the vast area of the Kara Sea there were set up 15 buoy stations with self-recording instruments for measurement of the speed and direction of currents. There were recorded water-level fluctuations in the open sea as well. [1]

In the postwar years, the Soviet Union began construction of a powerful icebreaker fleet for the Northern Sea Route. Icebreakers made it possible not only to improve navigation but also to establish high-latitude routes.

The first experience of using a nuclear-powered icebreaker to reach the North was the campaign of the icebreaker "Lenin" in 1961. In addition to testing the technical means and possibilities and a number of scientific observations, the purpose of the voyage was the disembarking of a new drifting station "North Pole" on the ice through an active floating ship, rather than an aircraft, as it had been done previously. The first high-latitude voyage of the icebreaker "Lenin" confirmed the possibility of freewheeling of powerful icebreakers in high latitudes in conditions of stable ice formation.[3]

In August 1977, the icebreaker "Arktika" conquered the North Pole. Since the goal was to achieve the North Pole, the development of the route was conducted from data of long-term observations of the behavior of the ice fields. Scientific and technical experts from various institutions reinforced the icebreaker crew. On August 17, the nuclear-powered icebreaker reached in active navigation for the first time ever the geographic North Pole, where the expedition crew conducted the planned research. During the expedition, they collected unique data on the behavior of the hull of the icebreaker when interacting with ice in different operating modes, tested devices for determining the ice cover thickness and a satellite navigation system under the conditions of high latitudes.
The end of the 80-ies was crowned by one of the last expeditions organized by the Soviet State. It was a high-latitude expedition of the icebreaker "Sibir" to the North Pole (1987). The main objectives of the expedition were to evacuate the drifting polar station SP-27 and deliver the new polar station SP-29. In the conduct of evacuation, researchers found that the ice situation allows them to reach the North Pole. On May 25, 1987, the icebreaker "Sibir" was the second ship that reached the North Pole in active navigation.[2]

In view of the complex research in the Arctic, discussed above throughout the period in question, the map (scale 1: 25 000 000) and its legend show:
- air expeditions (I. I. Cherevichny 1953, V. K. Bakhtinov 1958, "North-25" 1973), pointing out the work areas, the bases of the air expeditions, the areas covered by flying from the shore bases and from the drifting station "North Pole-21"
- hydrometeorological stations;
- nature reserves of national importance.

Separately, the additional inset map (scale 1: 50 000 000) represents the area of the drift stations "North Pole" (SP).

Fragments of the map of the development of the Arctic lands by the Soviet State and its legend are given in Figures. (Fig. 1,2)

![Figure 1. Map "Stage of the development of the Arctic lands by the Soviet State (1950 – 1991)" – Fragment](image-url)
In the late 1980s and early 1990s, the activities of the Soviet State was complicated by the radical changes in the country due to new political and economic conditions, which resulted in a reduction of the Arctic research. In 1991, the drifting polar station SP-31 concluded its work. Marine studies became performed much less frequently. In 1993, the high-latitude air expedition "Sever-45" finished working. There was a reduction in the number of hydrometeorological stations. However, the Arctic continues to be researched, and the next stage of its development began.

**The stage of the development of the Arctic lands by the Russian Federation (1991 – 2015)**

The beginning of a new stage of the development of the Arctic is characterized by the participation of Russian researchers in international expeditions, and a gradual intensification of work. A comprehensive study of natural, ecological conditions and the environment became developed in connection with the industrial development of the shelf. In the summer of 1994, aboard the scientific and expeditionary vessel "Akademik Fedorov" there was held an international expedition, together with Swedish scientists, "Tundra Ecology-94" along the Northern Sea Route. The program of the field work included comprehensive studies of the ecosystem status of the Arctic coast of Russia, identification of the negative consequences of anthropogenic impact on the vulnerable Arctic nature.

The first Russian drifting station "North Pole-32" started its activity in 2003. New models of equipment and machinery were tested. Throughout the period of the drift, scientists conducted measurements at depths of 3000 m or more, obtained materials on the problem of the interaction of the atmosphere and ocean, which were of importance for predicting natural disasters. The state was engaged in systematic research of the Arctic region, and by 2004, the next drifting station "SP-33" had started its work.[1]

The high-latitude Arctic expedition (VAE) "Arctic" was arranged in order to resume studies in the Central part of the Arctic Ocean. Since 2004, all activities for organizing and evacuating each drifting station have been supported by this integrated high-latitude sea expedition. Representatives of many local agencies and research institutions took part in expeditions, working mainly aboard the vessel "Akademik Fedorov". The objectives of the expeditions included a comprehensive study of natural conditions in the high-latitude Arctic and their variability in the modern climate epoch. On August 29, 2005, the expedition "Arctic-2005" aboard the research vessel “Akademik Fedorov” reached the North Pole without an ice-breaker escort.

In 2005, a squad of geologists and geophysicists started working aboard the “Akademik Fedorov” to go to the Arctic. In the area of the Lomonosov and Mendeleev Ridges, they obtained data to establish that the Lomonosov Ridge is a natural extension of the Siberian continental platform, and the Mendeleev Ridge is the ancient continental crust of the continental margin of Russia. In the summer of 2007, to detail the outer limits of the continental shelf of Russia, they checked up the geological junction of the Lomonosov and Mendeleev Ridges and the adjacent mainland margin of Russia in the Laptev and the East Siberian Seas. The atomic icebreaker “Rossiya” broke the ice at the North Pole for descending bathyscaphes.

The organization and carrying out of the 2007/08 International Polar Year on the initiative of Russia was the central event at the beginning of the 21st century. In 2007, the high-latitude deep-sea expedition "Arctic 2007" was organized by the Arctic and Antarctic Research Institute on board the icebreaker "Akademik Fedorov", the expedition took place under the leadership of Artur N. Chilingarov. The crew of the submersible "Mir-1" planted the State Flag of the Russian Federation for the first time in history at the geographic North Pole on the Arctic Ocean floor at a depth of 4261 m on August 2, 2007. In the course of the expedition, there was arranged the drifting station SP-35. The route of the expedition took place in certain areas of the Arctic Ocean, never visited before by the domestic ships. Besides, among
the results of the multidisciplinary research in the Arctic area found were new technologies of hydrometeorological support of navigation in the Arctic and freezing seas of Russia, organized in the form of workstations on the basis of modern electronic mapping and geographic information systems.

In 2012, the innovative educational project "Arctic Floating University" was implemented by joint efforts of the Northern Arctic Federal University named after M. V. Lomonosov (NARFU), the Federal Service for Hydrometeorology and Environmental Monitoring (Rosgidromet) and the Arkhangelsk branch of the Russian Geographical Society for young researchers of the Arctic to be able to manifest themselves in the real conditions of the Northern seas. The research vessel "Professor Molchanov" becomes the floating University for the period of the project. The voyages of the "Arctic Floating University" are made in summer every year.

In the summer of 2013, after repair work, the field stationary base of the Arctic and Antarctic Research Institute opened the research stationary base "Ice Base "Mys Baranova" ("Cape Baranova") on the Island of Bolshevik. The base is located on the shore of the Shokal'skogo Strait, separating the Island of Bolshevik and October Revolution Island of the Severnaya Zemlya archipelago. The neighborhood is characterized by the presence of a broad spectrum of natural sea ice, both lake and river origin, with a dome-like glaciers and icebergs. At the base they conduct meteorological, solar radiation, aerological and ozone observations, investigate into the physical-and-mechanical and morphometric characteristics of ice, the chemical structure of water masses, perform regular glaciological monitoring on the Mushketov Glacier and the adjacent areas. [6]

In December 2013, there was created the Russian Scientific Center on Svalbard / Spitsbergen (RNCS) and its infrastructure (it used to be a weather station). Svalbard / Spitsbergen is one of the unique test grounds for complex studies of the region in various fields of Earth Sciences as it is located on the border of the spread of warm waters of the North Atlantic current and the ice cover of the Arctic basin. [7]

The Center provides coordination of scientific investigations when different departments conduct them, an increase of efficiency of the scientific base and optimization of the mechanism for financial support of scientific activities. The Arctic and Antarctic Research Institute, which created a permanent Russian scientific Arctic expedition to Svalbard / Spitsbergen is the coordinator of the Center. Its primary purpose is the logistical support for the activities of the wintering and seasonal teams of expeditions.

The Research Center (RNCS) consists of two laboratory buildings, where they carry out chromatographic and spectrophotometric analyses of substances, and the unit of reception, processing and transmission of satellite information. On the basis of RNCS are made various test grounds such as environmental, meteorological, oceanographic, cryosphere-and-hydrology, and geophysical ones. Each test ground and laboratory is provided with specialized equipment. [7]

The scientific expedition vessel “Akademik Fedorov” continued the work of the determination of the outer limits of the continental shelf in July 2014 (VGX-2014). The members of the scientific team included the members of the “Marine Arctic Geological Expedition”, which carried out its mission during the Soviet period. A comprehensive study had the objective of creating the geological and geophysical basis for assessing the petroleum potential of the continental shelf beyond the exclusive economic zone of the Russian Federation in the Arctic Ocean. Throughout the voyage, they performed standard meteorological observations as well as continuous registration of the surface concentration of both ozone and carbon dioxide, using portable gas analyzers. [9]

The end stage of the development of the Arctic is marked by the organization of the next drifting station "SP-2015" under the auspices of the Institute of the Arctic and Antarctic. During the operation of the station there were carried out observations and studies in several areas: meteorology, aerology, oceanography, hydrochemistry, hydrobiology, sea ice, magnetology. [8]

The content of the research of the modern period is reflected by the map of a larger scale (1: 16 000 000), which made it possible to detail in the original and in the map legend items already highlighted in the previous section and add new information.

Polar stations are shown, classified as existing, conserved, automatic ones. In addition, they are differentiated according to the profile of studies into meteorological, marine hydrometeorological, river hydrological, aerological, and actinometric ones. Shown are the centers for comprehensive research restored at the site of the former polar station of: the Ice base "Mys Baranova" and RNCS. The current stage of the development of a network of especially protected territories (reserves) is characterized and displayed on the map through ecological-biological centers in the form of reserves, not only of Federal importance, but also in the form of the biosphere and national parks.
The scope of work of sea expeditions becomes more complex, partly international, environmentally directed, characterized by the studies on the shelf. The map marks them in accordance with the dates and names reflecting their characteristics: "Tundra Ecology-94" (1994), "Arctic-2007" (the International Polar Year), "Shelf-2010", "Outer limits of the Continental Shelf" (VGKS-2014). (Fig. 3,4)

The scale of the map allowed us to show in detail the Northern Sea Route – its standard routes of the voyage and the entire area of navigation routes.

As for the drifting stations "North Pole", the additional inset map contains not only generalized information on the area of drift as a whole, as it is on the map of the previous stage, but also specific information about the routes of drift of individual stations, the beginning and end of each drift under its individual name (SP-2015, SP-40, etc.)

*Figure 3. Map "Stage of the development of the Arctic lands by the Russian Federation (1991-2015)" - Fragment*
The designed maps of both stages are agreed on content, mathematical, and geographical bases. They are made in the TsNIIGAiK oblique perspective-cylindrical projection, the insert maps use the normal azimuthal conformal projection.

The process of creating the map can be divided into several stages: preliminary examination of the material, systematization of obtained data, the formation of the legend and the designing of the original. The map is compiled in a desktop publishing system (NIS) Adobe Illustrator. The integration of linear and areal objects, when using transformed maps, is conducted by the "transparent table".

**CONCLUSIONS**

Currently, the study of the Arctic is being continued. The results mapping produces a clear picture of the region studies, allows one to evaluate the research state and contribute to the organization, coordination and planning prospective activities. The designed and compiled maps can also be of interest in historical terms, for educational purposes, for a wide range of specialists in different fields and for anyone interested in the unique Arctic region.

Requirements to the article submission and dimensions (scales) of maps covering the territory of the Russian Arctic completely resulted in the submission of fragments only of the legends and those of the originals. Full-size maps are presented in the report.
REFERENCES


