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Arctic Forecasting: Formation of a Research Field

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Abstract. In the domestic literature, there are still not enough works devoted to a comprehensive description of the phenomenon of Arctic forecasting. This article distinguishes it from the general socio-economic context. The analysis of foreign studies on Arctic forecasting technologies and key factors allowed us to reveal the research question: can Arctic forecasting be considered a highly specific area? The work has examined physical-geographical and resource factors: climate, maritime transport, ice cover, oil production and others. Studies demonstrating the interrelation of factors were widely used: for example, climate and energy, social and economic changes. Based on the authors' approaches, a typology of Arctic forecast models has been developed, taking into account the number of variables considered and the quantitative-qualitative nature of the specifications. In the course of analyzing the dynamics of the research agenda of the European symposium "The Future of the Arctic", the evolutionary formation of the topic of Arctic forecasting is shown. The main feature is its reliance on resources as the basic essence of the Arctic economy. It is shown that the involvement of Arctic resources in the economic turnover depends on the world technological dynamics: through natural resources the Arctic economy is connected with the world economic processes. The phenomenon of Arctic forecasting includes a more merged, multitasking nature of natural-climatic and economic modelling than standard models for studies of environmental dynamics, with forecasting of positive and adverse social and economic consequences. The presented results structure the phenomenon of Arctic forecasting for the development of methodological approaches to substantiate the prospects for the development of polar and northern regions. The considered factors will be useful in developing state policy measures in relation to the Arctic zone of the Russian Federation.
Keywords: *Arctic, forecasting, regions, development scenarios, mineral deposits, shipping, climate*

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Introduction: specifics of Arctic forecasting

The future of the Arctic and its resources is becoming the subject of scientific research and the application of forecasting methodologies more and more often [1, Brekhuntsov A.M.; 2, Grigoriev M.N., 3, Skufina T.P., Korchak E.A.]. The essential part in the surveys is related to the reduction of uncertainty that follows any scenario forecast about both present and future changes in the Arctic [4, Kryukov, Kryukov]. This comprehensive ambiguity is often discussed in regard to the

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so-called turning points: definitions of critical thresholds when changes in Arctic territorial systems become irreversible [5, Evengård B., Larsen J., Paasche N.Ø.; 6, Sosa-Nunez G., Atkins E.]. Competition between different options passes through these turning points [7, Wormbs N.].

Extreme weather conditions and the impact of climate change make the Arctic one of the most rapidly changing regions, which qualitatively complicates forecasting techniques. These conditions require specialized methods and models for Arctic regions, including consideration of seasonality, probabilistic factors, hierarchical structure of connections (establishing links at the pan-Arctic, national and regional levels), models of environmental "responses" to rapid warming and the deployment of new types of economic activity. Increased demand for reducing uncertainty leads to a request for integrated, "connected" forecasting that includes climate, energy, economics, and shipping.

The current nature of complex Arctic processes requires consideration of various factors in forecasting. For example, modelling the dynamics of Arctic sea ice should include a complex combination of different phases, scales of area cover and time periods. Traditionally, physical-geographical forecasting is highly complex, which may use coupled models of the atmosphere, sea ice and ocean dynamics, even on a short-term horizon; and a certain type of connections between polar and mid-latitudes and the strength of their interaction in forecasting the physical-geographical environment can be introduced. The cohesion of the natural and socio-economic Arctic components is manifested in forecasting the current and future dynamics of permafrost soil, which affects the investment plans of resource companies for the introduction of new capacities, the urgency of repairing existing buildings and structures [8, Porfiryev B.N., Eliseev D.O., Streletskiy D.A.].

Against the background of these individual examples, the purpose of this article is to form an idea of Arctic forecasting as an independent phenomenon. Due to its specificity, it will differ from the approaches used for other territories because of the inclusion of a number of factors that are not typical of common methods. It is expected to fully reveal the trends associated with seasonal natural Arctic variability, predominantly resource-oriented economic activity, increased costs and the high-risk nature of the transport sector. The study is organized as follows: first, the factors determining the content of most Arctic models are considered. Then, their typology is developed, taking into account the scale and predominantly physical-geographical or socio-economic focus. The second part of the article discusses the evolutionary development of the Arctic forecasting within the framework of an institutionalized platform — the annual Brussels International Seminar on the Future of Polar Territories — and describes the directions of development of Arctic forecasting approaches.

Theoretical foundations of the Arctic forecasting phenomenon

The works on Arctic forecasting have so far been mainly focused on the prospects of resource extraction, climate change, geopolitics, and economic and social development as key factors shaping the future of the Arctic [9, Andrew R.]. In the work [10, Arbo P., Iversen A. Knol M. et al.], prospective Arctic researches in recent years are conceptualized on the basis of a sample of more than 50 publications. Similar reviews were conducted in [11, Mazo J.; 12, Young O.], but based on a much smaller number of works and a narrower thematic coverage.

An overview of scenario studies on the concepts and methodologies used is considered in [13, Erokhin D., Rovenskaya E.], where the key factors of the Arctic are grouped into several "baskets": climate and environment, extraction, supply and demand of resources, trade and economic issues; transport, shipping and infrastructure; indigenous peoples; governance and geopolitical issues, technological development. The wide range of potential scenarios for the Arctic's economic future depends primarily on regional investment conditions and global commodity prices. Rising temperatures and melting sea ice are exposing previously commercially inaccessible sources of hydrocarbons and other minerals, opening up new fishing grounds and opportunities for the use of new energy sources.

The role of climate is decisive in Arctic forecasting. The effects of climate change are nowhere on Earth more dramatic or more rapid than in the Polar regions. As a result, both biological and anthropogenic systems in the region are undergoing rapid transformation [14, Young O.].

The reduction of ice cover leads to the emergence of new economically and technically feasible trans-Arctic sea routes, simultaneously with the growth of industrial development. This is followed by the development and densification of infrastructure networks, increasing anthropogenic pressure on Arctic ecosystems, which can lead to an aggravation of relations between the Arctic states and large extra-regional states.

Since the type of impacts, their scale and rate of change have a profound impact on ecosystems and society, understanding of changes in the mechanisms of climate formation in the Arctic is required. Some specialized studies on natural adaptations also contain a detailed analysis of current and future changes in temperature, precipitation, etc. [15, Øseth E.]. Similarly, many reports on Arctic shipping consider changes in the area and thickness of sea ice as one of the conditions for increasing Arctic shipping [16, Brunstad B.; 17, Stephenson S.R., Smith L.C., Agnew J.A.]. Economic development is a major topic oriented towards Arctic forecasting, where the oil and gas industry is particularly highlighted [18, Anderson A.; 19, Harsem Ø., Eide A., Heen K.]. The following types of work can be classified as feasibility studies: [20, Mejlænder-Larsen M.; 21, Niini M., Arpiainen M., Kiili R.].

Despite the recurrence of many factors in determining the Arctic future, there are significant differences in how exactly and by what methods ideas about it are presented in predictive studies. Some works focus on the main trends that will shape the future, but do not present clearly outlined images. The weakness of such approaches is that they tend to assume that the future is entirely an extrapolation of the past. This often downplays uncertainty, leaving little opportunity for being prepared for possible "black swans". Visions project what can come true under a chosen mosaic of conditions, either as a desired situation or as an outcome that should be avoided. Typical of this group of works is that they consider the future as a fixed point.

The most common group of approaches — scenarios — are usually aimed at identifying drivers, trends and critical events, defining opportunities, threats and obstacles. Many scenarios are based on high or low thresholds for key parameters. A common practice is to complement two different scenarios with a "middle path" option that appears to be the most realistic. An alternative approach is to emphasize trends and drivers that can have a large impact, but which can also lead to high variability. In this case, scenarios are built around aspects of the implicit future, rather than the most likely trends. Modelling scenarios can also be developed on the basis of complex formal models that require significant amounts of data, primarily climate data.

The majority of publications consider a time horizon of 20 years or more, up to 2045–2050. Some works present the future as a whole, without mentioning any specific time horizon. Variations are also great in terms of thematic and geographical coverage. It is equally common to find studies that focus on individual sectors and specific countries and regions and on cross-sectoral issues where the Arctic is considered in a broader context. It is worth noting the inherent nonlinearity of Arctic forecasting. Change processes in the Arctic rarely occur without bifurcations. Large oil spills, maritime disasters, foreign ships entering national territorial waters without consent, conflicts in other parts of the world related to national interests in the Arctic, terrorist attacks, etc. can change the situation. Such events can be included in the economic development scenarios.

Typology of Arctic forecasting works

In the available literature, we found no attempts to categorize Arctic forecasting works. In this regard, we distinguish four types, describing the maximum number of published studies on the basis of the connections between the number of factors under consideration and the vision of the future. The presented division distinguishes single- and multi-factor approaches based on consideration of a single object of forecasting (climate, maritime transport, ice cover, oil production) or objects acting in interconnection (forecast of socio-economic changes; interrelation of climate and energy changes) [22, Pilyasov A.N., Kotov A.V.]. From another perspective, it is important to distinguish the type of the future under consideration: is it formed in connection with quantitative scenarios or purely qualitative? Based on these assumptions, we can talk about four classes of studies: "A" — single-factor quantitative; "B" — single-factor qualitative; "C" — multi-factor quantitative; "D" — multi-factor qualitative.

These forecasting trajectories are examples of the creation of an interconnected variety of methodological developments based on different capabilities of statistical data and the comprehensiveness of considering the Arctic as an independent object of research. It is important to emphasize the possibilities of transition between groups and the ability to begin forecasting based on any of the combinations (A–G) or their combination in structural modeling of different spatial levels (see Table 1).

Table 1

Classification of Arctic development forecasting works [1]

Specification		Description of the future	
		Quantitative	Qualitative
Models	Single-factor	**A:** Øseth (2011), Brunstad (2007), Bair, Müller-Stoffels (2019), Rabinowitz (2009), Dale (2018), Lindholt, Glomsrød (2011), Brigham (2007)	**B:** Coates, Holroyd (2019), Tsukerman, Ivanov (2013), Heininen et al (2019), Seidler (2009)
	Multi-factor	**C:** Andrew (2014), Stephenson, Smith, Agnew (2011); Harsem , Eide, Heen (2011)	**D:** Young (2021), Anderson (2009), Emmerson (2011, 2012), (2019), Duhaime, Caron (2006) Middleton et al (2021), Scolkovo (2020), Pilyasov, Kotov (2015), Haavisto et al (2016), Petrov et al (2021) Conley (2020), Kauppila, Kopra (2022), Lovecraft (2019), Brigham (2007), Mineev, Bourmistrov, Mellemvik (2022), Heininen(2008), Zaikov (2019); Myllylä et al (2016)

The type “A — single-factor quantitative models” combines developments primarily of a physical-geographical focus. They are devoted to the types of natural impacts (their scale and rate of change) on Arctic ecosystems and society. Some specialized studies on climate adaptation also contain detailed analyses of current and future changes in temperature, precipitation, etc. [15, Øseth E.].

An important part of the economic topics direction focuses on the marine sector of the economy. The sources are studies of the Intergovernmental Panel on Climate Change (for global climate forecasts). In Russia, the climate forecast section is based on assessment reports on climate change developed by Roshydromet. In recent decades, the service has noted a decrease in the number and duration of extremely cold periods and an increase in extremely high temperatures in the Arctic. At the same time, the frequency and intensity of events associated with heavy precipitation, flooding of inland water bodies, and destruction of sea coasts is growing, which complicates economic activity [2]. We should also note the works carried out as part of the assessment of marine shipping by the Arctic Council: [23, Bair B., Müller-Stoffels M.; 16, Brunstad B.; 24, Rabinowitz S.; 25, Seidler C.]. The development of maritime infrastructure and major investments (in communications technology, mapping and hydrography, search and rescue operations, environmental response, ice and weather forecasting, navigation aids, key regional ports) by Europe-

[1] Source: compiled by the author.
[2] The third assessment report of Roshydromet on climate change and its consequences on the territory of the Russian Federation. St. Petersburg, Science-Intensive Technologies Publ., 2022, 124 p.

an, Asian and North American business interest groups contribute to the growth of maritime activity [26, Brigham L.].

Type "B — single-factor qualitative models" differs from the previous one by the low prevalence of the calculated indicators. For example, the factor of the key non-renewable resource, which is usually oil and gas, is singled out, but without calculations, only indicating its role in the structural transformation of the regional economy as a whole [27, Coates K.S., Holroyd C.]. The work [28, Tsukerman V.A., Ivanov, S.V.] presents two qualitative scenarios for life support systems in the Arctic zone of Russia depending on the prospects of scientific and technological potential for an optimistic and conservative trajectory. An example of climate consideration in Arctic geopolitics is the work on comparative analysis of state Arctic strategies [29, Heininen L., Everett K., Padrtova B., Reissell A.]. Climate change — due to rapid changes in fragile ecosystems and, consequently, improved access to Arctic reserves — stimulates resource use and economic activity in extractive industries in the public and private sectors and maintains the leading role of states in the development of the region.

The "C — multi-factor quantitative models" type includes a small group of works devoted to complex prospects for resource extraction, climate change, geopolitics, as well as economic and social development as key factors shaping the future of the Arctic [9, Andrew R.]. A characteristic feature is the interrelationship of research questions: for example, changes in the area and thickness of sea ice and the possible increase in Arctic shipping [17, Stephenson S.R., Smith L.C., Agnew J.A.], factors influencing the development of the oil and gas industry in the region [19, Harsem Ø., Eide A., Heen K.].

The type "D — qualitative multi-factor models" is the most representative. They result in well-developed schemes aimed at identifying driving forces, trends, defining opportunities, threats and obstacles. Scenarios are built around various aspects of uncertainty, rather than the most probable trends.

In this group, the prospects of the Arctic economy are closely interconnected with a group of geopolitical options that take into account one or another degree of intensification of international cooperation in the Arctic [30, Pilyasov A.N., Kotov A.V.]. For example, in [31, Lovecraft A.L.], the "Northern harmony" scenario predicts a close international partnership in which countries share responsibility for sustainable development, environmental protection and Arctic regional security. In the "Business as usual" scenario, the Arctic Council helps to promote further cooperation in the macro-region, but national interests and political actions outside the Arctic lead to tense relations between states in various sectors. In the "Dangerous world" scenario, the Arctic countries focus on their own national policies with an emphasis on resource development and national security.

We note the constructiveness of the "D"-type models of understanding the Arctic macro-region as a dynamic frontier due to the synergistic influence of global climate change, increased transport accessibility and intensified development of minerals. The study [32, Mineev A., Bourmistrov A., Mellemvik F.] complements this body of knowledge by paying more attention to the dynamics of international policy and cooperation, including incentives in favor of the transition to a "green" economy.

In this group, the most significant part of the works is devoted to the development of the Russian Arctic, taking into account the role of market forces [33, Myllylä Y., Kaivo-oja J., Juga, J.], physical and geographical features, the dynamics of the world economy and the demand for hydrocarbon resources [34, Zaikov K.S., Kondratov N.A., Kudryashova E.V., Lipina S.A., Chistobaev A.I.]. In general, the driving forces determined for the Russian and global Arctic as a whole are similar, but differ in their priority action from the driving forces described for foreign Arctic regions. In particular, in Russian practice, special attention was paid to international relations, technology, domestic policy (management), climate, human capital, culture and economy of indigenous peoples, resource market conditions and environmental protection. Thus, according to A.N. Petrov and co-authors [35], within the framework of developing a comprehensive vision of the Russian Arctic development until 2050, the influence of heterogeneous factors was concentrated within the following ***scenarios***:

- "Harmonious Arctic", according to which external conditions are favorable, government policy encourages "bottom-up" movement. Innovation and creativity are, among other things, due to maximizing the regional ripple effect of Arctic megaprojects.
- "Self-reliant Arctic", which assumes strong domestic policies aimed at developing the region despite unfavorable resource, international and/or technological conditions, mainly by stimulating new enterprises not related to resource extraction.
- "Resource-dependent Arctic", which assumes active international cooperation, development of new technologies and high global demand for Arctic materials, combined with weak domestic policies that turn the region into a strong net supplier of resources.
- "Forgotten Arctic", according to which unfavorable external conditions are further aggravated by weak domestic policy, which leads to comprehensive stagnation and mass depopulation.

It should be noted that the topic under consideration has been extended to scenario forecasting of socio-economic development of the Eurasian Arctic [36, Haavisto R., Pilli-Sihvola K., Harjanne A. et al.]. The study covered a long-term horizon (up to 2040). Scenarios are proposed along three dichotomous axes (openness — closeness; public — private sector; ecologically problematic — clean region) to explain political, economic, social, technological and environmental characteristics.

Forming the topics of current forecasts: the example of the research agenda of the symposium "Arctic Futures"

Among the permanent international expert platforms, the Brussels symposium "Arctic Futures" [3] deserves attention, where various stakeholders met regularly during 2010–2023 to discuss

[3] Arctic Futures Symposium. URL: https://www.arcticfutures.org/ (accessed 23 June 2024).

Arctic prospects related to the economy and management. From the beginning of its work (2010), the goals of the symposium were:

- stimulating an open and frank dialogue among Arctic stakeholders on environmental, economic and social issues;
- selecting examples of Arctic cooperation in the field of research and management and replicating successful practices;
- analyzing the positions of various economic entities and promoting closer cooperation on vital strategic issues;
- providing an opportunity for the scientific community to demonstrate their research in order to select the best practices for managing the environment and resources of the region while preserving the traditions and way of life of indigenous peoples;
- discussing ways to use scientific information, research infrastructure and technologies to develop governance schemes.

In the report of the Director of the Arctic Economic Council M.K. Frederiksen in 2021, a number of global megatrends were mentioned that could become factors for the development of scenarios: urbanization, demographic dynamics, climate change, development of digital technologies and communications. Acceleration of economic changes in the Arctic is associated with cooperation between industry and university structures. Thus, the manager of the Northern Norway cluster Monica Paulsen pointed out that the Arctic cluster team (a public-private company) accelerates the dynamics of innovation and supports industry in this part of the country through the development of specialization industries: seafood production and processing of minerals and metals for European markets. Another example of innovation that has a strong impact on structural economic change is the development of the battery industry in the Norwegian Arctic. The territorial-industrial hub will consist of five gigafactories for the production of battery cells. Developing such a capacity would enable Norway to become one of the largest suppliers of these storage units in the EU and an important part of the global energy storage value chain [4]. Since the infrastructure already exists, supporting other industries, the construction of these plants seems to be an effective and efficient measure for the Norwegian authorities. Their biggest challenge will be to encourage their fellow citizens to move to the Arctic regions to work in these new “green” industries.

It should be noted that forecasting is related to determining the development potential of the basic industries. L. Raderschall and A. Sanabria showed at the Symposium in 2020 how the mining industry in northern Sweden contributes to regional economic development and how mining can become a more sustainable activity in the Arctic [5]. The benefits of mining for regional development include high-paying jobs, innovation and investment in infrastructure and social infra-

[4] The Battery Company Freyr Cuts in Giga Arctic Investment. URL: https://www.highnorthnews.com/en/battery-company-freyr-cuts-giga-arctic-investment (accessed 16 July 2024).

[5] Arctic Futures Symposium 2021 Executive Summary. URL: https://www.arcticfutures.org/uploads/archives_files/AFS21_Summary.pdf (accessed 16 July 2024).

structure, although it also comes with instability in regional growth and negative environmental consequences.

The symposia discussed key topics related to the climate, energy, economy and transport in the Arctic, which affect the prospects for the region's development. For example, in 2010, the key report was made by A. Levermann (Potsdam Institute for Climate Impact Research) on the patterns of global warming affecting the region as a whole. The author noted that the levels of carbon dioxide (CO2) and other greenhouse gases (nitrogen oxide and methane) have increased over the past century. The report also discussed the process of thinning and reducing the ability of winter sea ice to compensate for the melting of summer ice cover [6].

The section of Arctic forecasts from the perspective of the interaction between the physics of the Arctic environment and the life of biota can be illustrated by the materials of the report by O. Varpe (Norwegian Polar Institute), which assessed the relationships between the parameters of the state of sea ice, cloudiness, temperature and wind [7]. According to the expert, changes in sea ice are associated with most processes occurring on a global scale, including changes in the light regime, which is accompanied by a decrease in sea ice.

In the socio-economic aspect, marine spatial planning occupies one of the leading places. C. Ehler (President of the Ocean Visions organization) positioned it as a way to manage marine areas and ecosystems in the Arctic in order to avoid conflicts as the ice melts and industrial activity intensifies [8]. Such work develops ecosystem-based long-term management in the Arctic, which should be based on an integrated approach in all sectors of the economy, taking into account the associated impact of various activities. The first steps in creating a marine spatial planning regime include the identification of ecologically and biologically significant areas of the ocean, which are important sources of biodiversity.

Norway and, to some extent, Canada have similar management schemes (in the Barents Sea and the Beaufort Sea, respectively), which combine the needs of various sectors (oil and gas, fisheries, transport and ecosystems) within a single regulatory regime that ensures sustainable use of resources. In Russia, the prospects for marine spatial planning should be linked to the creation of the Marine Collegium, where it is planned to create a council for the protection of Russia's interests in the Arctic [9].

A traditional topic is the debate on the expansion of continental shelves, international borders and sovereign rights over natural resources in the Arctic. Thus, M. Takin (Center for Global Energy Studies) noted that longer summer melting seasons could lead to increased geological exploration and the discovery of new sea routes, such as the Northeast Passage and the Northern Sea

[6] Arctic Futures Symposium Executive Summar 2010. URL: https://www.arcticfutures.org/uploads/archives_files/afs_2010_executive_summary.pdf (accessed 16 July 2024).
[7] Ibid.
[8] Ibid.
[9] Putin instructed to create the Marine Collegium of Russia. URL: https://www.kommersant.ru/doc/6863685 (accessed 06 August 2024).

Route. Military-strategic issues are of great importance in this regard, but as a rule, they are not discussed in detail at the symposium.

Special attention is paid to forecasting the future of individual Arctic territories. For example, a unique feature of Greenland is its small settlements and isolated territories. It is important for socio-economic forecasting that the region is gradually taking steps towards independence from Denmark, having concluded a self-government agreement giving it the right to manage its own natural resources. The territory is an example of an Arctic space that is at a crossroads between an economy based on the traditional agro-industrial sector and the desire to move towards independence by using the economic opportunities of mineral resources.

It is important to distinguish between current forecasting in the economically viable Arctic and in "another" one — with resources of a more distant future. As a rule, economic development scenarios reflect assessments of the feasibility of key infrastructure projects. One such investment initiative is the Arctic Corridor, which could connect Finland and continental Europe with the deep-water ports of the Arctic Ocean, major oil and gas production areas, and the western end of the Northern Sea Route. An important project in the European Arctic is the North Bothnia Line, a high-speed rail line between the cities of Umeå and Luleå in Sweden [10]. For the European Union, the promotion of these projects is associated with increasing influence in the Arctic.

A major theme that has unfolded in recent years (2022–2023) and will influence Arctic forecasting in the long term is the growing demand for rare earth raw materials found in the Arctic. The European Union has established partnerships with its closest partners to adequately mitigate commodity security issues. Following the discovery of a rare earth deposit in northern Sweden (near Kiruna), it became clear that the Arctic could play an important role in supporting the "green transition", renewable energy sources, and the solution to the problem of abandoning fossil fuels and creating spatially distributed value chains. The most recent (November 2023) workshop highlighted the increasing availability of resources in the Arctic due to climate change, which triggered a discussion on the environmental, social and economic costs associated with access to these resources.

Conclusion: directions for further development of Arctic forecasting

The unconditional specificity of Arctic forecasting (in comparison with the forecasting of the development of a regular temperate zone territory) consists in the leading role of complex interacting factors: climate change; permafrost degradation; global demand for resource assets; development of transport and logistics infrastructure in combination with the physical and geographical conditions of the passage of sea arteries; geo-economic competition between polar countries.

[10] North Bothnia High-Speed Railway Line, Sweden. URL: https://www.railway-technology.com/projects/north-bothnia-high-speed-railway-line-sweden/#:~:text=North%20Bothnia%2C%20also%20known%20as,northernmost%20counties%2C%20Norrbotten%20and%20Vasterbotten (accessed 16 July 2024).

At different hierarchical levels, factors of global demand for natural resources are of particular importance — other factors are recognized as changing less radically in this relatively short period. The development of Arctic forecasting work can be facilitated by taking into account the role of technologies in the new global technological order, which determines the demand for new natural resources, and in modern projects implemented through new technologies for the extraction and processing of raw materials.

In scientific forecasting of economic development, these processes are transferred to forecasting the development of the economy of the Arctic regions as coastal territories, taking into account the factor of the proximity of the sea and land. The parameters of climate forecasts determine the assessment of the availability for economic development of confirmed and promising hydrocarbon resources, the mobility of the migration attractiveness of regions and the fluctuation of their territorial labor markets.

The combination of natural and economic factors forms options for a “green” economic transition in the Arctic, including forecasting the development of oil and gas resource extraction technologies, the sustainability of energy supply, and the differentiation of demand for electricity in remote isolated settlements. Their transport topography is complex, and it is necessary to develop methods for more complex deep learning of neural networks or probabilistic models for forecasting the use of renewable energy sources (wind generation).

The shifts from single-factor to multi-factor forecast models in the Arctic shows that the basis of state policy in the region should be the prevention of a narrow-sector approach to the development of support measures. Currently, at the early stages of implementation of large investment projects influenced by sanctions, it is necessary to forecast the development of individual factors and their interaction. This is important for the formation of instruments for the structural coherence of investments — their conjugation, targeted improvement of the economic structure of the Arctic territories. The potential for developing investment measures by federal institutions should be more clearly correlated with the capabilities of the Arctic territories, the diverse composition of the mineral resource base, taking into account the different transport accessibility, the variability of combinations of promising economic specializations and energy resources.

The combination of qualitatively heterogeneous data sources (from geodynamics and geoeconomics — ice, remote sensing, transport, general economic) allows Arctic models to acquire the property of “pulsation”. Their various combinations can forecast the “opening and closing” of windows of opportunities for increasing the volume of maritime trade, the favorable implementation of major investment projects, and adjusting the service life of social and household infrastructure. The skills of taking into account the creation of predictive models in the “Arctic version” directly affect the development of intelligent analysis systems, digital twin models (monitoring snow cover or cargo delivery to Arctic territories), self-adjusting algorithms (selection of energy supply options for villages or ice routes).

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