Peculiarities of climate change in the Arctic and implications for environmental management

Lyudmila Drachkova[1,*], *Nikolai* Kondratov[1,*] and *Anna* Trofimova[2,*]

[1]Candidate of Geographical Sciences, Associate Professor Higher School of natural sciences and technologies, Northern (Arctic) Federal University named after M.V. Lomonosov, 163002, Arkhangelsk, Russian Federation
[2] Department of Geography and Hydrometeorology, Higher School of natural sciences and technologies, Northern (Arctic) Federal University named after M.V. Lomonosov, 163002, Arkhangelsk, Russian Federation

Abstract. The Arctic is the high-latitude part of the Far North, including the land area and the Arctic Ocean marine environment within the exclusive economic zone of the Russian Federation. The importance of the Arctic issues is due to the fact that in the Russian Federation the formation and scientific rationale of priorities for the development of circumpolar territory are ones of the key objectives of Russia's economic development. The study of various areas and problems of Arctic development shows the particularly crucial role of geography in the formulation and solution of national economic objectives. The role of geography is becoming increasingly important not only because of the huge impact of the geographical factor in the Far North and the Arctic, but also due to remarkable differentiation of natural and social conditions of economic activity. In recent decades, the natural and socio-economic environment in the Arctic has been undergoing rapid transformation. One example is climate change, which may have an impact on environmental management on a global scale. The purpose of the article is to demonstrate the current trends of climate change based on sources and to identify the impact of these processes on the processes of environmental management.

1 Introduction

In the 21st century, the Arctic remains one of the most discussed topics in the scientific, economic, socio-humanitarian, and political spheres. The crucial tasks of economic the development of the Russian Federation include setting and scientifically substantiating priorities in the study and exploration of the Arctic territories. A well-founded choice of development priorities and the respective ways of their implementation requires clarification of Russia's position in the Arctic, specific knowledge about the current state of the Arctic environment and the perspectives of developing the region's resources in the context of climate change and globalization.

The Far North regions occupy more than a half of Russia's territory and are relatively well studied in geographical, geopolitical, historical and cultural, socio-demographic aspects. Such concepts as 'Arctic', 'North', 'Far North', while not exactly defined, are often used as synonyms in literature and state documents (development strategies). Among the Arctic states, Russia has the largest Arctic Sector. Taking the Arctic Circle as its southern border, the area of the Russian Arctic covers more than 9 million square kilometers, including 7 million square kilometers of the marine area, which corresponds to nearly a half of the area of the Arctic Ocean. The length of the coastline of the Russian Arctic is more than 22 thousand kilometers. The territory of the Russian Arctic covers significant developed areas near and above the Arctic Circle, including the areas of traditional natural resource use by indigenous peoples and the largest mineral deposits. Tourist recreational zones and wildlife reserves are also located here [1].

The interest to the Arctic stems from several reasons. One reason is that the Arctic region is currently undergoing irreversible transformations, the causes and consequences of which have not been fully understood. For example, air temperatures in the Arctic are rising faster than the global average. The Climate Doctrine of the Russian Federation defines climate change to be one of the global challenges of the 21st century, which must be addressed through an interdisciplinary approach comprising environmental, economic and social aspects of sustainable development [2]. The Strategy for the development of the Arctic zone of Russia until 2035 defines climate change as an important challenge to the socio-economic development of the region. The document says that climate change contributes to the emergence of both new economic opportunities and risks for economic activities and the environment [3]. Adaptation to climate change requires significant expenditures and international efforts. The media contribute substantially to the formation of public awareness, creating images of the consequences of shrinking sea ice coverage and ice depth in the Arctic

* Corresponding authors: drachkova@narfu.ru, n.kondratov@narfu.ru, a.trofimova@narfu.ru

Ocean, threats to biodiversity, resource wars of the 21st century. Secondly, countries both within (Denmark, Sweden, Norway, Finland, Iceland, Canada, the USA) and outside (China, Japan, the Republic of Korea, Singapore, India, Germany, Great Britain) the Arctic region, their trade unions and industrial corporations take an increased interest in the Arctic. the increasing role of the Arctic region in international cooperation stems from the fact the region is becoming key at the global level. The enhanced role of the area results from globalization, the reduction in deposits of mineral resources in traditional places of extraction, the development of transportation routes, the necessity to preserve the use of natural resource of indigenous peoples of the North, the development of tourism, and scientific research on climate change [4].

2 Main part

In natural and geographical terms, the Arctic has been identified by the Intergovernmental Panel on Climate Change (IPCC) as one of the most vulnerable world areas (along with island states, Africa and the African and Asian river deltas). The Arctic climate system exhibits forward and backward linkages that include ice, the cryosphere, permafrost, cloud cover, stratification of the Arctic Ocean, and geological substrate. The Arctic is a region of dynamic and unstable climatic processes, the imbalance of which leads to climatic shifts in the whole northern hemisphere. The urgent response to the climate challenge is conditioned by ongoing transformation of environmental problems into economic and political problems in the Arctic region. International problems may become a destabilizing factor for maritime activities (including naval activities) in the region. Analysis of the climatic features of the Arctic region is a problem of global importance. The need for analysis s due i to the fact that climate change has a double-edged impact on natural resources and the livelihood of the population around the world, including in the Arctic.

The Sixth Special Assessment Report of the IPCC (2018, Incheon, Republic of Korea) concludes that "... limiting global warming to 1.5°C will require rapid and far-reaching transition processes related to land, energy, industrial systems, and buildings, transportation and cities. Global carbon dioxide emissions caused by human activities will need to be reduced by almost 45% by 2030 compared to 2010 levels, reaching "net zero" by about 2050. This means that all remaining emissions must be balanced by removing carbon dioxide from the air" [5].

The first ice maps of the Greenland Sea and the Barents Sea were made at the Danish Meteorological Institute according to the data of based on ship observations in the spring-summer period. V. Yu. Wiese concluded (1937) that the warming process at the beginning of the 20th century was probably caused by a change in atmospheric circulation which was accompanied by an increase in the west and southwest winds over the Atlantic and the Norwegian Sea and an by increase in the Atlantic water inflow to the Arctic along with a simultaneous strengthening of the outflow to the Greenland Sea. The first third of the 20th century was noted by Wiese as a period of maximum warming in the Atlantic Arctic from Greenland to the Kara Sea in winter and a decrease in the ice cover of the Barents Sea and the Kara Sea in summer [6]. Modern concepts of temperature rise in the Arctic refers to a wider range of influencing factors.

Temperature trends in the Arctic have been changing over the 20th - 21st centuries, and the lack of regular instrumental monitoring does not allow to draw unequivocal conclusions about the direction of climate change." There is a trend of increasing temperature, which in certain areas of the world (Alaska, Northern Canada, Siberia) increased by 3°C over a period of 30 years (1971-2000). Though the magnitude and direction of the trend has varied, in recent decades the trend for the Arctic has been showing warming which is two times higher than global temperature increase" [7].

The Fifth IPCC Report states the fact that changes in the climate system during the industrial era are undeniable. Since the 1950s climate changes have been unprecedented from decades to millennia. Since 1850, the Earth's surface temperature has been higher than the previous decade, every decade the last three ones. The period of 30 years from 1983 to 2012 was the warmest in the last 1400 years in the northern hemisphere [8].

The rise in ocean temperature is the essential element of the increase of energy of the climate system. The oceans accounted for 90 percent of energy accumulated in the Earth's climate system from 1971 to 2010. The increase in ocean temperature was most pronounced globally near the surface, with a temperature increase of 0.11 [0.09 – 0.13] °C over the decade from 1971 to 2010. The distribution of observed and expected changes in global ocean surface temperature did not change qualitatively throughout the history of pattern implication for different scenarios of anthropogenic intervention. Data from the Hadley Centre SST2 set (since 1870) and CMIP3 models of ocean and atmosphere circulation point to elevated sea surface temperatures in the Russian Arctic, near the coast of Alaska and Greenland [8].

Atmospheric concentrations of major mixed greenhouse gases have increased and become unprecedented over the past 800 thousand years. Carbon dioxide concentrations have increased from their pre-industrial value (conventionally before 1750) by 40%, mainly due to CO_2 emissions from burning of fossil organic fuel and net emissions resulting from changes if the land use.

IPCC experts conclude that the state of the Earth's glacier systems is deteriorating everywhere, and the ice mass balance is negative almost everywhere. The area of sea ice is diminishing, which can be particularly seen in the Arctic during the warm season. In spring, the snow cover area decreases in the northern hemisphere. Sea level continues to rise at a rate that has exceeded the average of the previous two millennia since the middle of the 19th century [8].

The Arctic Council reports note that in the 21st century the average global temperature may increase by 2.8^0C (at present it is about 0.4-0.6^0C), while at the most

part of the land surface it may increase by 3.5^0C and in the Arctic – by 7^0C. Warming processes in the Arctic are twice as fast as in the rest of the world, which was especially noticeable in 2012. The area of Arctic land covered by snow in the beginning of summer has shrunk by 18 percent since 1966. There is a decline in the number of days with snow cover in coastal Alaska and the northern Scandinavian Peninsula. Snow cover thickness has decreased in the North American Arctic and increased in the Russian North. The authors of the report assume that in the 21st century, the Arctic Ocean will become completely ice-free in summer. However, this has not happened yet and navigation in the eastern seas of the Arctic Ocean is possible only for nuclear icebreakers [9].

According to the Snow and Ice Data Center (USA), the ice-covered area in the Arctic diminished from 5.92 million sq. km to 4.76 million sq. km in 2006-2012. NASA and Roshydromet have registered the absolute minimum of ice over the past 30 years. The area covered by ice decreased from 7.3 million sq. km in 1979 to 5 million sq. km in 2007 (5.1 million sq. km in 2013).

The amount of precipitation in the Arctic region increased by 15 percent between 1970 and 2012, while the area of sea ice decreased by 10-15 percent, the area covered by snow decreased by 10 percent, and the temperature of the top permafrost layer rose by 2^0. The southern boundary of Russia's permafrost territories moved about 30-80 km between 1970 and 2007. The freezing period of northern rivers has decreased, the river flow to the Arctic Ocean and the inflow of warm water from the Pacific Ocean increased. Thickness of sea ice in the Arctic Ocean over the past 30 years decreased by 45%, while in the seas of Siberia, the Far East and Alaska (the Laptev Sea, the East Siberian Sea, the Chukchi Sea, the Beaufort Sea) it has diminished by 87.5 percent. The glaciation area of Novaya Zemlya and Franz Josef Land decreased by more than 720 sq. km, while glaciation extent has reduced by 250 cu m (1.5 percent). There is no trend of slow warming in the territory of Russia. "Shrinking snow and ice surfaces, which reflect the significant part of the light give way to darker land and ocean surfaces that absorb more solar energy. It intensifies the heating of soil and air. …This can lead to a considerable increase in emissions of such greenhouse gases as carbon dioxide and methane in the Arctic… Melting glaciers and ice sheets contribute the most to global sea level rise. Arctic glaciers, ice caps and the ice sheet of Greenland produced 1.3 mm of the total annual global sea level rise by 3.1 mm between 2003 and 2008, which is 40 percent. Consequently, the Arctic's contribution to global sea level rise was much greater than previously expected" [10,12].

Climate change is a stressor for Arctic biological diversity, which includes 21 thousand species of plants and animals. About 10 percent of the world's catch of fish and seafood is origin from the Arctic. There is an invasion of trees in tundra ecosystems has been observed. The number of reindeer *(Rangifers)* and caribou *(Rangifer tarandus)* has dropped by a third in just one decade.

Assessing the impact of climate change on human economic activities in the Arctic is methodologically difficult. First of all, predictions of climate change based on physical and climate models are made for a period of 50-100 years, which does not correspond to long-term economic projections, which are usually made for a period not exceeding 10-20 years. Secondly, climate research trends focus on catastrophic global change scenarios. Economic calculations consider the temperature increase in the Arctic in terms of direct losses in the economy and social sector of individual states and the entire world. According to the calculations of foreign researchers (Shiklomanov, 2017), the consequences of permafrost degradation may result in the total renovation wal of the housing stock of Norilsk, Yakutsk, Vorkuta and Salekhard by 2050. The total volume of the housing stock of these cities are about 10 million sq. m and will require more than RUB 400 billion of investments. Across the Arctic, such investments could reach USD 160 trillion by 2100, or USD 2 trillion per year. It could account for 1.2 percent of the global GDP. Using the cost approach for Russia, the cost of cumulative (direct and indirect) damage from climate change by 2030could reach 3 percent of GDP per year, and in specific areas this index could reach be 5-6 percent of GDP. In total it may reach RUB 20 trillion (in 2011 prices). This estimate does not determine only the worst-case scenarios for the development of the Russian economy development under conditions of global climate change (global warming). If the economic situation worsens for some industries, on the contrary, it may improve for other industries. In the Russian Arctic, the temperature rise may result in an increase in the length of the growing season, expansion of farming and livestock areas; facilitating access to natural resources; lengthening of the navigation period in the seas of the Arctic Ocean, which may have a multiplicative effect on related sectors of the economy. It has been estimated that the ice-free navigation period may last for 90-120 days by 2025, more than 150 days by 2040 and over 200 days by 2090. As a result, taking into account mega-projects, the probable growth of the cargo turnover may exceed 50 million tons per year in the medium term. Direct income from ice escorting of ships along the Northern Sea Route could amount to RUB 30 billion annually. On the contrary, decrease in ice cover and the ice depth reduces the need for icebreakers. As the temperature rises, sea disturbance intensifies and the probability of iceberg occurrence increases. These conditions can have a negative impact on navigation and activities of oil and gas production facilities [11,14].

The water levels in reservoirs may rise as a result of the increased river flow into the Arctic Ocean basin. The risk of flooding and waterlogging of inhabited localities will increase, air humidity, frequency of fog and visibility will deteriorate.

As shown [11] with regard to the energy sector in the Russian Arctic zone, based on thermal power stations, due to the average annual air temperature increase the heating period is reduced. Consequently, expenses for fuel and heating systems are cut.

The cumulative effect of conditionally favorable impacts of climate change on the national economy by 2030 is projected to be characterized by an access of costs over expected benefits [11,15]. It should be kept in mind that these benefits will require new workforce competencies [16], innovative approaches in research activities, and technological innovations. This implies the need to attract investments [17], increase of expenses for education and scientific, research and experimental development, improvement of public administration. The uncertainty of climate change projections should be taken into account, as it has a negative impact on the accuracy of decisions made at the government level in the field of climate policy and subsequent investments into megaprojects, as well as in the determination of scenarios of economic development for the long term. In this regard, the estimates predicting that the Russian economy will get external impacts of climate change appear to be unreasonably optimistic. Assessment and projections of climate change impact on the dynamics and sectoral and territorial structure of the Arctic macro-region economy should take into consideration its territorial peculiarity which is strongly pronounced (due to the size of the macro-region) and the specifics of functioning of individual economic sectors of the Russian Arctic in the conditions of climate change [13]. Maintaining the reliability of energy supply will be provided by the existing types of energy systems in the short and long term. The challenge for the development of the Arctic could be the development of new industries characterized by an increased power demand. This problem will be solved by specialized energy companies within their competences. Reduced consumption of heat may be observed in the sphere of energy consumption. However, this process can also illustrate, firstly, a reduction in the number of energy consumers. Secondly, it is a consequence of the routine work on upgrading of heat and power supply systems, improving the quality of residential and public buildings, replacement of power supply schemes and equipment [11].

Negative impacts of climate change in the Arctic include growing public health risks (e.g., an increased infectious diseasies); increased frequency, intensity and duration of extreme precipitations, as well as floods, storms and other natural disasters; soil overwatering; increased fire hazards in subtundra forests; environmental imbalances (e.g., species displacement); increased energy consumption for air conditioning in summer.

3 Conclusion

The synergistic effect of climate change should be noted. Such effect is illustrated by the aggravation of anthropogenic risks and threats to Arctic ecosystems, which is the result of improved access to natural resources. This will lead to an increase in emissions polluting the environment. The specifics of the Russian Arctic lies in the predominant importance of social risks compared to environmental risks. This situation is explained by the fact that over 2.4 million people live in the Arctic, which exceeds the population in other Arctic regions.

References

1. D.A. Dodin, *Sustainable development of the Arctic (problems and prospects)* (St. Petersburg, Nauka, 2005)
2. Presidental Resolution, No. 861-rp validating Climate Doctrine of the Russian Federation. Available online: http://en.kremlin.ru/supplement/4822 (2009)
3. *The Strategy for the Development of the Arctic Zone of the Russian Federation and National Security up to 2035*, 26 October (2020)
4. A.I. Chistobaev and N.A. Kondratov, Arctic: geopolitical and geoeconomic interests of foreign countries, *Geopolitics and Security*, pp. 1-25 (2014)
5. An IPCC special report on the impacts of global warming of 1.5 °C above preindustrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Available online: https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/ (2021)
6. G.V. Alekseev et al., Evolution of the area of the Arctic sea ice cover under the conditions of modern climate changes, *Research of the Earth from Space* **2** (2015)
7. Yu.S. Tsaturov and A.V. Klepikov, Current climate change in the Arctic: results of a new assessment report of the Arctic Council Arctic: ecology and economics, 4-8 (2012)
8. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, Geneva, Switzerland, 2014), p. 151.
9. AMAP Climate Change Update 2019: An Update to Key Findings of Snow, Water, Ice and Permafrost in the Arctic (SWIPA) 2017. Arctic Monitoring and Assessment Programme (AMAP) (Oslo, Norway, 2019), p. 12.
10. Second Assessment Report on Climate Change and its Consequences in Russian Federation (Moscow: Roshydromet, 2014)
11. B.N Porfirev et al., The consequences of climate change for economic growth and development of individual sectors of the economy of the Russian Arctic Arctic: ecology and economics, 4-28 (2017)
12. G. Benoit, Agriculture, land, water and climate: Solutions for a world in transition Futuribles: Analyse et Prospective October, **438**, pp. 5-28 (2020)
13. B. Swynghedauw et al., 'Climat et Sante' de la Commission XIV Consequences of climate change on human and animal health [Article@Rapport 20-

07. Conséquences du changement climatique sur la santé humaine et animale] *Bulletin de l'Academie Nationale de Medecine*, **205(3),** pp. 219-226 (2021)

14. A. Cherepovitsyn, A. Lebedev, Drill Cuttings Disposal Efficiency in Offshore Oil Drilling, *Journal of Marine Science and Engineering,* **11(2)**, 317, doi:10.3390/jmse11020317 (2023)
15. P.S. Tcvetkov, A.E. Cherepovitsyn and A.B. Makhovikov, Economic assessment of heat and power generation from small-scale liquefied natural gas, *Russia Energy Reports*, **6**, pp. 391-402 (2020)
16. I.G. Gerasimova, I.S. Oblova, E.I. Golovina, The Demographic Factor Impact on the Economics of the Arctic Region, *Resources*, **10**, p. 117, doi: 10.3390/ resources10110117 (2021)
17. K. V. Matrokhina., V.Y. Trofimets, E.B. Mazakov, A.B. Makhovikov and M.M. Khaykin, Development of methodology for scenario analysis of investment projects of enterprises of the mineral resource complex, *Journal of Mining Institute*, **259**, pp. 112-124, doi: 10.31897/PMI.2023.3 (2023)