Current climate changes in the Arctic

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Summary

The properties of climate fluctuations are described, obtained as a result of a special statistical analysis of observational data from the world meteorological network of stations, taking into account the peculiarities of the northern regions. Using the example of air temperature, free and forced fluctuations of the characteristics of the climate system in their interaction are considered. New ideas about the structure of fluctuations and possible causes of climate changes have been formulated. A statistical model of periodic nonstationarity of climate is proposed for forecasting climate fluctuations for two decades, and a model for seasonal and monthly meteorological forecasts with an annual lead time is proposed. The practical significance of predictive developments is especially great in the harsh climatic conditions of the north, where the climate is one of the limiting factors of the industrial development of the northern regions.

Key words: climate change, time scale

The Arctic Council, an international organization of eight Arctic states, designed to promote cooperation in the field of environmental protection and sustainable development of the circumpolar regions, pays great attention to climate change in the Arctic. In 2000, the Arctic Council launched the preparation of the Arctic Climate Impact Assessment (ACIA) report. It was a joint project of two working groups of the Arctic Council: the Arctic Monitoring and Assessment Program (AMAP) and the Conservation of Arctic Floraand Fauna (CAFF). The result of the implementation of the project was a thousand-page scientific report, prepared by the end of 2004 and published by the

University of Cambridge [1]. 18 chapters of the report contained detailed information on the recorded changes in the atmosphere, cryosphere and hydrosphere, in ozone and ultraviolet radiation, in ecosystems of land and water. The state of forestry and agriculture, fishing, reindeer husbandry, hunting in a changing climate was assessed. The health of the population, the prospects of indigenous peoples and the preservation of their ways of life under the influence of the ongoing changes were discussed. UDC 551.582 (98) +551.585

Current climate change in the Arctic: results of a new assessment report of the Arctic Council Yu. S. Tsaturov, Ph.D., Federal Service of Russia for Hydrometeorology and Environmental Monitoring A. V. Klepikov, Ph.D. Antarctic Research Institute "

The article presents the results of the new report of the Arctic Council "Snow, water, ice and permafrost in the Arctic", dedicated to the assessment of the current situation in the Arctic cryosphere. Climate change has become a major problem in the Arctic over the past decades. The consequences of climate change, including damage to buildings, roads and pipelines, reduced opportunities for hunting, fishing, reindeer husbandry, negative impact on the health of the population of the northern territories, require the development of an adaptation strategy.

Key words: Arctic cryosphere, climate change in the Arctic, global climate research, ground-based hydrometric networks.

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The results of ASIA showed that there is a tendency for the temperature to rise, reaching almost 3 ° C over a 30-year period (1971-2000) in some regions (Alaska, Northern Canada, Siberia). Although the magnitude of the observed trends varied within a particular region and some regions experienced cooling, the overall trend for the Arctic over the past few decades has shown warming, almost twice the average global temperature rise on the planet. For 1971-2000. precipitation increased in most of the Arctic regions by 10% to 30%, sea ice area decreased by 10–15%, and land snow cover decreased by about 10%. Most glaciers in the Arctic were losing mass. In most of the Arctic, the temperature of the upper permafrost layer has increased by 1-2 ° C over 30-40 years. The duration of the freezing period of Arctic lakes and rivers has decreased, and the runoff of Arctic rivers has increased in recent years. Given the importance of the results of the ASIA assessment and due to the fact that the projects of the International Polar Year (IPY-2007/08) provided a lot of new data, the Arctic Council decided to carry out a similar assessment in order to track changes in the Arctic and Subarctic already in the first decade of the 19th century. ... It was decided to focus on 77. Contemporary Arctic Climate Change: Results of a New Arctic Council Assessment Report on Cryospheric Changes. The term "cryosphere" refers to a part of the earth's surface that periodically freezes or is constantly frozen. This includes snow, frozen ground, river and lake ice, glaciers, ice caps, ice sheets, and sea ice. The cryosphere is like a skeleton of the physical environment of the Arctic. It is an integral part of the climate system and affects the climate at both the regional and global levels. At the same time, parts of the cryosphere are extremely important for people living in the Arctic. Snow and glaciers provide the population with fresh water, river and lake ice provide mobility, sea ice enables sea animals to hunt and fish. The observed changes in the sea ice cover of the Arctic Ocean, in the Greenland ice sheet, in ice caps and glaciers, in the snow cover and permafrost of the Arctic over the past 10-15 years are dramatic and obviously diverge from the results of observations, which were carried out in the XIX-XX centuries. That is why the assessment of changes in the cryosphere has become the main task of the new climate project of the Arctic Council. AMAP, as well as the International Arctic Science Committee (IASC), World climate research program through the Climate and Cryosphere Project (CliC) and the International Arctic Social Science Association (IASSA). Note that since the start of the ASIA project in 2000, AMAP has been actively involved in the generalization and assessment of information on natural climate variability, on anthropogenic climatic changes, on the impact of global, regional and local climate changes and ultraviolet radiation on the Arctic environment. AMAP has now become one of the leading organizations on these issues. According to the SWIPA project, a new comprehensive assessment of the state of the cryosphere in the Arctic and Subarctic for the period from 2008 to 2011 is to be made. against a backdrop of climate change including the Greenland ice sheet, mountain glaciers and ice caps, sea ice and freshwater ice, permafrost and snow cover. It was planned to summarize modern scientific knowledge to recreate the picture of the ongoing changes and to develop mechanisms for adaptation to the challenges associated with climate change in the Arctic and Subarctic. An important part of the SWIPA project is the assessment of the socio-economic consequences of the impact of climate change and the proposal of measures for adaptation to them. A key moment for the preparation of a new assessment of the state of the cryosphere in the northern regions was the inclusion of data obtained in IPY-2007/08. The SWIPA project consisted of three sub-projects:

“Sea ice in a changing climate”, “Greenland ice sheet in a changing climate” and “Climate change in the terrestrial cryosphere”, which, in turn, consisted of four modules: “Snow”, “Permafrost”, “Glaciers and ice caps ”,“ Ice of rivers and lakes ”.

A new assessment report of the Arctic Council on the impact of climate change on snow, water, ice and permafrost in the Arctic was published at the end of 2011 [2]. Let us consider the main conclusions contained in the assessment report of SWIPA and related publications [3, 5]. The Arctic is getting warmer. The last six years (2005–2010) analyzed in the report have been the warmest period in the Arctic on record. The surface air temperature in the Arctic since 2005 has exceeded the average temperature for any five-year period since the start of measurements (about 1880). The Arctic is warming twice as fast as in the world as a whole. Data from studies of lacustrine sediments, annual tree rings and ice cores show that summer temperatures in the Arctic are higher than at any time in the past 2000 years. Unprecedented anomalies in ocean currents were recorded, including a greater influx of warm waters from the Pacific Ocean into the Arctic Ocean. These changes are the main driving forces behind changes in the Arctic cryosphere. Pointing to the cause of warming in the Arctic, the authors of SWIPA refer to the conclusions of the 4th assessment report of the Intergovernmental Panel on Climate Change (IPCC). They indicate that "... with a high degree of probability (over 90%), it can be argued that the increase in concentrations of anthropogenic greenhouse gases is responsible for most of global warming since the mid-20th century." The two components of the Arctic cryosphere - snow and sea ice - interact with the climate system to accelerate warming. The largest increase in temperature in the surface layer of the atmosphere was noted in autumn in areas where sea ice melts by the end of summer. It is assumed that the sea absorbs more solar energy during the summer due to the lack of ice cover. Additional energy is released in the form of heat in the fall, further contributing to the warming of the lower atmosphere in the Arctic. On land, the number of days with snow cover changed mainly in spring. Early snowmelt is accelerated by earlier and more intense warming of the land surface, which is no longer snow-capped. These processes are called feedbacks. Feedback for sea ice has been predicted by climate scientists in the past, but strong evidence for this was 78 Arctic: Ecology and Economics # 4 (8), 2012 Contemporary Arctic Climate Change Contemporary Arctic climate change has only been observed in the Arctic over the past five years. Other potential feedback mechanisms have also been found. They can make changes in the speed and even direction of climate change and associated changes in the cryosphere. Eight of these mechanisms should accelerate warming, and only one - cooling [3]. The intensity of the feedback mechanisms of the cryosphere and climate has not yet been quantitatively determined both within the Arctic and around the world. This entails significant uncertainty in predicting changes in the cryosphere and the Arctic natural environment. The extent and duration of snow and sea ice cover have decreased significantly throughout the Arctic. The area of the Arctic land covered with snow at the beginning of summer has decreased since 1966 by 18%. Coastal Alaska and northern Scandinavia have seen a significant reduction in the number of snow-covered days per year. These changes are largely due to the earlier melting of snow in winter. The depth of snow cover decreased in the North American part of the Arctic, but increased in the north of Russia. Over the past two to three decades, permafrost temperatures have increased by 2 ° C, especially in colder regions (typical permafrost temperatures range from –16 °

C to nearly 0 °, depending on location). The depth of the soil layer above the permafrost, which thaws annually in the summer months, has increased in Scandinavia, the Russian Arctic, west of the Urals and inland Alaska. Southern border of permafrost in Russia in 1970-2005. retreated 30-80 km to the north and almost 130 km over the past 50 years in the province of Quebec. Ice on lakes and rivers breaks open earlier than was observed in the past. The study of bottom sediments of lakes in the high-latitude Arctic indicates that the duration of the existence of ice cover on some lakes has significantly decreased over the past 100 years. Large ice packs melt faster. The total loss of mass of the Greenland ice sheet, according to new estimates, increased from about 50 billion tons per year in 1995-2000. up to 200 billion tons in 2004-2008. Over the past 100 years, nearly all glaciers and ice caps have shrunk in size. The rate of ice loss has increased in most regions, but especially in Arctic Canada and southern Alaska. The total loss of mass from glaciers and ice caps in the Arctic has exceeded perhaps 150 billion tons per year over the past decade, which is comparable to the estimates of losses from the Greenland ice sheet. The decrease in the area of sea ice in the Arctic over the past decade has been faster than in the previous twenty years. The decrease in sea ice area is happening faster than predicted by the models used in the preparation of the 4th IPCC Assessment Report. The area of sea ice (perennial ice) that has not melted in summer has been equal to or close to record lows each year since 2001. This value is now one third less than the average for sea ice from 1979 to 2000. New observations show that the average sea ice thickness has decreased and the ice cover is mainly represented by younger and thinner ice. Climate models predict even greater changes. The average temperatures in the Arctic in the autumn and winter months, even if it is possible to reduce the scale of carbon dioxide emissions into the atmosphere over the next decade, will still rise by 3-6 ° C by 2080. However, the climate models used in the preparation of the SWIPA report will not included the impact of the response of the cryosphere system, which can result in additional emissions of greenhouse gases from the Arctic environment. Precipitation in the form of snow and rain is predicted to increase throughout the year, but especially in winter. Despite this, the Arctic is expected to become drier in the summer. This is due to the fact that a higher air temperature will cause more water evaporation, snow will start to melt earlier, and the water regime will change. With increasing precipitation in the form of snow, all forecasts indicate that the height of maximum snow cover in winter will increase in many regions. The largest increase (15-30% by 2050) is expected in Siberia. But even in this case, the duration of the snow cover by 2050 will decrease by a maximum of 10-20%. Models also predict that the permafrost will continue to melt. It is predicted that sea-ice thickness and sea-ice extent in summer will continue to decline in the coming decades, although significant fluctuations will be observed from year to year. It is assumed that by the middle of the century the Arctic Ocean will be almost completely free of ice during the summer. This means that there will no longer be a permanent presence of thick perennial ice. Climate models predict a 10-30% decline in mountain glaciers and ice caps by the end of the century.

The Greenland ice sheet is expected to be melting faster than it is currently, but there are currently no models that can accurately predict how these and other Arctic continental ice packs will respond to projected climate changes. This is due to the fact that there is still no complete understanding of the dynamics of ice and the complex interactions between the ocean, snow, ice and the atmosphere. 79 Contemporary Arctic Climate Change: Results from a New Arctic Council Assessment Report Changes in the cryosphere are causing fundamental changes in Arctic ecosystems. Changes in the thickness and structure of the snow cover affect the soil, plants and animals. Some species, such as the short-billed bean goose, will benefit from reduced snow cover in spring. However, animals that graze in snow-covered pastures will suffer if the rains in the winter create an ice crust on the snow. This phenomenon is increasingly seen in northern Canada and Scandinavia. Less snow storage and faster snow melting are the cause of summer drought in forests, wetlands and lakes that feed on melt water. Melting permafrost also leads to drainage and desiccation of wetlands in some places and their appearance in others. The disappearance of ice cover from rivers, lakes and seas will change the animal and plant communities in the aquatic environment. The disappearance of large areas covered by sea ice will cause great ecological damage to species adapted to life on ice, including polar bears, seals, walruses, narwhals and some microbial communities. Many animals, including bowhead whales, depend on small crustaceans that inhabit the sea ice. A given food source will change if the ice boundary recedes. Such changes in ecosystems will have a direct impact on water supply, fish and forest supplies, traditional food and grazing lands used by the inhabitants of the Arctic territories. For example, it was assumed that populations of subarctic and arctic fish species (including valuable commercial fish) could change if the sea ice receded. Uncertainty about the supply of living natural resources makes planning for the future difficult. Melting permafrost can have a positive impact on forests in areas where there is enough water for trees to grow, but insect pests are causing increasing problems. The numbers of some preyed animals, such as seals and walruses, decline as habitats change. Others migrate to new habitats, so hunters have to travel long distances.

Cryosphere changes affect livelihoods and living conditions in the Arctic. Access to the northern territories by sea is facilitated in the summer, when the sea ice disappears, which creates conditions for more active shipping and economic activity. Offshore oil and gas activities will benefit from a longer period when the sea is not covered with ice, but threats from icebergs may increase due to an increase in their number. The shrinking sea ice is creating challenges for local people who use the ice to travel and hunt as they have to travel long distances on precarious ice in more hazardous conditions. On land, access to many places will become more difficult as winter ice roads thaw earlier and later freeze, and as permafrost degrades. Industrial exploitation associated with winter roads will require the concentration of heavy-duty traffic.

transport during the coldest period of the year. Shorter periods when ice and snow roads can be used will greatly affect local communities that use land transportation to transport goods in order to maintain reasonable prices for goods and ensure profitability, especially in northern Canada and Russia. Some mainland areas are becoming more accessible to mining as glaciers and ice caps recede. Melting permafrost in some regions will increase the risk of deformation of buildings, roads, runways and other technical structures, which will also be facilitated by poor design quality in the past. Buildings and other infrastructure are exposed to risks associated with increased snow load and flooding resulting from ice jams on rivers or sudden discharges of water from glacial lakes. More than 60% of the Arctic coastline is sealed and protected by ice. If fast ice breaks down earlier and permafrost degrades, rapid erosion can occur. Along the coastline of the Laptev and Beaufort Seas, the recorded rate of retreat of the coastline inland has reached more than two meters per year. In Alaska, some Inuit settlements are preparing to evacuate in the event of a sea attack. In the short term, the increasing melting of glaciers creates new opportunities for hydropower, with potential benefits for industry. In the longer term, the amount of melt water will decrease as the glacier area shrinks, which is likely to have a negative impact on electricity production. Melting ice and snow will release pollutants that have been stored in them for years, allowing pollutants to re-enter the environment. The exposure of humans and higher mammals to contaminants that accumulate in the food chain may be even greater. The growing accessibility of the Arctic creates new economic opportunities. Cruise tourism is growing in popularity. More and more people are coming to see the impact of climate change on Arctic glaciers, such as the Ilulisat glacier in Greenland. The increased flow of tourists can become a problem for the traditional way of life of local communities and the level of 80 Arctic: ecology and economy No.4 (8), 2012 Modern climate change in the Arctic Modern climate change in the Arctic for the provision of services, as well as increase requirements for the efficiency of infrastructure (for example, aviation services, navigation equipment and other security measures). The disappearance of arctic nature and landscape changes could have a negative impact on the tourism industry in the long term.

Changes in the Arctic cryosphere have an impact on the global climate and ocean level. Shrinking, snow and ice surfaces, reflecting a significant part of the light, give way to darker surfaces of the earth or ocean, which absorb more solar energy.

This enhances the warming of the soil and air. There is evidence that similar processes occur in the Arctic Ocean as sea ice recedes, as well as on land, where snow begins to melt earlier. This could cause a significant increase in methane and carbon dioxide emissions in the Arctic due to heating of soil and freshwater systems and the melting of permafrost soils on the seabed. The cumulative impact of these effects on the global climate is not yet predictable. Freshwater inputs into the Arctic Ocean from all major sources, which include river runoff, snow / rainfall, melting glaciers and ice caps, and the Greenland ice sheet, are increasing. According to calculations, an additional 7,700 km3 have entered the Arctic Ocean in recent years, which is equivalent to covering the entire territory of Australia one meter deep. There is a risk of changes in the system of major ocean currents that affect climate on a continental scale. Melting glaciers and ice sheets are the largest contributors to ocean level rise. Arctic glaciers, ice caps and the Greenland ice sheet provided 1.3 mm of the total annual rise in the level of the World Ocean by 3.1 mm in 2003-2008, which is more than 40%. Thus, the contribution of the Arctic to the rise in the level of the World Ocean turned out to be much greater than previously assumed. There is great uncertainty in the estimates of the future level of the World Ocean. Recent model calculations show an increase of 0.9–1.6 m by 2100. Compared to that observed in 1990. Changes in the Arctic cryosphere will have an impact on the entire world. Rising sea levels are one of the most serious consequences of the cryosphere change for society. Higher mean sea levels and more destructive storms will have a direct negative impact on millions of people living in low-lying coastal areas. Rising sea levels will increase the risk of flooding in densely populated coastal cities such as Shanghai and New York. On the other hand, economic activities on a global scale can benefit from cryospheric changes in the Arctic, for example, the opening of transpolar sea routes across the Arctic Ocean will shorten the distance between Europe and the Pacific by 40% for ships compared to current routes, which will reduce air emissions and energy consumption. Some unique arctic animal species, such as narwhals, will face specific threats when cryospheric changes occur. Decreases in cryospheric habitats such as sea ice, wetlands in permafrost regions will impact migratory mammals and birds around the world. These negative impacts on biodiversity are of global concern. Urgent adaptation is needed at all levels. Changes in the cryosphere primarily affect the population at the local level, so local communities will be forced to develop strategies to respond to emerging risks. At the national and regional levels, adaptation requires leadership from governments and international organizations to enact new laws and regulations. For example, a new fishing regime will be needed as fish stocks change. New standards need to be developed for construction, especially in regions where permafrost is melting. States will have to invest in transport infrastructure due to the shorter period of use of winter roads. Search and rescue operations will need to change in response to increasing traffic and risks at sea, and accurate forecasts of weather and sea conditions will be needed to ensure the safety of shipping. Arctic communities are mobile and will actively respond to changes in the cryosphere. However, the high rate of change can surpass the ability to adapt. Knowledge and research is needed to predict how living conditions might change and to assess possible adaptation options. In this regard, the interests of the indigenous population require close attention.

Changes in the cryosphere are driving change not only in the Arctic. Cryosphere and climate change is taking place in the context of social change, which can present even greater challenges. When developing adaptation strategies, the totality of social, climatic and cryospheric changes must be taken into account. A rapid reduction in greenhouse gas emissions is needed. Climate change is an urgent and potentially inevitable threat to human communities. Global climate studies using modeling show that dramatic and widespread reductions in greenhouse gas emissions are required to ensure that global average temperatures rise within 2 ° C above pre-industrial levels. 81 Contemporary Arctic Climate Change: Results of a New Assessment Report of the Arctic Council Combating anthropogenic climate change is a common pressing problem for the world community, requiring global action and international participation. In accordance with the ASIA report [1], the ministers of the Arctic Council recognized that timely, weighed and coordinated action is needed with regard to global emissions. They endorsed a number of policy recommendations to limit greenhouse gas emissions and adopted strategies that address greenhouse gas emissions and limit them in the long term to levels consistent with the ultimate goal of the United Nations Framework Convention on climate change. The main findings of the SWIPA report, in particular on the high and growing rate of change in cryospheric conditions in the Arctic, once again emphasize the need for stronger urgent measures in this direction. Uncertainty can be reduced by ongoing research. The results of ongoing monitoring, research and modeling indicate with a high degree of confidence that significant changes are taking place in the Arctic cryosphere that will continue in the future. Some of the changes are in line with forecasts, but the sea ice response has been faster than predicted just five years ago. Even so, a significant amount of uncertainty remains, especially regarding the timing of future changes and the impact of interactions (responses) between the cryosphere and climate system components. More reliable observing networks are needed to reduce the uncertainty of future estimates. Measurements from satellites and aircraft have improved the ability to observe certain elements of the Arctic cryosphere, such as the spread of sea ice and snow cover. Monitoring other key elements of the cryosphere, such as sea ice thickness, snow depth, permafrost and glaciers, requires ground based observations. equipment [4]. Many ground-based hydrometric networks for observing snow cover, freshwater ice and precipitation have been reduced or completely lost, and objects for observing sea ice, main ice and physical properties of snow are located at large distances from each other. Observing networks should be expanded to obtain reliable data on the cryosphere, which are necessary for monitoring, improving models and assessing the quality of satellite observations. The report identifies the most important questions to which there is still no answer:

• What will happen to the Arctic Ocean and its ecosystems if melting ice and increased river flow are added to the freshwater flow?

• How fast can the Greenland ice sheet melt?

• How will changes in the Arctic cryosphere affect the global climate?

• How will the changes affect the population and economy of the Arctic?

Answering these questions requires improved observational networks. A better understanding of the complex interactions of the physical, chemical and biological environment in the Arctic is needed. There is a lack of systematically collected information on the impact of cryospheric changes on human society. Thus, the report Snow, Water, Ice and Permafrost in the Arctic confirmed the importance of climate-induced changes in snow cover, sea and land ice in the Arctic and their profound implications for local, regional and global communities. The combination of the impact of the changing cryosphere, climate change and the rapid development of the Arctic creates political challenges for the Arctic communities, as well as for the world community. The traditional way of life is most vulnerable to changes in the cryosphere. Collaboration and coordinated efforts at all levels are needed to respond to change and increase the adaptive capacity of Arctic ecosystems and populations.

The report Snow, Water, Ice and Permafrost in the Arctic will be used to create a new version of the Assessment Report on Climate Change and Their Consequences in the Territory of the Russian Federation, which is currently being prepared by Roshydromet and the Russian Academy of Sciences. The conclusions of the SWIPA report are also important when planning specific activities of the “Strategic Action Program for the Protection of the Environment of the Arctic Zone of the Russian Federation”.

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