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Arctic climate variability and ice regime of the Lena River delta lakes

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Abstract. Climate variability in the Russian Arctic in 1991-2017 is examined based on the mesurements of the air temperature at 19 meteorological stations. The average annual air temperature at the stations fluctuated relative to the climatic baseline of 1961-1990 by 0.5-4°C in 1991-2004. Since 2005, it was higher than the climatic baseline at all stations annually. The increase in the air temperature was most pronounced in the winter months from November to February at all stations (more than 15ºC at some stations in some years). The increase in the air temperature in the summer months was noticeably smaller. The baseline level of the average monthly air temperature from November to February was exceeded most prominently at high latitude meteorological stations located at Wiese Island, Severnaya Zemlya, and Franz Josef Land (16-17ºC in some years, starting with 2005). Stations located at a distance from the ocean, such as Khatanga and Tiksi, are characterized by a smaller temperature increase compared to coastal and island stations, such as Barenzburg, Wrangel Island and others. Smaller deviations of the air temperature from the baseline level are typical in the western sector of the Russian Arctic (Murmansk, Svyatoy Nose). The influence of the Arctic climate variability on the ice regime of arctic lakes is considered according to Flake model (http://www.flake.igb-berlin.de/) for the Lena River Delta lakes.

1 Introduction

The study of the Polar Regions is currently one of the priority research areas. As noted in the Special Report on the Ocean and Cryosphere in a Changing Climate IPCC 2019 [1], “The Polar Regions are losing ice, and their oceans are changing rapidly. The consequences of this polar transition extend to the whole planet, and are affecting people in multiple ways.” The most noticeable climate changes occur in high latitudes of the northern hemisphere [1-3], which creates the threat of irreversible changes in the vulnerable natural sites of the Arctic – estuaries, coastal ponds, lakes, marshes and flooded areas, all of which continue suffering from the human activity.

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The main features of the recent Arctic climate change noted in the IPCC 2019, as well as the consequences of these changes, are as follows: an increase in the air temperature and the temperature of the surface layer of the Arctic Ocean during the open water period; a decrease in the surface area of sea and "land" ice, the disappearance of perennial sea ice, a decrease of land glaciers, a decrease in snow cover on ice and on land, as well as the ice cover of the lakes; late freezing of the Arctic seas; a sharp decrease in the albedo of the surface of the Arctic Ocean in the summer due to the disappearance of large areas of sea ice; an increase in cloudiness; a retreat of permafrost and land subsidence; the formation of new lakes; an increased river flow into the seas of the Arctic Ocean; habitat change, such a loss of a unique biodiversity of high arctic species and expansion of subarctic species [1]. These changes affect the processes occurring in the lithosphere, hydrosphere, atmosphere and biosphere, which taken together determine the importance of the study of the Arctic climate variability.

Currently, the methods of studying the Arctic climate variability include numerical modeling, remote sensing, and data collection from the meteorological stations. Modern models make it possible to study natural Arctic climate variability with different time scales, ranging from inter annual to multi-decade, that also take into account various scenarios of anthropogenic impact (see, for example [4, 5]). Remote sensing helps studying the spatial distribution of albedo, temperature, sea ice, and others climate parameters [6]. The measurements at meteorological stations, though often discontinuous and without the required length, or simply absent, as is the case for the central Arctic, still remain an indispensable component in the process of scientific analysis and interpretation of the simulation results and satellite data.

Current work presents the analysis of the Arctic climate variability based on the data of the air temperature measurements at meteorological stations of the Russian Arctic in 1991-2017. The influence of the Arctic climate variability on the ice regime of the lakes of the Lena River delta over the past 40 years is also considered within the framework of the Flake model [7] and ERA-5 reanalysis data [8].

2 Study sites and methods

2.1 Air temperature data from meteorological stations of the Russian Arctic

The air temperature data at 19 meteorological stations of the Russian sector of the Arctic (Table) were analysed for 1991-2017 and the period of 1961-1990 was established as a climatic baseline level. Next, deviations from this baseline were calculated for each year in the period of 1991-2017, and for each month of each year. The data for these calculations were obtained on the website of RIHMI-WDC, the Federal State Budgetary Institution All-Russian Scientific Research Institute of Hydrometeorological Information – World Data Center http://meteo.ru/data [9].

2.2 Ice regime of the arctic lakes of the Lena River delta

The study focused on the ice regime of the small arctic lakes located on the Samoylov Island in the Lena River delta. The ice regimes of these lakes were numerically simulated using the one-dimensional parameterized Flake model [7]. Long-term measurements of the water temperature of three lakes of Samoylov Island in 2009-2012 were used to verify the Flake model [10]. The features of the climate and landscapes of Samoylov Island were considered in [11, 12], and the Lena River delta hydrology in [13].

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Table. The coordinates of the meteorological station.

Index WMO	Station	Station coordinates	
		N	E
20046	Name of E.T. Krenkel	80°37′	58°03′
20069	Wiese Island	79°30′	76°59′
20087	Golomyanny Island	79°33′	90°37′
20107	Barentsburg	78°04′	14°15′
20292	Name of E.K. Fedorov, OGMS	77°43′	104°18′
20476	Sterlegova	75°25′	88°54′
20667	Name of M.V. Popov	73°20′	70°03′
20674	Dixon Island	73°31′	80°24′
20744	Malye Carmaculas	72°22′	52°43′
20891	Khatanga	71°59′	102°28′
20946	Name of E.K. Fedorov	70°27′	59°05′
21802	Saskylah	71°58′	114°05′
21824	Tiksi	71°35′	128°55′
21946	Chokurdah	70°37′	147°53′
21982	Wrangel Island	70°59′	181°31′
22028	Teriberka	69°12′	35°07′
22113	Murmansk	68°58′	33°03′
22140	Svyatoy Nose	68°09′	39°46′
22165	Kanin Nose	68°39′	43°18′

3 Results and discussion

3.1 The Arctic climate variability

The average annual air temperature at the stations fluctuated relative to the climatic baseline level of 1961-1990 by 0.5-4°C in 1991-2004. Annually since 2005, it was higher than the climatic baseline at all stations. The increase in air temperature was most pronounced in the winter months from November to February at all stations (more than 15ºC at some stations in some years). The increase in the air temperature in the summer months was noticeably smaller. The average monthly temperature from June to September, averaged over the period of 1991-2017, exceeded the norm by no more than 2ºC and not more than 3.2ºC for the period of 2005-2017 at all stations (Fig. 1). The baseline level of the average monthly air temperature from November to February was exceeded most prominently at high latitude meteorological stations located at Wiese Island, Severnaya Zemlya, and Franz Josef Land – Wiese Island, Golomyanny, and Name of E.T. Krenkel (16-17ºC in some years, starting with 2005). Stations located at a distance from the ocean, such as Khatanga, Chokurdah, Tiksi, and Saskylah, are characterized by a smaller temperature increase with exceeded the baseline level by 2-5ºC (the average monthly temperature of the winter months averaged over the period of 2005-2017) compared to coastal and island stations, such as Barentsburg, Dikson Island, Wrangel Island, Sterlegova, Name of M.V. Popov, Name of E.K. Fedorov, where the increase was around 3-7ºC. Close to zero and negative deviations of the February air temperature are characteristic of stations located further from the ocean. Smaller deviations of the air temperature from the baseline level are typical in the western sector of the Russian Arctic (Murmansk, Svyatoy Nose, Kanin nose, Teriberka) – just over 2ºC throughout the year, with a minimum in June or July.

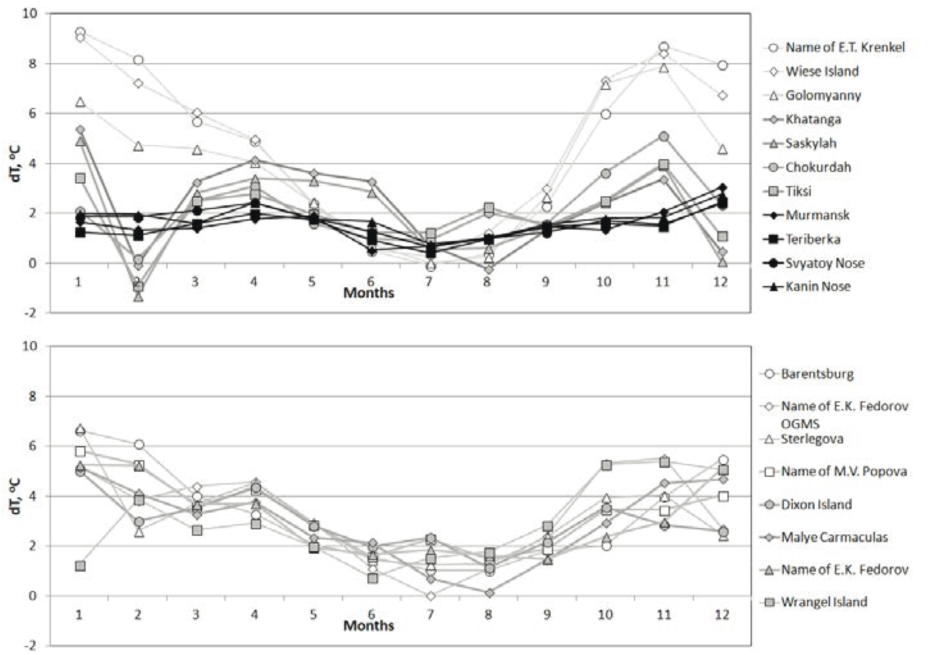

Fig. 1. Deviation of the average monthly temperature from the climatic norm averaged over the period 2005-2017 at meteorological stations of the Russian Arctic.

3.2 Modelling of ice regime of the Arctic lakes

A model Flake [7] calculations of the ice-on and ice-off date for the lakes of Samoylov Island and comparison with the data of year-round temperature measurements in these lakes in 2009-2012 [10] allowed us to establish that the model reproduces the ice phenomena quite well.

A model Flake calculations of the ice regime of the lakes of Samoylov Island for 1979-2018, taking into account the atmospheric impact specified by the ERA-5 reanalysis [8], showed that the average ice thickness and the duration of ice period decreased by 3 mm per year and by 0.5 days per year (Fig. 2).

4 Conclusions

In this study, we investigate how the air temperature changes in different regions of Russian Arctic in 1991-2017. It is found that the air temperature rises more intensively in winter months compared to summer at all investigated meteorological stations. The highest increase in air temperature was found on high-latitude islands and archipelagos, the lowest are characteristic of the western sector of the Russian Arctic. The features of climate variability in different regions of the Arctic are formed under the influence of a number of factors, such as features of atmospheric circulation, the influence of topography, location relative to the ocean, sea currents and others [1, 14]. The revealed peculiarities of the air temperature variability in different regions of the Arctic can lead to different consequences for the ice regime of the lakes in the Arctic zone. Flake model calculations, taking into account the ERA-5 reanalysis data, showed a decrease in the ice period and the maximum thickness of ice on the Arctic lakes of the Lena River delta. The revealed changes in ice phenology of Arctic lakes are not as dramatic as on the Arctic seas [3, 6], however, this important ecological phenomenon requires further in-depth study.

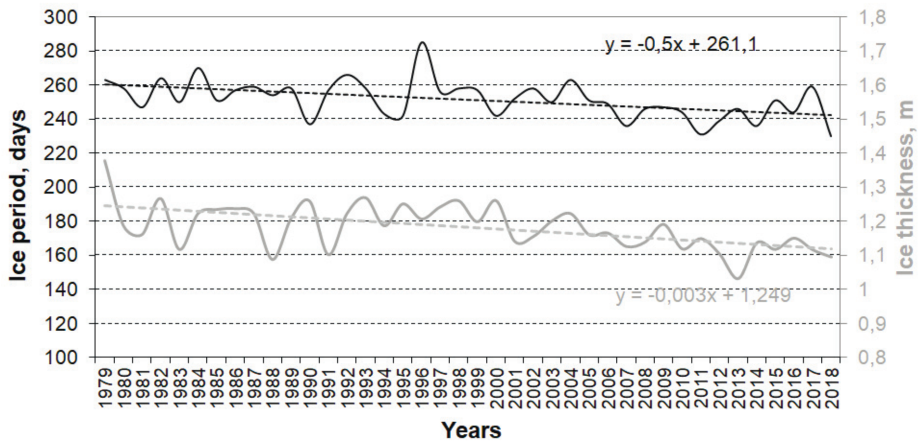

Fig. 2. The duration of the ice period (left axis, black line) and the maximum thickness of ice (rigth axis, grey line) on the lakes of Samoilovsky Island in 1979-2018 according to model Flake calculations. Dashed lines - linear trends. The linear trend equations are shown in the figure.

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