On the issue of climate change in the Arctic zone of the Russian Federation

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Abstract. The Arctic is one of the four regions of the world, classified by the Intergovernmental Panel on Climate Change as the most vulnerable region to climate change. A comparative analysis of the climate in almost half a century of the Purovsky District of the Yamalo-Nenets Autonomous District was carried out. We have established that the average annual air temperature and the amplitude of temperature fluctuations remained practically unchanged. In recent years, there has been an increase in precipitation in the cold season. There is a decrease in wind speed in the cold (except February) and in warm seasons. The number of cases without wind has decreased 2.8 times.

1. Introduction

One of the global problems facing humanity today is the changing planetary climate. Despite the fact that the views of scientists on the root causes of the observed climate changes are very different, the fact of the existence of the changes is beyond doubt [1]. Thus, at present it is possible to consider the established fact of the temporal dynamics of the Earth's climate occurring in separate regions in different scales and intensity [2]. At the same time, there is no single point of view on the main causes and trends in the dynamics of the modern climate, as well as its consequences for individual components of the natural environment. Therefore, recently in scientific circles [3-7] the dynamics of the climate, especially of the polar zones of the Earth, is actively studied. In modern studies, climate change, including in the Arctic, is taking an increasingly prominent place [6]. The Arctic is of great scientific and practical interest for both Russian and foreign scientists. First, as a powerful environmental regulator that can have a significant impact on the global climate system, in particular on ecosystems, people's way of life, their economies, etc. [8], since the Arctic is a "weather kitchen". Secondly, the Arctic is one of the four regions of the world assigned by the Intergovernmental Panel on Climate Change (IPCC) to the regions most vulnerable to climate change [6,9].

The urgency of the problem is exacerbated by the fact that the climatic significant processes and feedbacks operating in the Arctic climate system, the factors determining the regional climate changes in the region, the functioning of the climate system as a whole [9].

The aim of our work was to conduct a comparative analysis of the climate in almost half a century (1938 - 1950 and 2006-2010) using the example of the Purovsky District of the Yamalo-Nenets Autonomous District (YNAO).

2. Materials and methods

Climatic data were obtained according to the Climatological directories of the USSR for 1938 - 1950 [10,11] and on the site materials https://rp5.ru/ for 2006-2010. [12] from the meteorological
station of Tarko-Sale. To study the climatic conditions of the Purovsky region of the Yamalo-Nenets Autonomous District, the temperature features were analyzed: the average monthly and mean annual air temperature, the maximum and minimum air temperature, and the amplitude of the temperature variations in the atmospheric air. In addition to the temperature characteristics of this region, the amount of precipitation, wind speed and direction, and the number of cases of calm are also considered.

Qualitative and quantitative characteristics were subjected to statistical processing using the integrated software package "IBM SPSS Statistics 21". In the normal distribution, the following statistical parameters were used: mean value (mean arithmetic mean, median, mode), variance and its derivative (mean square deviation). Comparison of the reliability of differences or similarity between the statistical characteristics obtained in the study of compared samples (by the Student's criterion) was made. To calculate the reliability of the differences between the mean values, the standard error of the arithmetic mean was calculated. In the absence of a normal distribution, nonparametric methods were used to compare two samples with the calculation of the Wilcoxon pair test.

3. Results of the study
The average monthly and average annual air temperature is given in table 1.

Table 1. Average monthly, average annual air temperature and amplitude of temperature fluctuations for the considered periods of time, C.

| Name      | Average monthly and mean annual air temperature | Amplitude of temperature fluctuations |
|-----------|-----------------------------------------------|-------------------------------------|
|           | 1938 – 1950 | 2006 – 2010 | 1938 – 1950 | 2006 – 2010 |
| January   | -24.96±1.57 | -24.18±0.35 | 34.25±2.71 | 39.42±1.89 |
| February  | -22.2±1.22  | -25.72±0.31a| 37.38±1.61 | 32.84±2.92 |
| March     | -17.77±0.82 | -13.5±0.25***| 41.18±1.22 | 41.5±2.6 |
| April     | -5.92±0.79  | -7.1±0.27   | 32.81±1.4 | 35.2±1.03 |
| May       | 0.39±0.59   | -0.51±0.16  | 31.15±1.59 | 26.24±2.36 |
| June      | 10.25±0.71  | 11.24±0.18  | 26.6±1.02 | 27.96±0.93 |
| July      | 14.92±0.49  | 16.90±0.16**| 24.39±0.87 | 25.9±1.44 |
| August    | 12.95±0.39  | 12.19±0.13  | 27±0.88   | 22.44±1.25# |
| September | 6.48±0.49   | 6.53±0.14   | 19.82±1.75 | 25.64±1.82# |
| October   | -3.42±0.83  | -2.44±0.2   | 28.11±2.61| 28.72±4.87 |
| November  | -15.59±1.15 | -17.61±0.29 | 36.46±1.46 | 37.94±2.16 |
| December  | -22.52±1.32 | -22.54±0.31 | 42.38±1.02 | 36.34±1.28## |
| Year      | -5.51±0.4   | -5.31±0.14  | 76.85±0.83 | 76.54±3.43 |

- * the reliability of differences with the average monthly and mean annual air temperature for 1938 - 1950. (** - p < 0.05; *** - p < 0.01; *** - p < 0.001).
- # - the reliability of differences with the amplitude of temperature fluctuations for 1938 - 1950. (# - p < 0.05; ## - p < 0.01).

It has been established that in recent years there has been a decrease in the mean monthly temperature in the cold period of the year (in February, at p < 0.05) and an increase in the warm period (in July at p < 0.01). As for the average annual air temperature for 1938 - 1950 and 2006 - 2010, it practically did not change (-5.51 ± 0.4 °C and -5.31 ± 0.14 °C, respectively).

We calculated an important characteristic of weather and climate - the amplitude of temperature fluctuations (table 1), which is defined as the difference between the maximum and minimum air temperature (table 2).

Thus, the annual amplitude of temperature fluctuations did not practically change during the considered periods of time, with the exception of August (p < 0.05) and December (p < 0.01), where the temperature difference was higher for 1938 - 1950 and September, where the temperature difference is lower (p < 0.05).

As can be seen from table 2, there were no significant changes in the minimum values of air temperature during the analyzed periods. However, the maximum values of air temperature in recent years have become higher, especially in January, March, July, November. This confirms the presence of a change in the Arctic climate towards its warming.
responding adverse meteorological conditions in the region, including the dangerous wind speed [13]. The climatic parameters necessary for the realization of these calculations are determined by climatic data, the quality, volume and methods of processing the meteorological observations used while doing so must comply with the mandatory metrological requirements for measurements in accordance with Order No. 436 of the Ministry of Natural Resources of Russia of 19.10.2015 "On Approving the List of Measurements Relating to the sphere of state regulation of ensuring the uniformity of measurements and performed in the implementation of climate are atmospheric precipitation - one of the links of moisture exchange on Earth. The average daily rainfall for the years 1938 - 1950 and 2006-2010 is presented in table 3.

Table 3. Average daily rainfall, mm.

| Name  | Average daily rainfall, mm |
|-------|----------------------------|
|       | 1938 – 1950 | 2006 – 2010 |
| January | 0.43±0.05 | 0.76±0.06*** |
| February | 0.42±0.05 | 0.68±0.05*** |
| March | 0.43±0.03 | 0.84±0.06*** |
| April | 0.76±0.11 | 1.61±0.17*** |
| May | 1.26±0.17 | 0.87±0.1* |
| June | 2.15±0.21 | 1.87±0.19 |
| July | 1.97±0.33 | 2.28±0.24 |
| August | 2.13±0.32 | 2.65±0.27 |
| September | 2.04±0.27 | 1.8±0.17 |
| October | 1.25±0.14 | 1.36±0.09 |
| November | 0.71±0.07 | 1.22±0.08*** |
| December | 0.55±0.08 | 0.84±0.06* |
| Year | 1.2±0.05 | 1.34±0.04* |

* p<0.05; ** p<0.01; *** p<0.001.

When analyzing the average daily rainfall for 2006-2010 in comparison with 1938 - 1950 their increase was observed in January, March, April, November (p < 0.001), in February (p < 0.01), in December, and also for the year (p < 0.05). And for the cold period of 2006 - 2010 there is an increase of about 1.4 times in comparison with 1938 - 1950.
of activities in the field of hydrometeorology and related her areas, and obligatory metrological requirements to them, including indicators measuring accuracy " [14]. The average annual wind speed is shown in Table 4.

Table 4. Average annual wind speed, m/s.

| Name      | Average annual wind speed, m/s | 1938 – 1950 | 2006 – 2010 |
|-----------|--------------------------------|-------------|-------------|
| January   | 3.22±0.24                      | 2.48±0.05** |
| February  | 3.52±0.25                      | 3.48±0.09   |
| March     | 3.94±0.29                      | 2.47±0.05***|
| April     | 4.29±0.19                      | 2.69±0.05***|
| May       | 4.25±0.13                      | 2.93±0.04***|
| June      | 4.25±0.14                      | 2.58±0.05***|
| July      | 3.58±0.11                      | 2.38±0.05***|
| August    | 3.25±0.12                      | 2.04±0.04***|
| September | 3.23±0.16                      | 2.26±0.04***|
| October   | 3.89±0.16                      | 2.53±0.04***|
| November  | 3.52±0.24                      | 1.95±0.03***|
| December  | 2.78±0.28                      | 2.05±0.04** |
| Year      | 3.64±0.09                      | 2.38±0.01***|

* p<0.05; ** p<0.01; *** p<0.001

We found that in recent years of our studies, the wind speed both for cold (except February) and for warm periods has significantly decreased. The number of cases without wind (calm) became 2.8 times less.

In order to more fully characterize the wind regime of this region, we studied the direction of the wind. So for the years 1938 - 1950 the southern, north-western winds prevailed, and for 2006-2010 - south-western, north-western. Apparently, this is due to temperature differences between not very distant areas, which can be caused by different absorption coefficients of sunlight or different heat capacities of the surface.

4. Conclusions and suggestions

In recent years, due to technogenesis and general circulation of the atmosphere in the Arctic zone of Russia, there have been significant changes in the mean monthly temperature and amplitude of its fluctuations in some period of the year without changing the average annual indicators. Polar day and night cause an extremely uneven supply of solar radiation during the year. This loss was previously compensated by the inflow of warm air and water masses (southern and north-western directions) in the Arctic. In recent years, there has been a trend towards a decrease in the influx of warm air masses due to the reduction of southern winds. In recent years, winds in the region have become predominantly weak in the south-west and north-west directions, and their frequency has increased 2.8 times. Apparently, this is due to temperature differences between not very distant areas, which can be caused by different absorption coefficients of sunlight or different heat capacities of the surface. It is known that the anticyclonic circulation in the Siberian region of the Arctic develops in the winter. The average air temperature in February (the coldest winter month) has become significantly lower and ranges from -26.03 to -25.41 °C. The minimum temperatures did not change significantly. The average air temperature in July (the warmest summer month) became significantly higher and ranged from 16.74 to 17.06 °C. The maximum temperature was also higher and averaged 30.56 ± 1.24 °C. The increase in the maximum air temperature in 2006-2010 points to climate change in the Arctic zone of Russia towards its warming. Obviously, smoothing out the inversion of the air temperature can reduce the cooling of the surface in these areas. Here, in recent years, there has been an increase in the amount of precipitation to a greater extent due to snowfalls during the cold period of the year.
Thus, Purovsky region of Yamalo-Nenets Autonomous District for the analyzed period (≈ 50 years) there is no evidence of global warming. Nevertheless, the climate has become milder with increasing both the amount of precipitation and the redistribution of them due to the cold season. In this direction the work will continue.

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