

Research at the MSU Meteorological Observatory site in 2024

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Abstract. The St. Petersburg Economic Forum emphasized the importance for the development and support of the coastal infrastructure of the Northern Sea Route of the system of state monitoring of permafrost conditions that is being created in Russia in view of the ongoing climate change. Within the framework of this system, the staff of the Moscow State University Meteorological Observatory is carrying out test thermometric boreholes both on sites with natural cover and on sites without it. The article discusses the first results of these works.

1 Introduction

The weather features of the beginning of 2024 in the Moscow region, for which a comparison with the weather features of previous years was made, and the presented climatic research at the site of the Moscow State University Meteorological Observatory, including the observation of the spatial and temporal variability of snow cover, as well as the thermal state of soils, the change in which is an undoubted indicator of responses to climate change, are relevant, because the ongoing climate change leads to an increase in the frequency of abnormal weather conditions in the Moscow region.

2 Materials and Methods

Weather patterns at the beginning of 2024 could be a factor of natural hazards. Thus, January 2024 in Moscow was generally colder than in previous years [1-6]. According to data from the VDNKh weather station, the average monthly temperature in January was -10.1°C , which is 3.9°C below the norm. The minimum temperature of -27°C was recorded on January 4, while the maximum temperature of 2.1°C was observed on January 30. There were two periods of relatively cold weather (January 1-8 and 12-14) and one period of warmer weather (January 23-31). Precipitation equivalent to 85% of average precipitation fell during January, with the heaviest precipitation of 9 mm recorded on January 11. The average snow cover thickness was 31 cm, and the maximum snow cover thickness of 46 cm was also observed on January 26.

However, in February 2024, Moscow was warmer than usual and the amount of precipitation was above average. The average monthly temperature was -4.5°C , which is 1.3°C above the average norm. During February, there were three periods (February 8-11,

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14-16 and 20), during which a negative temperature anomaly of -3 to -6°C was observed. On all other days, the average daily temperature was 1 - 8°C above the multiyear average. On February 7, 19 and 21, the average daily temperature was within the normal range. The lowest air temperature of -17.1°C was recorded at night on February 10, and the highest temperature of 4.9°C was reached in the afternoon of February 28 (Figure 1).

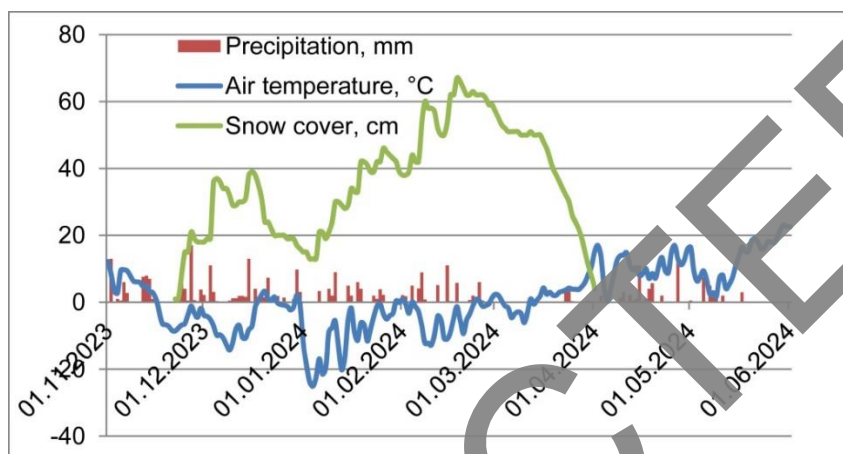


Fig. 1. Changes in temperature, precipitation and snow cover thickness at the beginning of 2024 in Moscow

The graph in Figure 1 shows that the amount of snow steadily increased in January and February, reaching a maximum of 67 cm at the VDNKh weather station in the second half of February and over 70 cm at the MSU Meteorological Observatory. These values are above the multiyear averages. The calendar winter of 2023/24 also had a very significant amount of precipitation – 173 mm, which is a rare phenomenon. Judging by the amount of precipitation, this winter is among the five snowiest winters recorded in Moscow in recent years, after the winter seasons of 2000-2001, 1965-1966, 2022-2023 and 2017-2018. Overall, the 2023-2024 winter season in Moscow was characterized by increased snow accumulation.

Overall, the calendar winter in Moscow was one degree colder and much snowier than normal, with an average air temperature of -6.4°C , slightly above the current climatic norm for Moscow (-7.5°C). January was particularly cold, with an average temperature of -10°C (the current January norm is -6.3°C) (Figure 2).

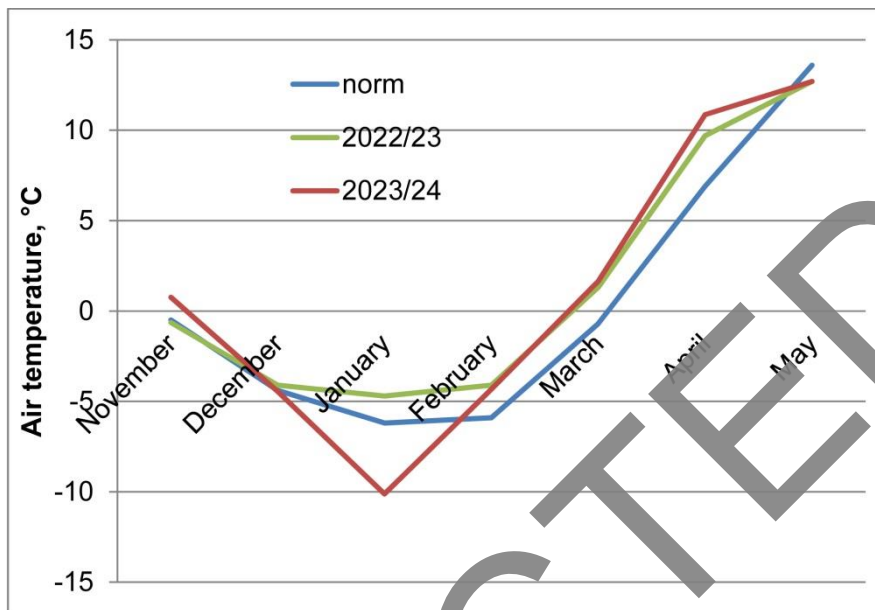


Fig. 2. Mean monthly temperatures at the beginning of 2024 and 2023 and long-term averages in Moscow

The graph in Figure 2 also shows that March and April were likewise on average 3-4°C warmer than the long-term averages, and the average temperature for May was even slightly below the long-term averages. Also in the first half of May 2024 there was an unusually intense cooling and frost (Figure 1), and the average temperature was only 6.7°C. The second half of May was characterized by an average temperature of 17.6°C, with the average monthly May temperature around 12-13°C.

The return of cold weather and snowfall in May in the European territory of Russia (ETR) is a dangerous natural phenomenon, as most ornamental and agricultural plants and trees have already started their vegetative period. Thus, these frosts can have a significant impact on agriculture, especially horticulture, as early frosts can damage flowering fruit trees and destroy crops. Farmers tend to expect such weather conditions in May and take precautions, for instance delaying seedling planting to minimize potential losses (<https://de.m.wikipedia.org/wiki/Eisheilige>) [7].

The return of cold weather and snowfall in May in the European territory of Russia (ETR) became more frequent due to the disruption of atmospheric circulation processes and the increase in climate contrast in the background and in connection with its warming. So in early May 2024 Arctic air masses coming from the Arctic Ocean led to a significant decrease in temperatures across the country, the temperature was 6-8 degrees below normal, snow fell. These were cold air masses that came from the White Sea basin and led to a significant drop in temperature for the territories of the European part of Russia - Vologda, Leningrad, Kostroma, Ivanovo, Yaroslavl, Tver regions, the Republic of Karelia. A cyclone centered over the north of the European territory of Russia was pumping Arctic air. And the zero isotherm even in the daytime hours passed at a level of about 500 m, as a result of which precipitation fell in the solid phase. On the background of low positive daytime temperatures and negative night temperatures, a temporary snow cover was established in places even in the Middle Belt. In Moscow the existence of snow cover in May 2024 was fragmentary, and nearby on the Klin-Dmitrovskaya ridge (exceeding about 300m) in May 2024 the snow cover existed for more than a day. Therefore, such a cold beginning of May in Moscow has not been for a quarter of a century. Total frosts all over

the capital region. However, it is not only the capital that has suffered from the cold: Voronezh, Lipetsk and Tambov regions have introduced a state of emergency in agriculture due to frosts. The last time frosts in early May in the capital were recorded in 1999, when it was -3.8. Since the founding (since 1948) of the VDNKh reference weather station, the thermometer columns have fallen below zero only 5 times (1950 -3.2; 1952 -3.1; 1972 -0.1; 1999 -3.8; 2023 -0.9). The record of the minimum temperature for the entire history of meteorological observations in Moscow belongs to 1918, when the minimum thermometer showed -5.6 (Table 1).

Table 1. Events of May Cold and frost return in the Moscow region in recent years

Date	T_min	T_max	Abnormality	Snow days	Snow cover
08-12.05.2017	-1...1°C	5...9°C	-10°C	4	<0.5
19-20.05.2002	1...2°C	4...8°C	-11°C	2	-
12-16.05.2000	0...1°C	5...13°C	-11°C	1	-
01-14.05.1999	-1...4°C	3...12°C	-11°C	3	-
12-17 20-22.05.1980	0...2°C	4...11°C	-11°C	3	-
19-21.05.1974	-1...1°C	3...10°C	-13°C	3	-
09-10.05.1972	-2...0°C	3...10°C	-12°C	2	-

3 Results

According to (<https://www.rbc.ru/society/09/05/2024/663cc4ee9a7947c142815e98>), the global climate change towards warming has been underway in Eurasia at least for more than 30 years. However, the current increase in the frequency of May frosts is of course also related to this, because with such a shift of the climate in a certain direction, permanent phenomena of abnormal order begin. Abnormal weather phenomena may include droughts, floods and snow in spring. Therefore, within the framework of the state budgetary theme on the study of the danger and risk of natural processes and phenomena by the staff of the research laboratory of snow avalanches and mudflows are carried out on the territory of the meteorological observatory of MSU, including observation of the spatial and temporal variability of the snow cover, as well as the thermal state of soils, the change of which is an undoubted indicator of responses to climate change.

Observations of the spatial and temporal heterogeneity of the snow cover have been conducted by the laboratory staff on the territory of the MSU meteorological observatory for more than 10 years [8-20]. The snow cover accumulation regime from the beginning of its occurrence to its descent was considered. Ground measurements of the snow cover height, thickness of specific layers, their density, shape and size of crystals in pits and trenches 20 m long with a step of 1 m were also made. Based on the data obtained, calculations were made and schemes of spatial variability of density in the trenches were plotted. Research in the trench was conducted 4 times during the winter. In addition, snow pits were additionally surveyed weekly. Their results characterize the snow thickness at different developmental stages.

Also in the fall of 2021, an experimental thermometric borehole of about 18 meters was drilled on the meteorological site of the MSU meteorological observatory with natural cover and an experimental system of temperature monitoring of soils was installed, which

has already been operating on the site of the MSU meteorological observatory for some time. During the drilling of the borehole at the MSU meteorological observatory site, a soil core was collected and characterized. The soil core extracted during drilling was studied under laboratory conditions. The main constituent rock was loam. The thermal conductivity and heat capacity of the constituent rocks were determined using the KD2Pro device (<https://decagon.ru/environment/kd2pro/>). The chemical and lithologic composition of the constituent soils was also determined.

Also in the fall of 2023, an experimental thermometric borehole was drilled at the meteorological site of the MSU meteorological observatory with a remote natural cover. A soil core was collected and characterized while drilling the borehole at the MSU Weather Observatory site. The soil core extracted during drilling was studied under laboratory conditions. The main constituent rock was also loam. Moisture content, thermal conductivity and heat capacity of the constituent rocks were determined using the KD2Pro device (<https://decagon.ru/environment/kd2pro/>). The chemical and lithological composition of the constituent soils was also determined.

4 Conclusions

The work on the study of the spatial and temporal variability of the snow cover, as well as on the preparation and drilling of thermometric boreholes on the site with and without natural cover, and on the selection and subsequent study and description of the selected soil core allowed to determine the values of thermal conductivity, heat capacity and chemical composition of the soil. Moreover, these works allowed to collect materials for a full-scale thermophysical modeling of the soil temperature in a computer program both for the site with natural cover (snow and vegetation) and for the site without it, to compare them and to assess the contribution of climate change.

Such a comprehensive thermophysical modeling of soil temperature in a computer program for assessing climate change based on thermometric well data can be one of the tools in the creation of a global state network for monitoring the thermal state of perennially frozen soil. At the St. Petersburg International Economic Forum the development of Russia's Arctic zone and the Northern Sea Route was discussed, and it was argued that the integrated development of this harsh region requires a special approach and special technologies, and this cannot be done without taking into account climate change, and it is important to ensure the development of the Northern Sea Route and the stability of its coastal infrastructure located in the zone of thawing permafrost.

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