Snow thermal state monitoring at the observation site of Lomonosov Moscow State University (MSU) in 2024

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Abstract. The 2023 climate report suggests that there may be rising greenhouse gas levels, record global temperatures and significant glacier melt. The summer of 2024 saw some of the highest temperatures on record in the Northern Hemisphere, with Moscow experiencing its warmest September in 150 years and an unusually dry climate. Snow observations at MSU involve analysing a number of factors related to snow cover dynamics, including snowfall types, accumulation, and melting processes. Research also encompasses measuring snow density and structure, accommodating uneven terrain, and understanding weather influences on snow and ground thermal state and heat transfer properties. The findings contribute to our collective understanding of the cryosphere's evolution amidst climate change.

1 Introduction

The 34th annual international report, entitled "The State of the Climate in 2023", has recently been published. It contains an assessment of climate change on our planet. According to the latest research, there is a growing consensus among scientists that the concentration of greenhouse gases is continuing to increase. In 2023, the figure stood at 419.3 ppm, which represents a 50% increase compared to the levels seen in the pre-industrial era. In comparison to the level recorded in 2022, this indicator has seen a slight increase of 2.8 ppm. It would appear that global air temperatures over both oceans and continents have reached record highs since 1850. It would seem that temperatures over land have also reached a new record high, based on observations made over the course of history. It would seem that the Alps have recorded a notable decline in glacier mass since measurements began in the 1970s. In 2023, we observed that the surface water temperature in the world's oceans reached record levels over the past 170 years of observations. It would be fair to say that this new record is slightly higher than the previous one, set in 2016, by 0.13°C. It would seem that the average global ocean level has also reached an all-time high over the past 12 years, exceeding the 1993 level by 101.4 mm. According to satellite measurements, there has been an increase of 8.1 mm compared to 2022.

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2 Material and methods

Due to the ongoing global warming on Earth, the summer of 2024 has become the hottest on record in the Northern Hemisphere. Temperature records were broken in June, July and August, including the hottest day and the warmest summer ever measured. According to the European Copernicus service, the summer of 2024 was the hottest on record in the Northern Hemisphere. The average temperature in the summer months (June-August) in the northern latitudes reached a record high. It exceeded the average for the period from 1991 to 2020 by 0.69°C, breaking last year's record by 0.66°C.

September 2024 also became the warmest in the history of meteorological observations in Moscow, which has been conducted since 1874. The average monthly temperature was +18°C, which makes this September a record for the last 150 years. A new record has been set this September, there was no a single rain. Even 2023, when only 8 millimeters of precipitation fell, such dryness was not observed. September 13 was the warmest day in the last 75 years. The temperature reached +26 degrees, which is 1.9 degrees higher than the previous record set in 1998. Despite the extraordinary warmth, the night of September 22-23 was the coldest of the season. At the VDNKh weather station, +2.2 degrees were recorded, and in some areas of the Moscow region, for example, in Cherusty, the temperature dropped to -4.1 °C (Figure 1).

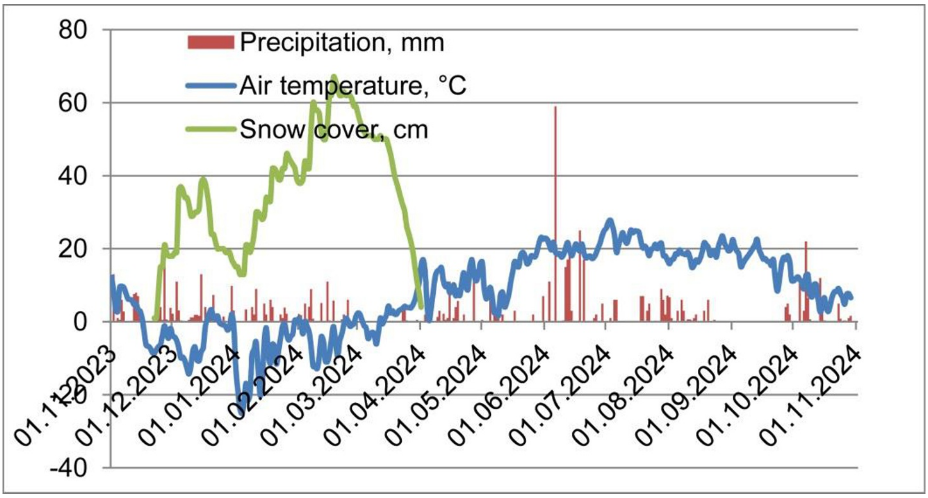

Fig. 1. Air temperature, snow and precipitation variations in hydrologic year 2023-2024 in Moscow (VDNKh).

The first precipitation in the form of snow was noticed in Moscow on Pokrov, October 14, 2024. On the morning of October 15, after a snowfall in the Central region, the temporary existence of a snow cover was recorded. The main weather station in Moscow, VDNKh, noted an uneven layer of wet snow with a height of 1 cm. The autumn 2024, the first snow fell in Moscow even before the frosts began. Negative temperatures have not been recorded on the territory of VDNKh since May 9, 2024. The frost-free period in the Moscow in 2024 lasted until October 18. In 2023, it ended on October 11, in 2022 — on October 12, in 2021 — on October 7, and in 2020 — only on November 9 [1-8].

Fig. 2. Snow study at observation site of Lomonosov MSU (first snow on October 15, 2024).

3 Results and discussion

As a prospective in snow study at the meteorological site of Lomonosov MSU discussed the characteristics and dynamics of winter, snow cover, and the processes involved in snow formation and melting. It defines the beginning and end of winter on the basis of consistent snow cover, noting that these dates are determined retrospectively. The variations in snow cover duration existence. The types of winter precipitation, including snowflakes, wet snow, and ice pellets. In addition, meteorological conditions and terrain influence snowpack formation and density. Variations in snowflake shapes, snow accumulation, and weather patterns throughout the winter months are also examined, emphasizing that the most significant snow growth occurs in December and January. By February, signs of solar melting appear, and by March, significant temperature fluctuations between day and night affect snow conditions.

It also covers methods of measuring snow accumulation for accurate height measurements and techniques for identifying different layers of snow based on density and structure. The importance of weather conditions on snow characteristics is demonstrated by describing different types of snow crystals and their properties. The process includes multiple measurements to account for uneven terrain and the creation of snow profiles to analyze snow distribution influenced by terrain and vegetation. Special attention has been paid to the study of the spatial and temporal structure of the snow cover and its density inhomogeneity [9-20].

Considering this, the influence of snow cover on the thermal state of the ground at the observation site of the Moscow State University Meteorological Observatory was evaluated. For this purpose, a previously developed algorithm and a calculation scheme based on the Fourier law were used. The results were compared with the data of actual observations. It turned out that they were in good agreement. A deep borehole was drilled in the area with natural snow cover to study the temperature distribution along the soil column. In the early summer of 2024, a thermometric borehole was also drilled in the area where the natural cover had been removed. Thermal sensors and a logger were installed and measurements began. These studies help to understand the characteristics of heat transfer and the propagation of a cold wave in the ground and snow. Both observations and simulations were used.

In order to study the heat transfer from the ground to the snow and to the atmosphere in winter, the thermal sensors were also placed vertically in the snow cover and horizontally on the ground surface at the boundary with the ground and snow of the meteorological site. Thus, the temperature variation in the snow cover and on the border of snow with the ground was to be recorded in the winter of 2024-2025 at the observation site. It was supposed to compare the results of these thermal observations with the results of the snow thermal simulations based on the Fourier law calculation scheme.

Fig. 3. Thermal sensors placed vertically and on the ground surface on the meteorological site.

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