Thermometric observations in boreholes with and without natural cover at Moscow State University, Russia

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Abstract. The article examines the influence of vegetation and snow cover on the soil thermal regime, based on the results of thermometric observations in boreholes at the MSU meteorological observatory. The study was conducted at two sites: one with natural cover and one without. Measurement results established that the presence of vegetation and snow cover significantly affects soil temperature, particularly during the winter period, where these covers protect the soil from freezing and ensure more stable thermal conditions. Differences in annual temperature fluctuations were also identified, confirming the hypothesis that the absence of cover leads to increased soil temperature due to greater solar radiation influx. This work emphasizes the importance of considering these factors in the context of climate change and their impact on ecosystems, and it proposes directions for future research.

1 Introduction

The soil thermal regime plays a key role in ecosystems by determining soil biological activity and the processes occurring within it. In the context of climate change and anthropogenic impact, it is important to understand the factors influencing temperature fluctuations in the upper soil layers. Among these factors are vegetation and snow cover [1–3].

Vegetation regulates the soil's heat balance by providing shade and reducing solar radiation exposure. Plant root systems improve soil structure and increase its water retention capacity. During winter, snow cover protects the soil from sharp temperature fluctuations by creating an insulating layer.

The aim of this study was to analyze the influence of vegetation and snow cover on the soil thermal regime based on observational data from the MSU meteorological station.

The soil thermal regime is shaped by external environmental factors (the atmosphere) and the underlying geological layers. The primary heat transfer mechanisms include conduction, convection, and thermal radiation. Soil temperature depends on climatic conditions, depth, soil composition, and moisture content.

Vegetation forms a complex system of interdependencies with the soil thermal regime. It affects heat exchange between the soil and atmosphere by blocking solar radiation in

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summer and retaining heat in winter. Different vegetation types possess distinct characteristics, leading to variations in the soil thermal regime.

Snow cover exhibits low thermal conductivity and high insulating properties. It protects the soil from frost during winter by maintaining stable temperature and moisture levels. The thickness and density of snow cover can vary significantly, affecting the depth of soil freezing. Such studies of soil thermal regimes are especially important under conditions of climate change, as they provide insight into the consequences of temperature changes for ecosystems, agriculture, and water resources [4–6].

2 Materials and Methods

The study sites selected were located at the MSU Meteorological Observatory, where two boreholes were drilled. A KM-10I drilling rig was used for the borehole drilling. The KM-10I is a modernized version of the KM-10 motor drill. The working depths of the boreholes were 10 and 18 meters. After drilling, thermocables were placed inside the boreholes to measure soil temperature profiles twice daily (see Fig. 1).

Fig. 1. External view of the thermocable

The thermocables were installed such that one was placed in the borehole at the site with snow and vegetation cover (see Fig. 2), while the other was placed in the borehole at the site without natural cover (see Fig. 3). These thermocables provided data on temporal changes in soil temperature profiles.

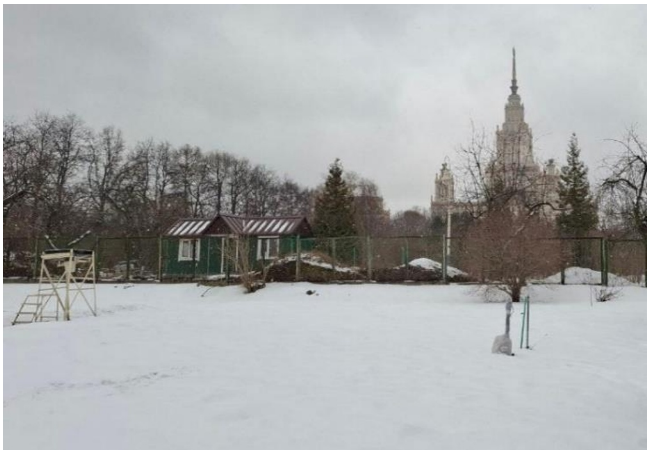

Fig. 2. MSU Meteorological Observatory site with snow and vegetation cover.

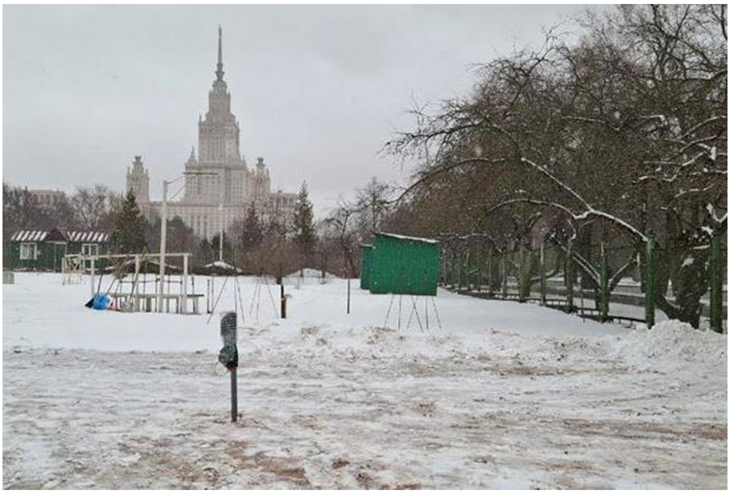

Fig. 3. MSU Meteorological Observatory site without snow and vegetation cover.

The study was conducted using direct measurement and computational methods to analyze the influence of different types of cover on the soil thermal regime. Temperature data were obtained by installing temperature sensors in the boreholes and performing regular measurements and data collection.

3 Results and Discussion

The temperature measurement results in both boreholes at the time points of August 15, 2024, November 15, 2024, and February 15, 2025, are presented in Figures 4–6.

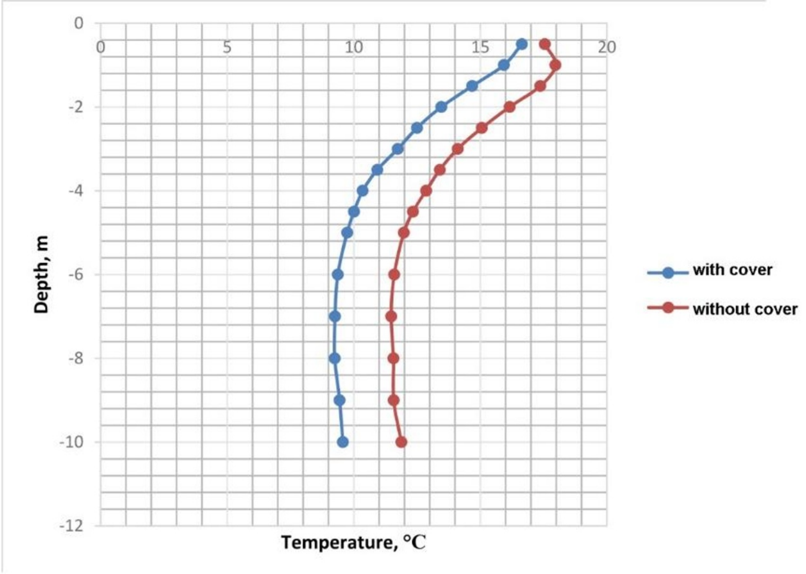

Fig. 4. Temperature changes in boreholes at sites with and without natural cover at the MSU meteorological observatory on August 15, 2024.

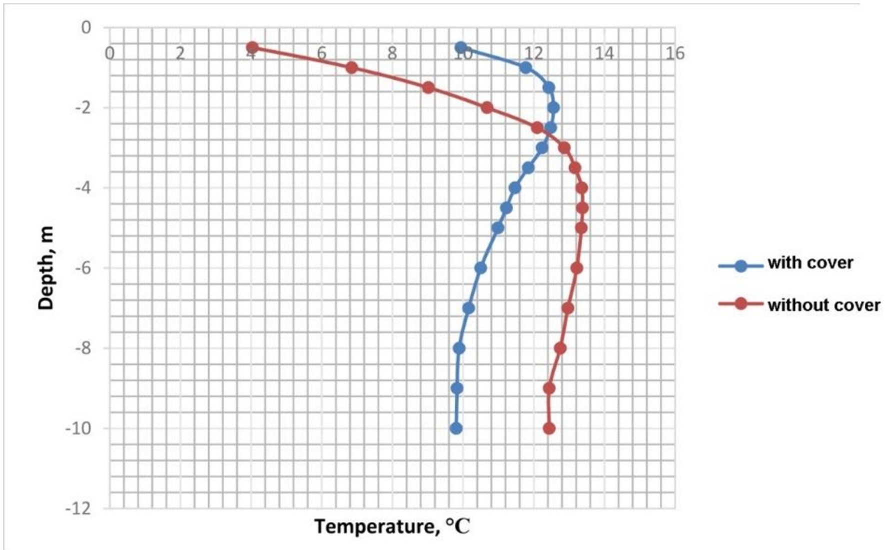

Fig. 5. Temperature changes in boreholes at sites with and without natural cover at the MSU meteorological observatory on November 15, 2024.

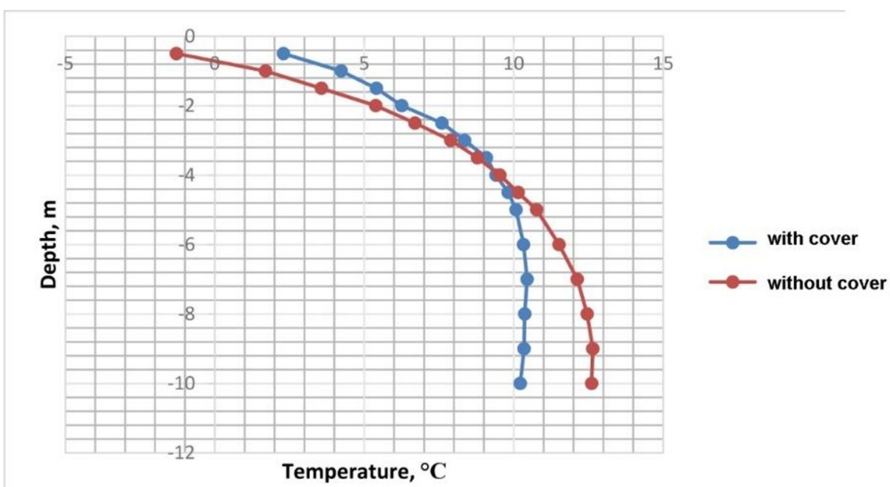

Fig. 6. Temperature changes in boreholes at sites with and without natural cover at the MSU meteorological observatory on February 15, 2025.

The graphs presented in Figures 4–6 depicting temperature changes in the boreholes demonstrate the influence of snow and vegetation cover on the soil thermal regime.

Preliminary data analysis revealed significant differences in soil temperature regimes depending on the presence of vegetation and snow cover. For example, during the cold season, the temperature in the upper part of the borehole with snow and vegetation cover was considerably higher compared to the temperature at a similar depth in the uncovered borehole. Conversely, during the warm season, the temperature in the upper part of the borehole with vegetation cover was lower compared to that at a similar depth in the uncovered borehole. Additionally, in winter, slight soil freezing was observed at the site without cover, whereas at the site with snow and vegetation cover, soil temperature remained consistently non-negative, and no soil freezing occurred due to the protective properties of snow [6-7].

Furthermore, the annual temperature wave at the site with snow and vegetation cover penetrates deeper into the soil with a certain delay compared to the site without cover.

However, at the site lacking natural cover, the soil temperature at the depth with no annual temperature fluctuations was 12°C, while at the site with covers it was 10°C. According to data from the MSU Meteorological Observatory, the average annual air temperature in 2024 was 8.2°C, marking a record high for the meteorological observation period and exceeding the 2023 value by 0.2°C. These findings thereby support the hypothesis that, in mid-latitude regions, removal of natural cover contributes to an even greater increase in deep soil temperature, due to reduced surface reflectivity and increased heat influx from solar radiation [8-9].

4 Conclusions

Thus, vegetation and snow cover exert a significant influence on the soil thermal regime. This impact is crucial for understanding the processes occurring within ecosystems, especially under conditions of climate change. Future research should focus on a more detailed analysis of the effects of different types of vegetation and snow characteristics on soil temperature regimes.

Acknowledgements

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