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Ground thermometric studies at the MSU meteorological observatory site

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Abstract. The paper presents the first results of the drilling and construction of a thermometric well in an open area without natural cover at the site of the MSU meteorological observatory taking core samples from the well. Information is given on the moisture, thermal conductivity, and heat capacity of the ground, as well as on the freezing temperature. The results of meteorological studies and studies of the factors that significantly influence snow cover are also presented.

1 Introduction

According to climate websites (https://climate.copernicus.eu/, https://public.wmo.int/en/media/news/, https://www.nasa.gov/) September 2023 was the warmest September on record, following the warmest August, July and June 2023. In September 2023, the average temperature on Earth will be as follows +16.58°C. It is on 0.87°C higher than normal according to Japanese reanalysis data JRA-55 (https://jra.kishou.go.jp/JRA-55/index_en.html). For the Northern Hemisphere, the anomaly is as follows 0.99°C. Never before in September has the temperature crossed the mark +16 degrees Celsius. Previously, the warmest September was September 2020. Then the temperature was +15.98°C, which is much lower than now. The same temperature anomalies were also observed in Moscow.

The observed climate change has led in particular to an increase in climate contrast, and the increased reduction of summer sea ice in the Arctic has led to increased evaporation from the water surface and more frequent anomalous precipitation. For example, already on 26 October 2023, the first snow fell in the Moscow region. The next day a snow cover with a height of 2 to 6 cm was already formed, and on 28 October the thickness of the snow cover was from 3 cm in the south of the region to 12 cm in the north-east. Such a snow cover usually forms in Moscow only in November. This first unstable snow cover lasted for 5 days and melted on 31 October. However, the following first half of November 2023 was also very warm: The mean monthly temperature in November is as follows -0.5°C (http://www.pogodaiklimat.ru/). The actual temperature of the first half of the month according to observations was as follows 6.2°C (https://rp5.ru/). The deviation from the norm was as follows +6.7°C. The norm of precipitation totals in November: 52 mm. In the first half of the month 48 mm of precipitation fell. This amount is 91% of the norm. Lowest air temperature (0.1°C) was 16 November. Highest air temperature (15.8°C) was on 1

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November. Thus, in Moscow in the first half of November 2023 there was anomalously warm weather, exceeding the November norm on 6.7°C. In general, according to the new climate norms (1991-2020), a steady air temperature transition through the 0°C to negative values occurs in Moscow from 12 November. However, in 2022 this transition occurred on 15 November, and in 2023 it occurred on 17 November. So this year the arrival of meteorological weather in Moscow in autumn 2023 (i.e. the moment when there is a steady transition of average daily temperatures through zero towards negative values) occurred only on 17 November. On 23-24 November snow began to fall intensively. So on 24 November the thickness of the snow cover in Moscow was 8 cm and reached about 15 cm on the morning of 25 November, which is the highest value for 25 November since 2004 and is usually reached by 17 December. The temperature on 24 and 25 November in Moscow was about -6 - -8°C. In the afternoon of 26 the amount of snow did not increase and the temperature rose to -3°C. There was very heavy snowfall on the evening of 26 and the night of 27. On 27 November there was a slight thaw to +2°C, and there was also freezing rain. The thickness of the snow cover on 27 November in Moscow at the VDNH weather station was 21 cm. During the night of 26-27 November, about 16 mm of precipitation fell in Moscow, which is quite a lot.

In general, the date 23-24 November 2023 can be considered the date of snow cover establishment in Moscow in the winter period 2023-2024. For comparison, 15 November 2022 is considered the date of snow cover establishment in Moscow in the winter period 2022-2023. The date of the earliest stable snow cover since 2000. - 29 October 2016. This is followed by 14 November 2001 and 2007, 15 November 2022 and 18 November 2004.

2 Materials and methods

The influence of climate change on the state of permafrost soils is considered in [1-12]. In the Russian Federation, also in recent years, the following is being created **State system** background **monitoring of permafrost conditions.** An experimental system of ground temperature monitoring has been operating for a long time at the MSU meteoobservatory site [13-15]. However, in light of the described rapid climate changes, in autumn 2023, the efforts of staff and students of the Department of Cryolithology and Glaciology and the Laboratory of Snow Avalanches and Mudflows of the MSU Faculty of Geography initiated the drilling of a borehole in the open area without natural cover at the MSU meteorological observatory (Figure 1).

Drilling was carried out with a drilling system manufactured by the Russian drilling equipment manufacturer "Vorovsky Plant". During drilling, soil core was taken and studied in laboratory conditions. The results of the core study are given in the following section

Fig. 1 Drilling a borehole in an open area without natural cover at the MSU meteorological observatory

3 Results and discussions

While drilling a borehole in an open area without natural cover at the MSU meteorological observatory, a soil core was taken and described (Figure 2)

Fig. 2. Soil core from a borehole in an open area without natural cover at the MSU meteorological observatory

The soil core extracted during drilling was analysed in laboratory conditions. The main constituent rock was loam. The mass moisture content (by weighing the original and dried samples), as well as thermal conductivity and heat capacity of the constituent rocks were determined using the KD2Pro device (https://decagon.ru/environment/kd2pro/). The results are plotted in the graphs in Figure 3

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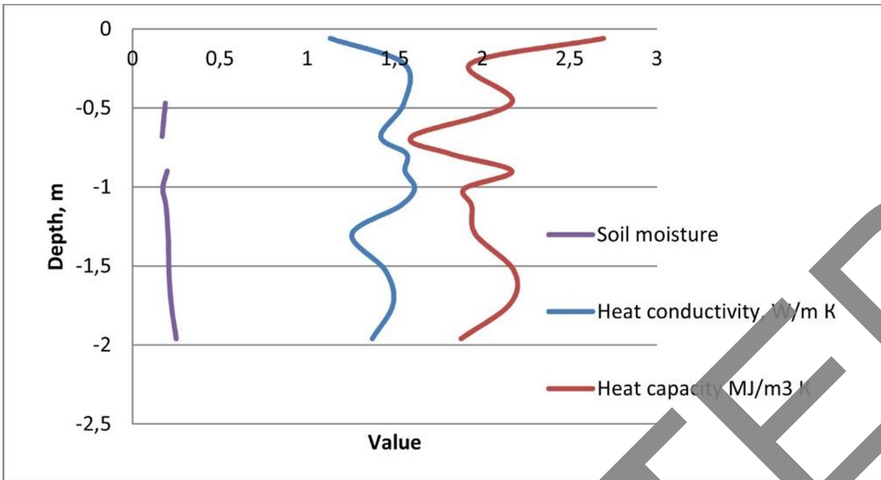

Fig. 3. Moisture content, thermal conductivity and heat capacity of the constituent ground rocks of the core from the borehole in the open area without natural cover at the MSU meteorological observatory

The graph shows that the mass moisture content of the core soil was of the order of 17-20%. The thermal conductivity was 1.2-1.5 W/m K and the heat capacity of the constituent rocks was of the order of 2 MJ/m^3K and, in general, varied quite moderately with depth. The freezing point was also determined for the selected soil samples from the drilled borehole, which turned out to be equal to approx. -2°C (Figure 4).

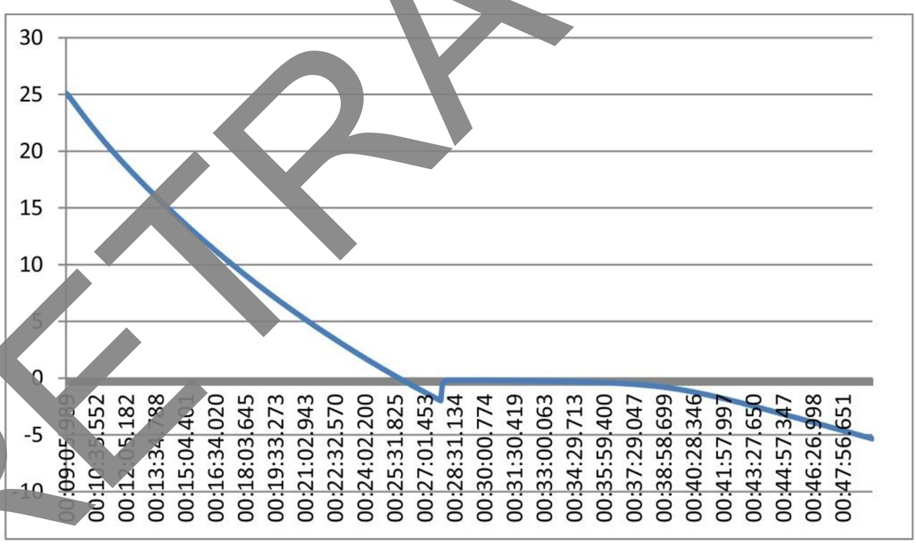

Fig. 4. Freezing temperature of ground rock cores from a borehole in an open area without natural cover at the meteorological observatory of MSU

Ground temperature was also monitored at an open area without natural cover at the MSU meteorological observatory by means of exhaust thermometers. The results of its multi-year averaging are shown in Figure 5.

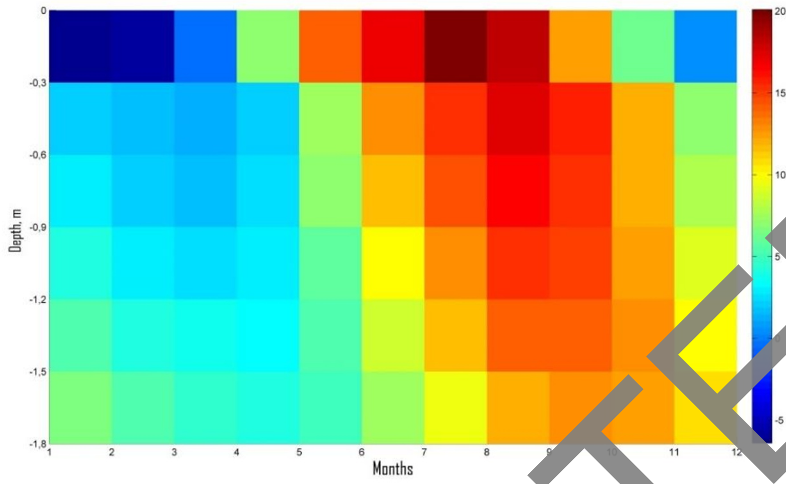

Fig. 5. Annual change in ground temperature at the open area without natural cover at the MSU meteorological observatory (multiyear averaging)

Figure 7 shows that the depth of seasonal freezing in the open area without natural cover at the MSU meteorological observatory is about 30 cm.

4 Conclusion

The works on preparation and drilling of a thermometric borehole, as well as selection and subsequent study and description of the selected soil core, performed at the experimental site without natural cover of the MSU meteorological observatory in autumn 2023 allowed to achieve some results. The values of soil moisture, thermal conductivity and heat capacity were determined, as well as the freezing point of the underlying soil. Information about the soil thermometry and the value of seasonal frost depth was also given. In this way all materials were collected and prepared for thermophysical modelling of ground temperature in the computer program.

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