INFLUENCE OF EXTREME WEATHER CONDITIONS AND SNOW ACCUMULATION REGIME ON GROUND FREEZING DEPTH IN RUSSIA IN WINTER PERIOD 2019/2020

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The climatic factors, such as temperature conditions and snow cover thickness undergo a change and variations. Variations of climatic conditions, snow cover thickness and coupled with it ground freezing depth also leads to permafrost thawing and the damage of constructions and pipelines, the landslides on the slopes. In particular in relation to recent decade's climate alteration at least in the Arctic, the growth of ground temperature and increase of seasonal thawed layer is observed. Summary effect from alteration of air-temperature and snow cover thickness can result in additional few degrees heating (+2+3°C). It is not critical for permanently frozen ground with the temperature of -8-10°C, but for the permanently frozen ground with the temperature of -3-5°C and higher this may lead to thawing and increase of seasonal active layer. As a reason of anomalous warm winter 2019/2020 in Russia, as well as in Europe and USA, is considered non-typical situation in Arctic, where the extremely stable area of low pressure in the vicinity of North Pole was present and which does not let the cold air masses to move away from its borders. This situation resulted in the consequences that on the most of the territory of Russia, USA, Northern Europe and Eastern Canada the temperature of winter months was on few degrees more than usual. And the spring months 2020 in west and central Siberia and in the Russian Arctic was also very hot (figure 1).

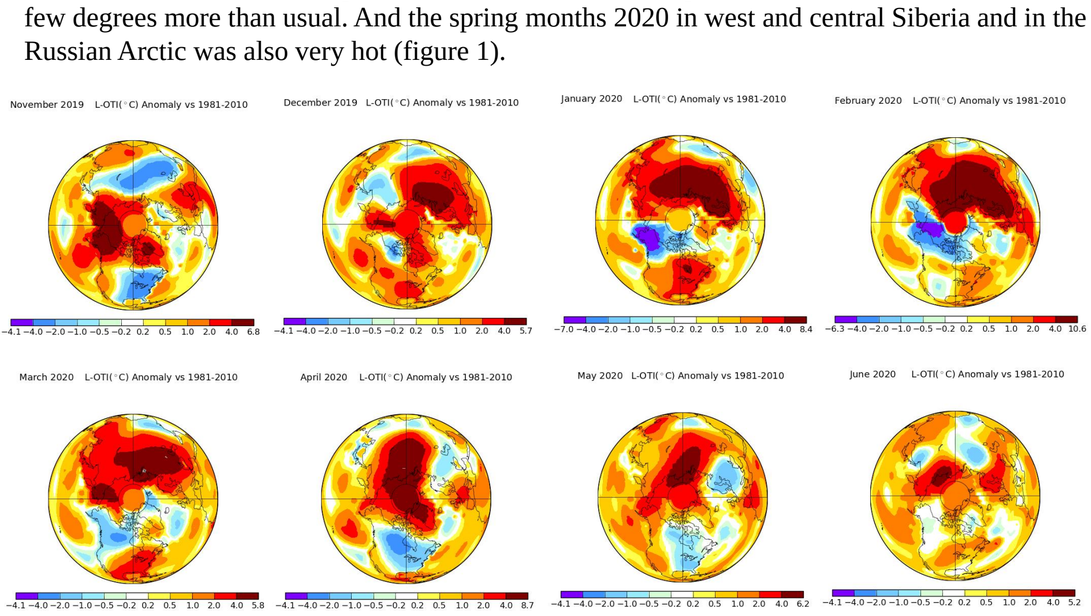


Fig. 1. Anomaly of air temperature in the November, December 2019 and in the first half of 2020 in Northern Hemisphere

According to measurements of the temperature in the borehole in the vicinity of Norilsk, the temperature of the permafrost at a depth of 6 to 18 meters is -2°C. This means that temperature of permafrost there is rather high and the permafrost there is rather vulnerable. And mean annual air temperature according to the Norilsk weather station for 1981-2020 was -8.4°C and had a positive trend (figure 2).

Also at the CALM polygon (Talnah) there the active layer for the time interval from 2005 to 2019 had an average value of 95 cm with an average trend of 1.3 cm increase per year amounting to 90 cm at the beginning of the period and more than 100 cm on average at the present time (figure 3).

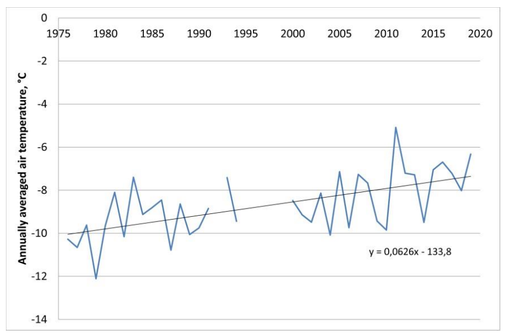


Fig. 2. The annually average air temperature of Norilsk for 1975-2020.

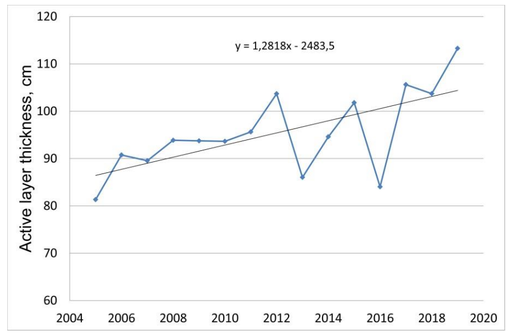


Fig. 3. Active layer thickness at CALM polygon near Norilsk (Talnah).

Particularly the thickness of the active layer at CALM polygon (Talnah) varies from 45-50 cm to 125-150 cm, depending on landscape-specific conditions. The maximum thickness of active-layer is observed at landscapes represented by sparsely-vegetated patterned ground and dry hillocks. The minimum ALT was found in the polygonized peatlands. The maximum three-year grid average ALT is 87.3 cm, with minimum 50 cm, maximum 126.5 cm, and standard deviation is relatively small and does not exceed 15 cm.

According to the Norilsk weather station data the air temperature in Norilsk in November of the winter-spring period 2019/2020 was -20.9°C, with an average norm for 1981-2010 value -20.3°C. In December, it was -20.5°C (with an average norm of -25.2°C), in January it was -19.2°C (with -26.1°C), in February -15.7°C (with -26.7°C), in March -16.5°C (with -20.6°C), in April -2.8°C (with -14°C) in May 3.9°C (with -4.1°C) and in June 11.8°C (with 7.3°C) exceeding the mean monthly temperature norm for 1981-2010 in average for 6°C (Figure 4).

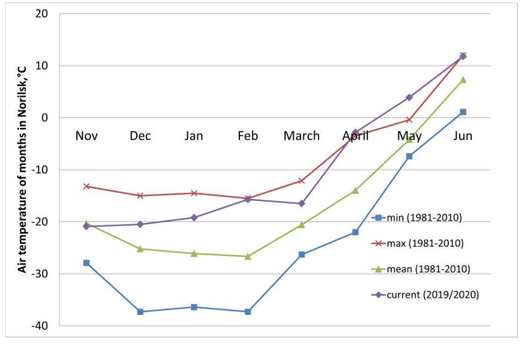


Fig. 4. Mean air temperature in the winter-spring months of 2019/2020 and average, maximum and minimum monthly values for 1981-2010 in Norilsk

RESULTS

-The air temperature in the winter-spring months (November-May) in west and central Siberia and Russian Arctic exceeded the long-term 1981-2010 averaged values on 4-6°C. Due to such warm winter period months 2019/2020, largely increasing in recent decade's amount of snow and snow cover thickness and hot spring months of 2020 in West and Central Siberia and Russian Arctic the winter ground freezing was not very intensive and active layer thickness at the beginning of the summer was rather high. This led to the oil tank construction damage in Norilsk on 29 May 2020 due to the instability of the basement and catastrophic oil spill into the river happened.

In our study, according to the VDNKh weather station data the air temperature in Moscow in November of the winter period 2019/2020 was 1.8°C, compare with an average norm for 1981-2010 value -1.2°C. In December, it was 0.8°C (with an average norm value -5.2°C), in January 0.1°C (with an average norm value -6.5°C), in February -0.3°C (with -6.7°C) and in March 3.8°C (with -1.0°C). So the exceeding of the average norm values for 1981-2010 were 3°C in November, 6°C in December, 6.6°C in January, 6.4°C in February, 4.8°C in March.

The amount of precipitation according to the VDNKh weather station in Moscow in the winter season (November-March) of 2019/2020 was slightly less than the norm (1981-2010). In November 2019 it was 35 mm of precipitation with an average norm for 1981-2010 55 mm. In December it was 33 mm with an average norm of 52 mm, in January 55 mm with an average norm of 52 mm, in February 40 mm with an average norm of 41 mm and in March 45 mm with the norm of 35 mm.

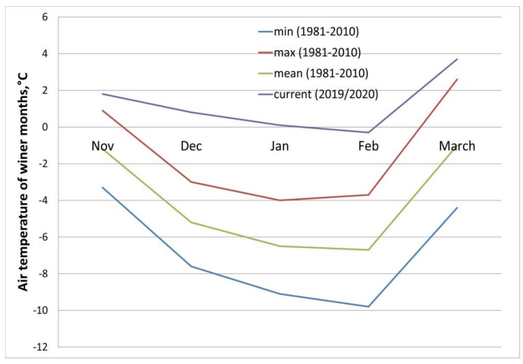


Fig. 5. Variations of air temperature in winter months of 2019/2020 in Moscow

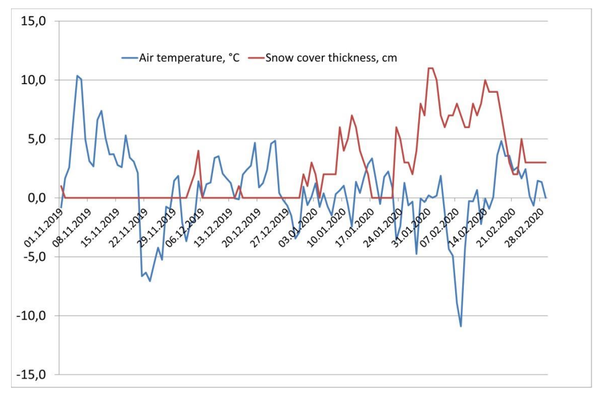


Fig. 6. Variations of air temperature and snow cover thickness of the 2019/2020 winter period.

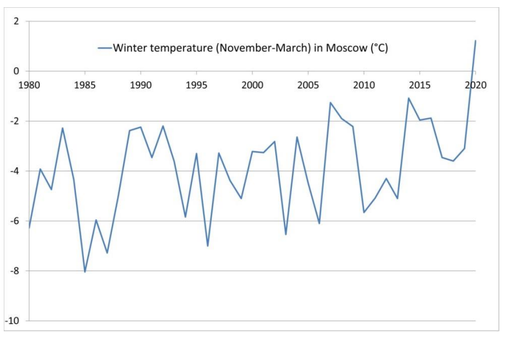


Fig. 7. Variations of air temperature in winter seasons 1980-2020 in Moscow

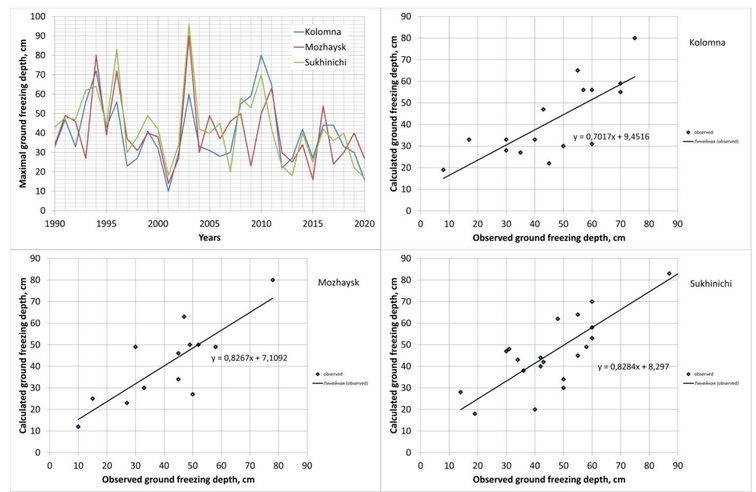
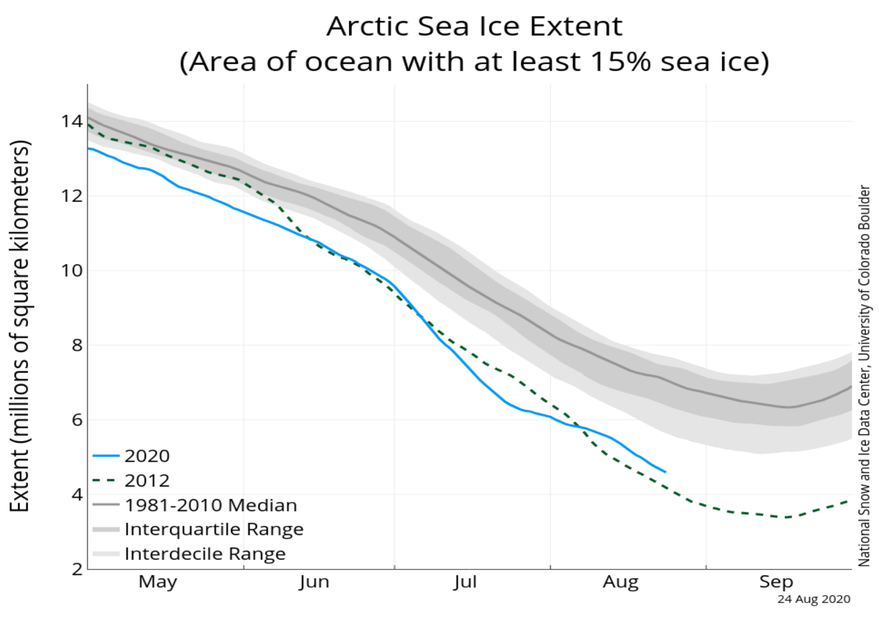


Fig. 8. Ground freezing depth variations in Moscow region and correlation of observed and estimated ground freezing depth in 1990-2020

RESULTS:

-Due to extremely warm weather conditions the onset of snow cover, in particular in Moscow and the Moscow Region in the winter season 2019/2020 finally occurred only on January 23 (although it was also temporary present from December 30 to January 18), and it was constantly exposed to thaws, and its thickness did not exceed 11 cm. These values are record-breaking, since only in the winter of 2006/2007, according to the data of the VDNKh weather station, the onset of snow cover was only on January 21 and in the winter of 2013/14 the maximum snow cover thickness for the season reached only 15 cm.

-Despite of such extremely warm weather conditions (almost all months had positive monthly averaged temperature), ground freezing in Moscow region in winter period 2019/2020 also developed although a bit weaker than comparatively to the other years. This happened because of presence of extremely thin isolating snow cover and some cold days. This was verified by constructed calculating scheme for the ground freezing depth.



RESULTS

-Due to the hot spring months and June 2020 the increase of the natural fires in Arctic in the beginning of July 2020 got wide spread.

-The sea ice area in the Laptev Sea was also at an all-time low for the end of June 2020, as it was in the entire Arctic sector of Russia. The area of sea ice in the Arctic Ocean for the end of June 2020 was 260,000 km2 less than in the 2010s, 930,000 km2 less than in the 2000s, 1,540,000 km2 less than in the 1990s, and 2,150,000 km2 less than in the 1980s.