Влияние экстремальных погодных условий и режима снегонакопления на промерзание грунта в России зимой 2019/2020

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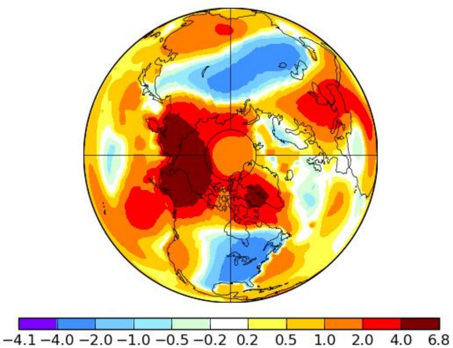
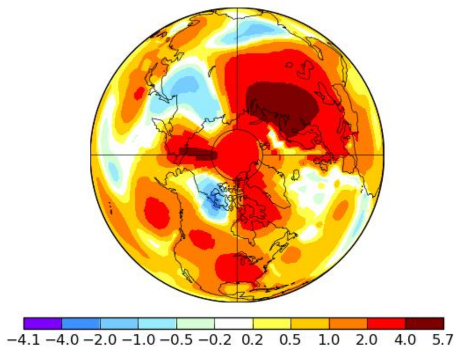
Anomaly of air temperature in the November, December 2019 and in the first half of 2020 in Northern Hemisphere

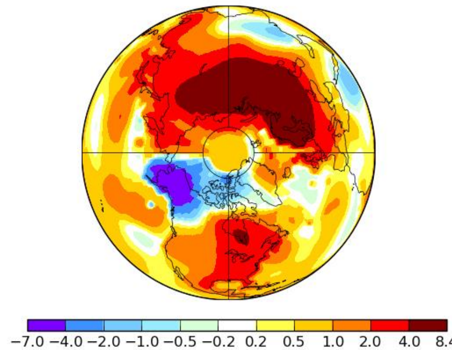
November 2019 L-OTI(°C) Anomaly vs 1981-2010



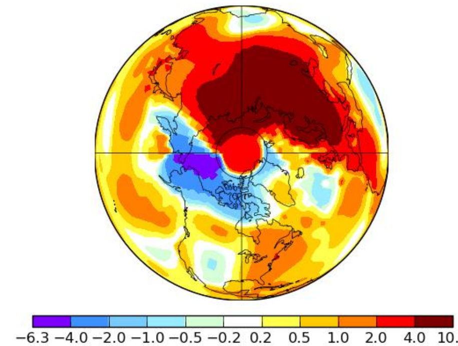
December 2019 L-OTI(°C) Anomaly vs 1981-2010



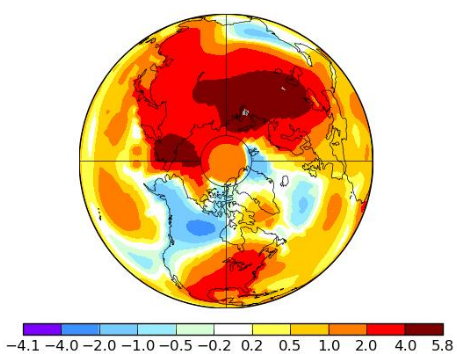
January 2020 L-OTI(°C) Anomaly vs 1981-2010



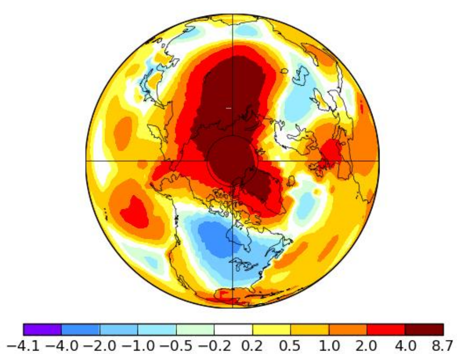
February 2020 L-OTI(°C) Anomaly vs 1981-2010



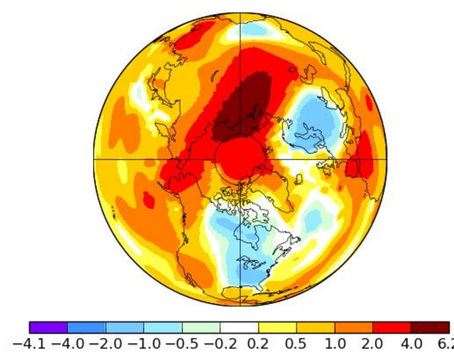
March 2020 L-OTI(°C) Anomaly vs 1981-2010



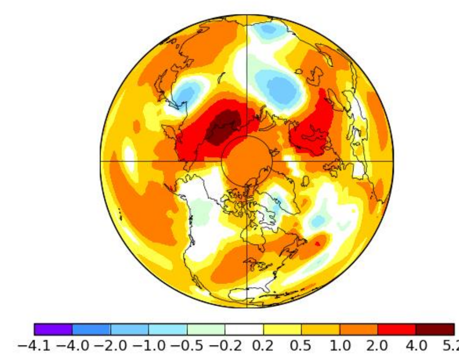
April 2020 L-OTI(°C) Anomaly vs 1981-2010



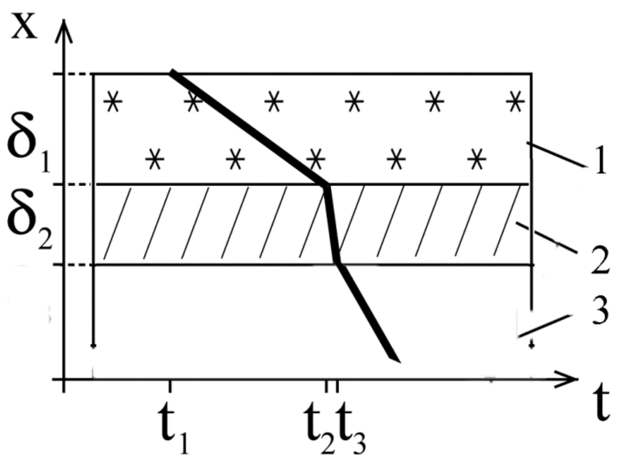
May 2020 L-OTI(°C) Anomaly vs 1981-2010



June 2020 L-OTI(°C) Anomaly vs 1981-2010



Stepwise calculating scheme



Calculation scheme considers ground freezing (3) below the massif of frozen ground (2), covered with snow cover (1) in winter season on the base of daily data on air temperature and snow cover thickness. The equation of heat balance is written as: $F_1 = cLV + F_2$, where

F_1 – is heat outflow through snow cover and frozen ground from ground freezing interface (W/m^2);

cLV – heat value for phase transition in the ground,

c -ground moisture content (1-4 kg/cm*m^2),

L - energy of H_2O phase transition (335 kJ/kg), V - rate of movement of ground freezing interface (cm/s);

F_2 – heat outflow for cooling of thawed ground in front of ground freezing interface (W/m^2).

Heat flux is expressed according to Fourier law by means of temperature gradient and heat conductivity as $F = \lambda$ (grad T). Heat conductivity and heat flux through combination of two media (snow and frozen ground) can be expressed as:

$$F_1 = \lambda \frac{\Delta T}{\Delta x} = \frac{\Delta T}{\left(\frac{\Delta x_s}{\lambda_s} + \frac{\Delta x_{fg}}{\lambda_{fg}} \right)} = \frac{T_{air}}{\left(\frac{h_s}{\lambda_s} + \frac{l_{fg}}{\lambda_{fg}} \right)}$$

Here T_{air} – air temperature,

h_s и l_{fg} – snow cover thickness and ground freezing depth, and

λ_s и λ_{fg} – heat conductivity of snow and frozen ground.

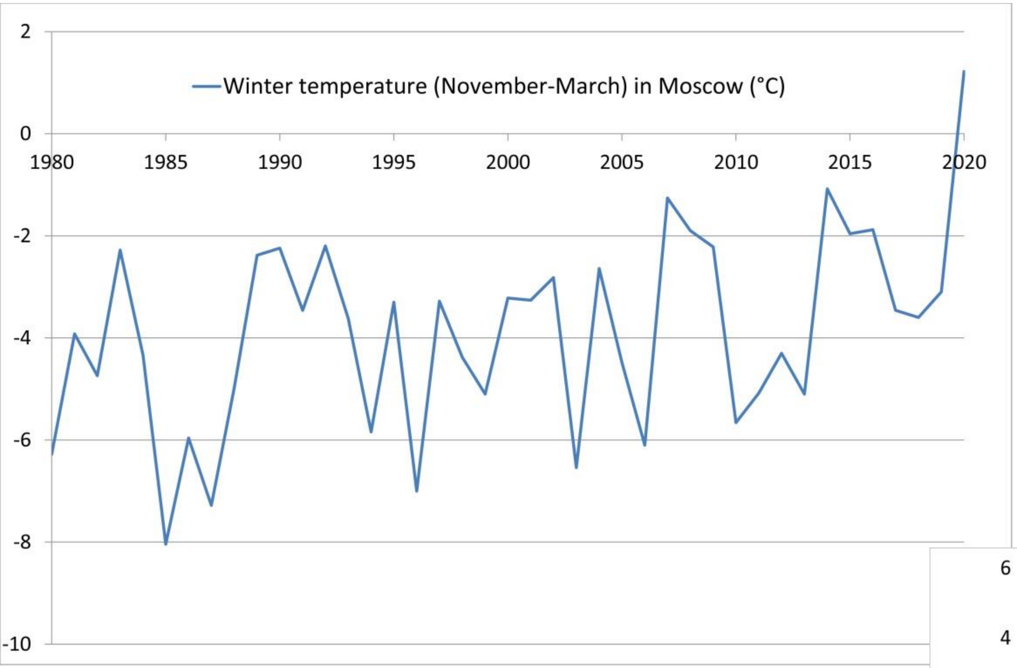
Stepwise calculating scheme

It was supposed, that on the depth of 10 m in ground there is a point of zero annual temperature oscillation with temperature value T_0 about 3°C. That is why

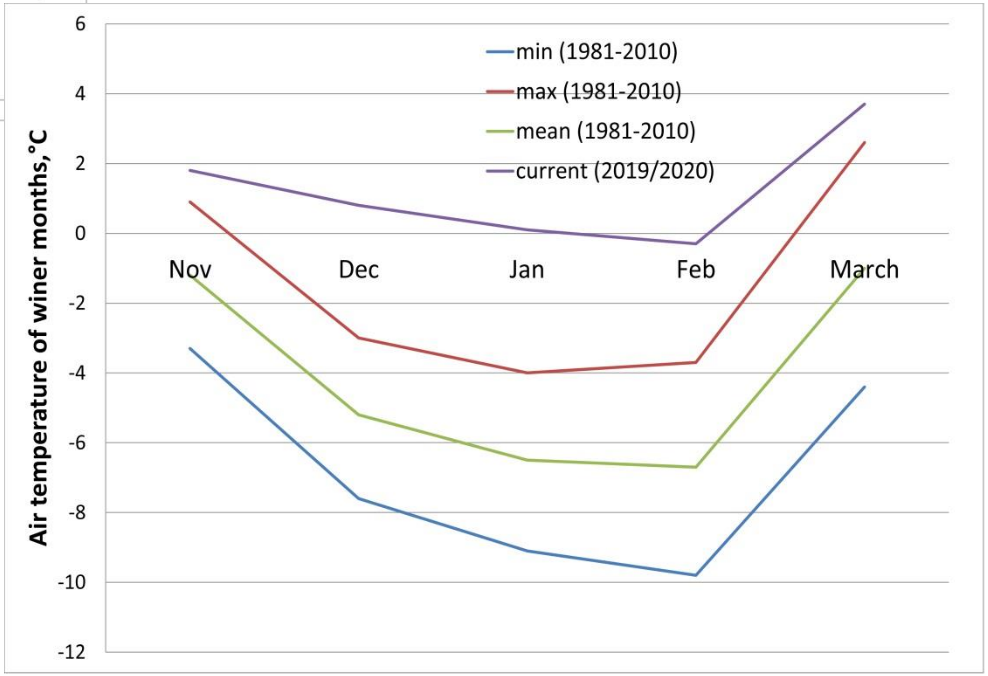
$$F_2 = \lambda_{thg} \frac{\Delta T}{\Delta x} = \lambda_{thg} \frac{T_0}{10 - l_{fg}}$$

Calculations were done with the step-size of one day. For initial conditions it was supposed that frozen ground thickness l_{fg} was equal 0.5 cm. For each time step (for each day) the rate of movement of freezing interface V and the value frozen ground thickness l_{fg} for the next day (time-step) were calculated. Averaged heat conductivity of snow was assumed to be equal 0.18 W/m °C. Averaged heat conductivity of thawed and frozen ground were assumed to be equal 1.5 and 1.8 W/m °C.

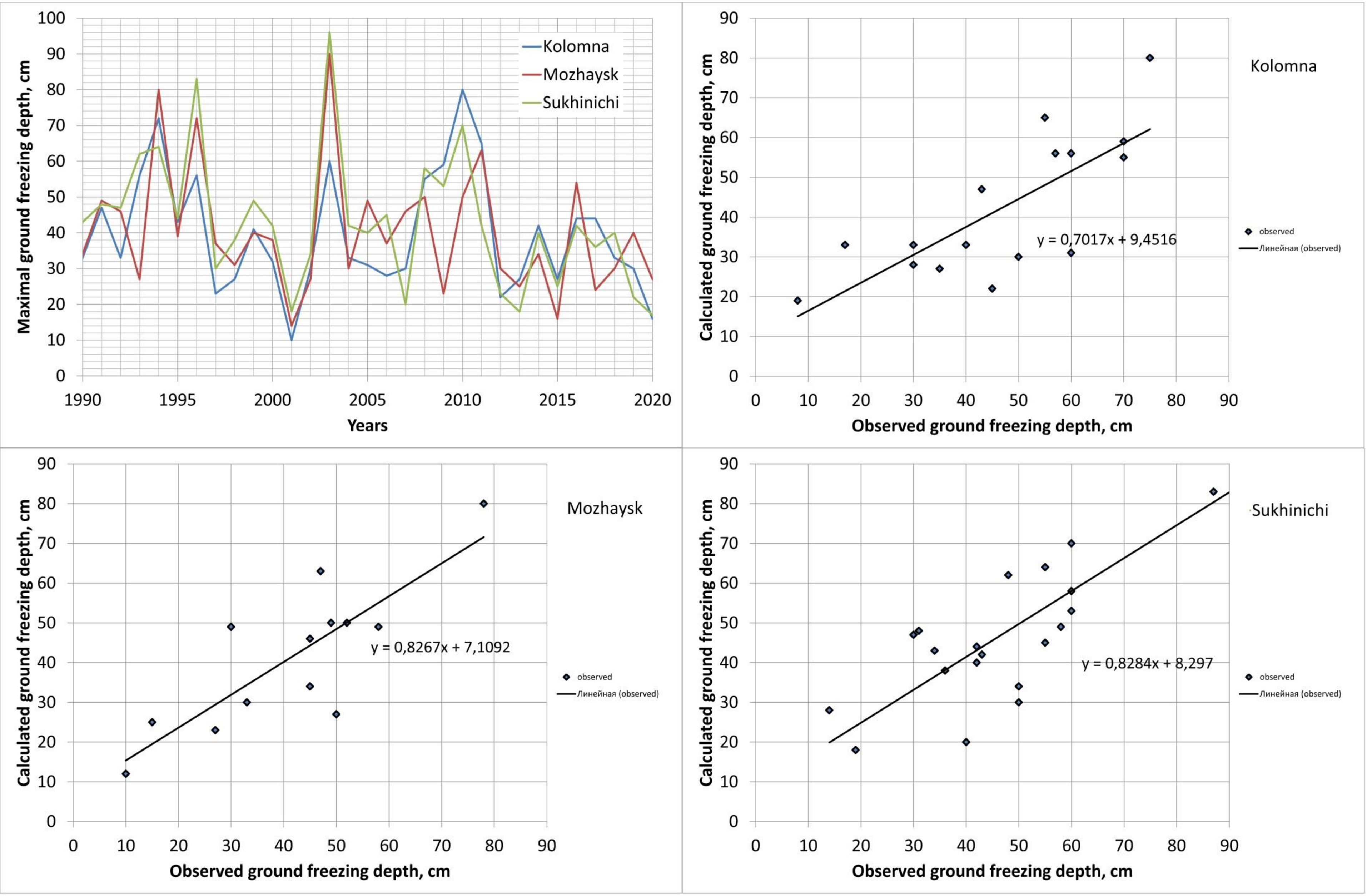
Variations of air temperature in winter seasons 1980-2020 in Moscow



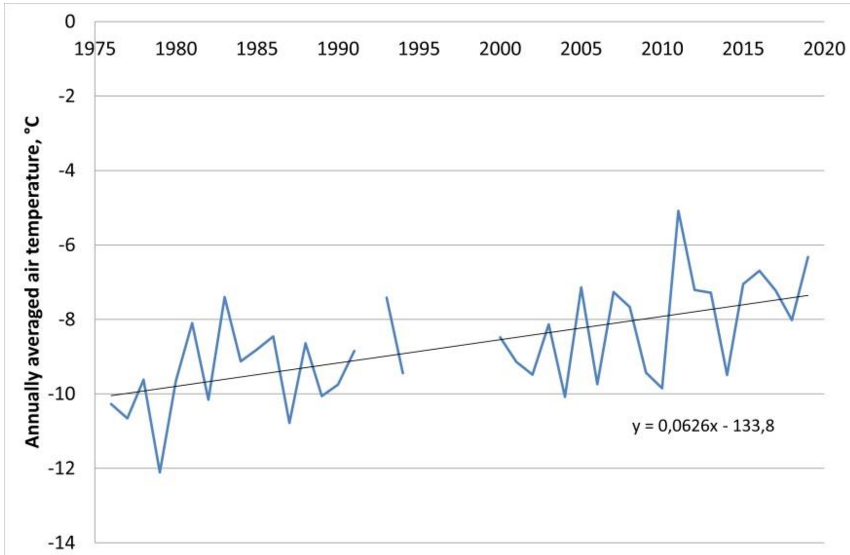
Variations of air temperature in winter months of 2019/2020 in Moscow



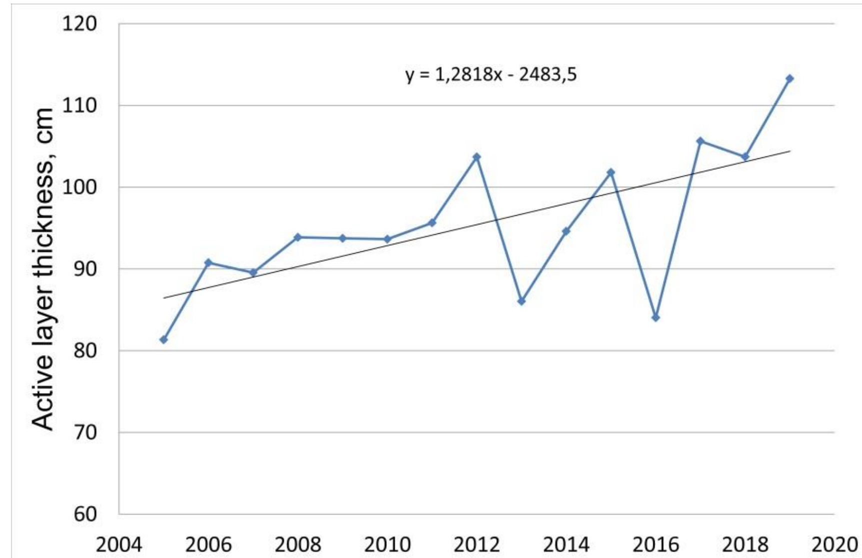
Ground freezing depth variations in Moscow region and correlation of observed and estimated ground freezing depth in 1990-2020

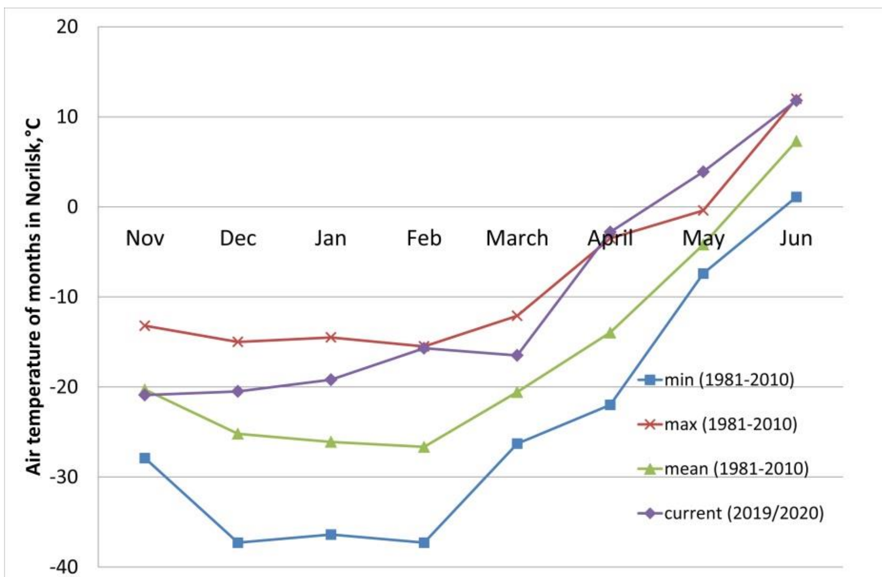


The annually average air temperature of Norilsk for 1975-2020.



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





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

RESULTS AND CONCLUSION 1

-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 AND CONCLUSION 2

-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 [9] 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.

-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.