Tipping points for permafrost thawing in the Yamal Peninsula region under current global warming

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Problem of permafrost thawing under global warming is a one of key climatic problems [1]. The Yamal Peninsula region in the Arctic covered by permafrost is characterized by high sensitivity of surface temperature under global climate changes [2]. There is a high risk for permafrost melting under continuing global and regional warming.

Here, tipping points for permafrost thawing in the Yamal Peninsula region are estimated using data [3] for the annual-mean temperature at the surface from.

Figure 1a shows interannual variations of the temperature T at the surface in Marre Sale on Yamal Peninsula during past half a century (1974-2023). Linear trend of T for the period 1974-2023 was estimated to be equal to dT/dt = 0.85 (±0.16) K/decade with coefficient of correlation r = 0.61. According to this trend we can expect the achievement of T = 0°C (as a necessary conditions for permafrost thawing) after year 2080 (t_{cr}).

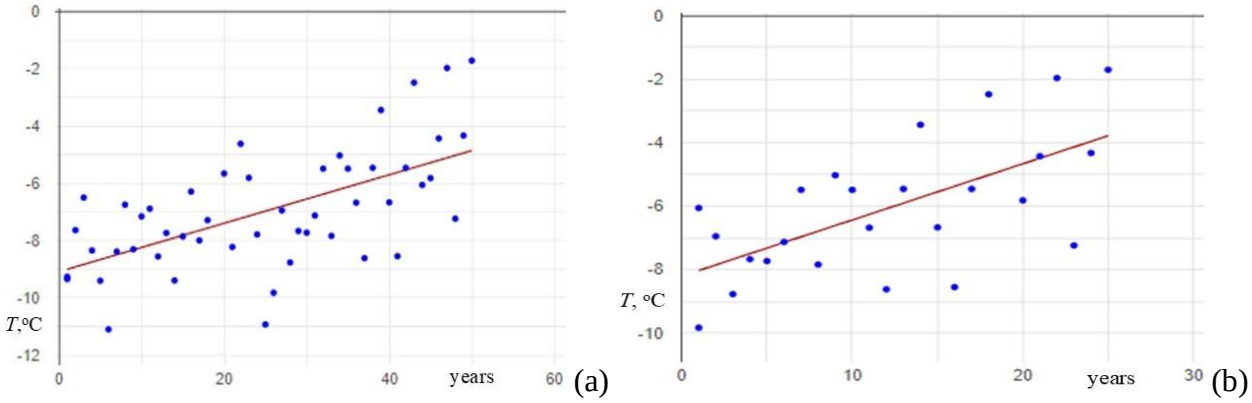

Fig. 1. Interannual variations (relative to 1973) of the temperature at the surface in Marre Sale during 1974-2023 (a) and 1999-2023 (b). Straight line characterizes linear regression.

Figure 1a reveals nonlinear dependence of temperature variations on time. Figure 1b shows interannual variations of the temperature at the surface in Marre Sale on Yamal Peninsula for the period 1999-2023. Linear trend of T for the period 1999-2023 was estimated to be equal to dT/dt = 1.77 (±0.46) K/decade with coefficient of correlation r = 0.63. The trend of T for 1999-2023 is twice as large as for 1974-2023 as a whole. According to this trend we can expect the achievement of T = 0°C after year t_{cr} = 2045.

Also, variations of T in Marre Sale in dependence on changes in global temperature at the surface T_{gl} for the period 1999-2023 (Fig. 2a) were analyzed with the use of corresponding According to corresponding linear regression

$$T = a + b\,T_{gl}. \qquad (1)$$

The coefficient of regression b in (1) can be used as an estimate for the sensitivity parameter $dT/dT_{gl} = 7.53$ (±1.60) with the coefficient of correlation $r = 0.70$. This result means that annual-mean temperature in Marre Sale is rising during past decades (1999-2023) more than 7.5 times faster than the global mean.

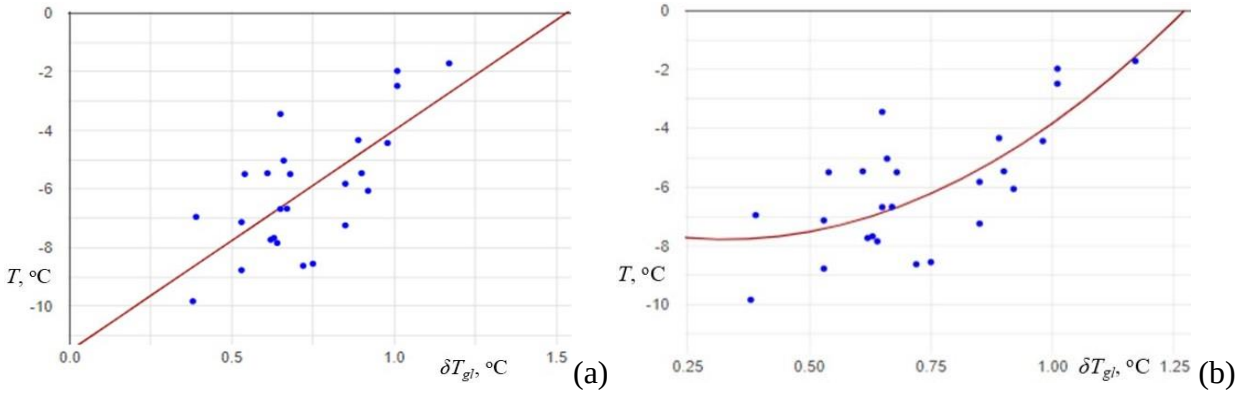

Fig. 2. Annual-mean temperature at the surface in Marre Sale in dependence on anomalies (relative to 1951-1980) of annual-mean global temperature at the surface δTgl with corresponding linear (a) and quadratic (b) approximations.

According to obtained results we can expect the achievement of T = 0°C at the T_{gl} anomaly $\delta T_{gl\text{-}cr}$ = 1.53K relative 1951-1980 or $\delta T_{gl\text{-}cr}$ = 1.76K relative 1850-1900. This value is between 1.5K and 2K – critical levels according to the Paris Agreement on global climate change.

It should be noted that the value of δT_{gl} was equal to 1.17K relative 1951-1980 – only 0.36K less. The trend of T_{gl} for the period 1999-2023 was estimated to be equal to 0.20 (±0.04) K/decade (with r = 0.77). According to these estimates we cand expect the achievement of critical annual-mean conditions T = 0°C in Marre Sale within next two decades.

In the case of parabolic approximation $T(T_{gl})$ (Fig. 2b) we can expect the achievement of T = 0°C at the T_{gl} anomaly $\delta T_{gl\text{-}cr}$ = 1.27K relative 1951-1980 or $\delta T_{gl\text{-}cr}$ = 1.50K relative 1850-1900. This value is larger than δT_{gl} in 2023 less on 0.1K and corresponds to the lower critical condition 1.5K in the Paris Agreement on global climate change.

These results were obtained within the framework of the RSF project 24-17-00211.

References

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2. Mokhov I.I. Climate change: Causes, risks, consequences, and problems of adaptation and regulation. *Herald of the Russian Academy of Sciences, 2022, Vol. 92, No. 1, pp. 1–11.*
3. https://data.giss.nasa.gov/gistemp/