Regional climate changes in the Holocene according to model estimates

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Regional climatic changes in the high latitudes of the Northern Hemisphere impact the thermal regime of permafrost, resulting in disruption of permafrost zone stability. This instability might result in adverse economical, environmental and social consequences, such as disruptions of communication and power lines, as well as of oil and gas pipelines. Moreover, the development of destructive geomorphological processes leads to subsidence, water logging and release of greenhouse gases, such as carbon dioxide and methane. The exclusion of these gases from the biogeochemical circulation chain causes an increase of their emissions and, therefore, strengthening of the positive feedback between the permafrost ecosystems and the atmosphere. Additionally, the dissociation of relict gas hydrates generates gas emissions that can also contribute to regional climatic changes.

The growth of near-surface temperature affects the thermal regime of permafrost. In this research, the warmest over the last 10 thousand years periods are analyzed: the Holocene optimum (about 6 thousand years ago) and the present time period (Fig.1.). Fig. 2 (a) presents the estimates of the linear trend of average annual surface temperature for northern Eurasia according to the ERA-Interim reanalysis for 1991-2016.

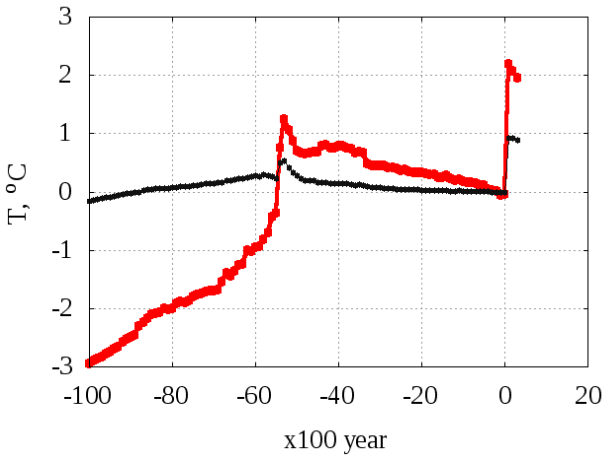

Fig. 1. Anomalies of the global (black line) and regional (north of Western Siberia) (red line) surface temperature according to CLIMBER-2 [1].

Maximum near-surface warming trends were obtained for the northern regions of Western Siberia. According to observations for the period 1979-2014, the growth rate of air temperature in the permafrost regions is 2.5 times higher than the global warming rate over this period [2]. The spatial heterogeneity of the obtained trend estimates is revealed. In particular, the regions with negative trends are observed. The spatial distribution of the surface air temperature trend is compared to the trend of the temperature in the upper 3 m of permafrost, calculated with the model of heat transfer in permafrost [3] using the data of the global climate models of the CMIP5 project (CSIRO-Mk3-6-0, GISS-E2-R, IPSL-CM5A-LR, MIROC-ESM). The strong correlation of the maximum trends (more than 0.03–0.04 °C / year) of the surface air temperature and the permafrost

temperature in the northern part of Western Siberia is revealed. The trend of the surface temperature in the winter and autumn seasons is 0.04 and 0.05 °C / year.

In order to compare the current climatic conditions of the Yamal Peninsula and its adjacent areas with the Holocene optimum, the surface temperature according to the ensemble of global climate models of the international project PMIP3 - Paleoclimate Modeling Intercomparison Project Phase III (https://pmip3.lsce.ipsl.fr) is analyzed.

(a) (b)

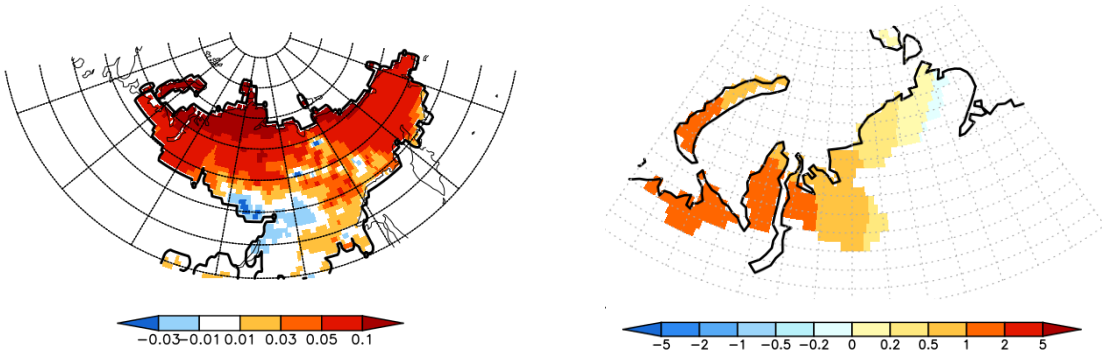

Fig. 2. (a) Trend of surface temperature (°C / year) for the regions of the northern Eurasia permafrost according to the ERA-Interim reanalysis for 1991-2016. (b) The difference in summer surface temperature (°C) in 2009–2013 and in the Holocene optimum according to calculations with an ensemble of climate models.

The average difference in surface air temperatures in 2009–2013 and in the Holocene optimum for the Yamal Peninsula by the ensemble of model calculations is obtained equal to 1.2 ± 0.8 °C. According to the model results, modern warming in the north of Western Siberia already exceeds that of the Holocene optimum. According to [4], in recent decades there has been a rapid increase in the summer temperature in Yamal. According to the data (acquired in this research), the positive temperature anomalies already exceeded the temperature anomalies of the Holocene optimum even at the beginning of the XXI century.

Acknowledgments. This work was supported by the Russian Foundation for Basic Research (17-05-00561, 18-05-60111, 19-05-00409); the Presidium of the Russian Academy of Sciences.

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