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# Predictive modelling of terrestrial and sub-aquatic permafrost in Northern Eurasia: implications for the global carbon cycle and climate

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Permafrost contains about 1670 Gt of carbon, which is nearly one half of the global soil carbon pool. The concept of "methane bomb" associated with the rapid release of significant amounts of methane from thawing permafrost and amplification of the global climate change has been widely discussed in the scientific literature. Particular concerns are associated with thawing Siberian wetlands, and with the East Siberian Arctic Shelf (ESAS). Recent observations indicate high concentrations of methane over ESAS, up to 7-8 ppm at selected locations over the Laptev sea, while the latitude-mean atmospheric methane concentration equals 1.85 ppm. Some researchers attribute it to the increased gas permeability of thawing sub-sea permafrost, destabilization of hydrates and enhanced venting of methane to the atmosphere trough taliks. In this study we use mathematical modelling to calculate the past, present and future state of the Northern Eurasian terrestrial and sub-aquatic permafrost, to quantify the contribution to the global methane balance, and to evaluate the climate feedback.

GIS analysis of small-scale digital topographic maps indicated that the total area of Siberian wetlands is approximately 0.7 million km$^2$, of which ca 0.35 mln km$^2$ are located in permafrost regions. Estimated net flux of methane from the frozen wetlands under the current climatic conditions is about 28.5 Mt/y. According to our model results, projected by the mid-21st century changes in the volume of the seasonally thawing organic-rich soils and higher soil temperatures may increase the methane flux from Siberian frozen wetlands by 6-10 Mt/y, which is likely to increase the atmospheric concentration by 100 Mt and lead to ca. 0.01 °C global temperature rise.

We used a comprehensive model forced with the transient regional climatic scenario to simulate the dynamics of permafrost and the depth to the boundaries of hydrate stability zone (HSZ) at ESAS over the period from the last glacial maximum 18-20 Ky b.p. up to the end of the millennium. The model is based on the heat transfer equation and explicitly accounts for the effect of salt diffusion in the bottom sediments by coupling the thermal and mass fluxes. We used a climate scenario suggesting that at the time of inundation (ca 8 Ky b.p.) the top sediment layer warmed by ca. 12 °C from -13.5 °C (mean annual air temperature) to -1.5 °C (bottom water temperature). Temperature was set to this constant value until 1985. Since then in accord with modern observations we imposed 0.09°C/year trend until 2100, and afterwards prescribed the temperature to constant value of 11.5 °C. The rate of temperature change in the 21st century in this schematic scenario by far exceeds all IPCC projections. It has been made intentionally to explore the likelihood of the so-called "methane bomb" concept under most favourable, though highly unrealistic, climate conditions.

Ultimately, our results do not support this hypothesis indicating that enhanced concentrations of atmospheric methane at ESAS are not related to recent climatic changes. Our main conclusion is that in the following 1000 years permafrost layer characterized by near-zero gas permeability will remain at ESAS above the HSZ preventing the massive escape of methane to the atmosphere except for the fault zones, where it seeps already under the current conditions.

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