Increasing carbon and nitrogen stocks in active layer under permafrost thawing

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Ongoing and projected warming is most pronounced in the northern high latitudes. It can result in changes in the thermal and hydrological conditions of permafrost, seasonal dynamics and spatial distribution of plant communities in ecosystems and initiate natural processes with negative consequences for infrastructure of settled territories. The total increase of the mean permafrost temperature and thickness of the thawed layer above permafrost can cause extensive settlement of the ground surface and activate some destructive geocriological processes. Soils in the high latitudes are expected to respond strongly to climate change, but still little is known about associated carbon and nitrogen variability. Thawing of permafrost soils and increase of active layer thickness can intensify a decay of the organic matter and lead to an increase of greenhouse gases emission from soil to the atmosphere that, in turn, reinforces the global warming. These processes can essentially change dynamics of carbon and nitrogen fluxes in ecosystems of the polar regions.

Main characteristics of permafrost using numerical scheme of heat and moisture transfer in the atmosphere-underlying surface-soil accounting for dynamics of frozen and thaw layers boundaries with water phase changes [1] are obtained. External atmospheric forcing for this scheme is given for the period of 2001-2100 according to realized the SRES A1B scenario using the climate models ensemble from the WCRP CMIP3 Multi-Model Database. By the late 21st century, the increase in annual mean air temperature reaches 5-6ºC in the high latitudes of Western Siberia and Chukotka (Fig. 1a).

a b

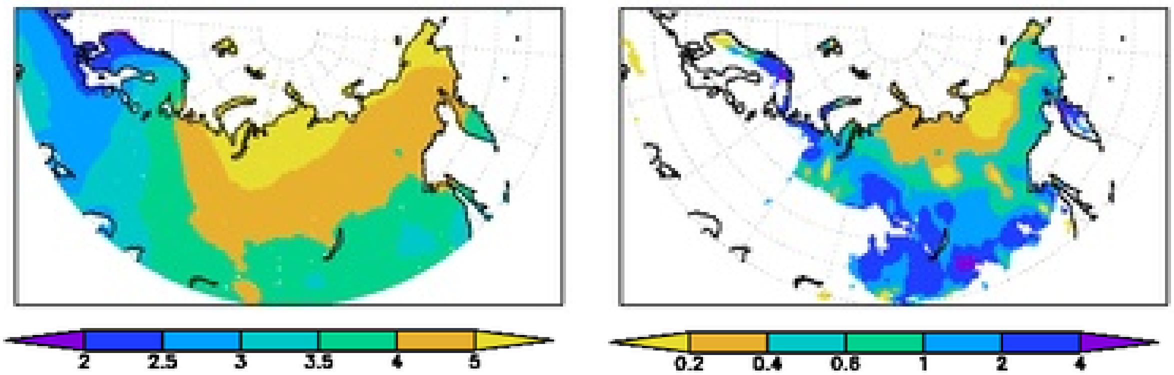

Figure 1. Change in annual mean air temperature, ºC (a) and thaw depth, m (b) of Northern Eurasia for 2091-2100 relative to 2001-2010.

The annual warming by 2100 equals 3-5 ºC in Eastern Siberia and 2-3ºC in Nothern Europe. In winter, the spatial structure of the air temperature is similar to annual mean changes, but with strongly warming reaching 6 ºC in the Western Siberia. The warming is generally larger in winter than in summer.

For this climate scenario, depths of seasonal thaw and taliks in regions occupied by permafrost in 21st century are calculated. Maximal changes (3-4 m) of melted layer depth due to talik formation are expected at the southern boundary of Eurasian permafrost in the end of the 21st century (Fig. 1b). According to be obtained estimates, these changes amount to 2-3 m in the northern part of the Western Siberia and in the Baikal region, while they are expected about 0.2-0.3 m in the northern part of the Eastern Siberia. During the last 20 to 30 years of observations the increases in talik thickness range from 0.2 to 6.7 m in all geocryological zones of the northern European Russia [2].

Increase of melted layer depth may involve carbon and nitrogen stored in the permafrost in the global biogeochemical cycle. The soil carbon and nitrogen concentration distribution are taken from ORNL DAAC data set [3]. According to the model calculations, the carbon concentrations will increase substantially and exceed 6-8 kg/m2 in the southern permafrost region by 2100 (Fig. 2a). This scenario is also valid for nitrogen concentration (Fig. 2b).

a b

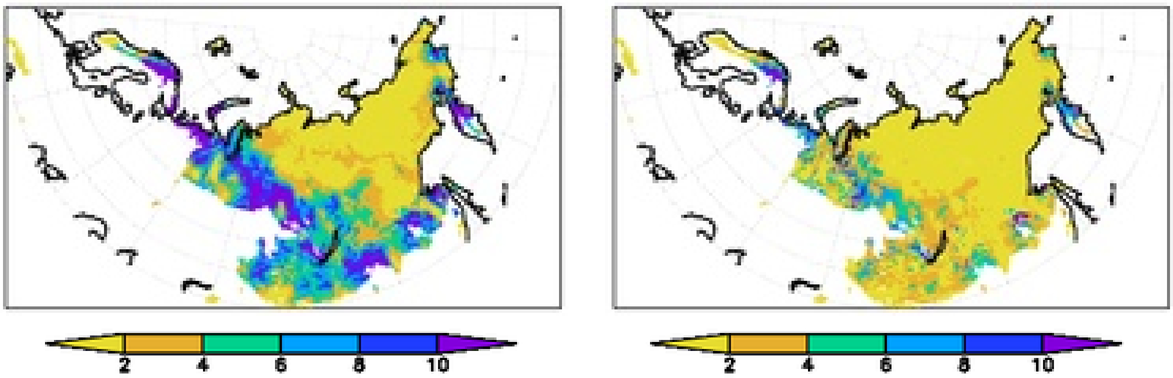

Figure 2. Change of the carbon (a) and nitrogen (b) concentrations (kg/m^2) in frozen soils of Northern Eurasia for 2091-2100 relative to 2001-2010 by thawing.

Carbon and nitrogen storage in the active layer of the northern Euroasian permafrost in the beginning of the 21st century is estimated to be 89 GtC and 41 GtN respectively. Increase of the carbon storage due to the permafrost melt is estimated to be about 60%. Soil carbon changes under the process of edoma thaw are estimated to be 5.4 GtC to the end of the 21st century while the nitrogen increase can amount to 25 GtN. These results compare well with the estimates by [4].

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