Geophysical Research Abstracts,
Vol. 11, EGU2009-142, 2009
EGU General Assembly 2009

Methane emission from Russian frozen wetlands under conditions of climate change

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There is growing evidence that the climate change will have significant impact on permafrost, leading to warming, thawing, and disappearance of the frozen ground. Arctic soils contain 14%-30% of all the carbon stored in soils worldwide, many of which is accumulated in the Arctic wetlands (Anisimov & Reneva 2006). Wetlands occupy almost 2 million km^2 in the circumpolar region, contain about 50 Gt C, and because of the high groundwater levels favour the production of methane in the anaerobic carbon-rich soil layer (Anisimov et al 2005). Methane has 21-times stronger greenhouse effect than the equal amount of CO_2, and there are growing concerns that enhanced CH_4 emission may have significant effect on the global radiative forcing. The goal of our study was to estimate the potential increase in the methane emission from Russian frozen wetlands under the projected for the mid-21st century climatic conditions and to evaluate the effect it may have on global radiative forcing.

We used digital geographically referenced contours of Russian wetlands from 1:1,000,000-scale topographic maps to calculate the total area (350 000 km^2) and the fraction of land they occupy in the nodes of 0.5 by 0.5 degree lat/long regular grid spanning permafrost regions. These data were overlaid with the results from predictive permafrost model (Anisimov & Belolutskaia 2003, Anisimov et al 1999) forced by CCC, HadCM3, GFDL, NCAR climatic projections for 2050 under B1 emission scenario (ref. http://ipcc-ddc.cru.uea.ac.uk/ and http://igloo.atmos.uiuc.edu/IPCC/). Ultimately, we calculated the increase in the amount of organic material that may potentially become available for decomposition due to deeper seasonal thawing of wetlands in the Russian part of Arctic. Following (Christensen et al 2003a, Christensen et al 2003b) we hypothesised that the temperature and substrate availability combined explain almost entirely the variations in mean annual methane emissions. We used the results of numerous calculations with the full-scale carbon model simulating a large variety of soil and temperature conditions to derive a simple parameterization that links the relative changes of methane flux with soil temperature and active layer thickness:

$$J_2/J_1 = \exp 0.1(T_2 - T_1) \quad \sqrt{Hd2/Hd1},$$

where J – methane flux, T – ground temperature, H_d – thaw depth, subscripts 1 and 2 designate the baseline and future climatic conditions current and the future time slices.

Our results for the mid-21stcentury indicate that the annual emission of methane from Russian permafrost region may increase by 20% – 40% over most of the area, and by 50% – 80% in the northernmost locations, which corresponds to 6–8 Mt y^{-1}. Given that the average residence time of methane in the atmosphere is 12 years, and assuming that other sinks and sources remain unchanged, by the mid-21st century the additional annual 6–8 Mt source due to thawing of permafrost may increase the overall amount of atmospheric methane by approximately 100 Mt, or 0.04 ppm. The sensitivity of the global temperature to 1 ppm of atmospheric methane is approximately 0.3 ^{o}C (Ramaswamy 2001), and thus the additional radiative forcing resulting from such an increase may raise the global mean annual air temperature by 0.012 ^{o}C.

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