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Polar amplification of climate change through release of greenhouse gases from thawing permafrost

1 O. Anisimov, S. Reneva

State Hydrological Institute, St.Petersburg, Russia (oleg@OA7661.spb.edu)

Large uncertainties exist in quantifying the feedbacks to the global climate system in the circumpolar region. Currently Arctic and sub-Arctic have near-zero annual balance of carbon in the form of CO2, however they contribute to the radiative forcing through emission of methane. Even in tundra areas that are net sinks of carbon, significant emissions of methane lead to positive forcing since it has 21-times stronger greenhouse effect than the equal amount of CO2. Models project that the northern circumpolar region is likely to become a weak sink of carbon during future warming, while the changing balance between methane and carbon dioxide emissions will govern the net radiative forcing. The goal of this study is to evaluate the potential changes of methane emission from the thawing permafrost under the projected for the future climatic conditions.

Arctic soils contain approximately 455 Gt C, or 14% of the global soil carbon, of which about 50Gt C are accumulated in the Arctic wetlands. Warming and deeper seasonal thawing of the Arctic wetlands as well as the soil drying/wetting are main factors controlling the future emission of methane. We used the GCM-based climatic projections for the mid-21st century, permafrost and soil carbon models, and digital contours of 112,520 wetlands to evaluate the potential changes in the emission of methane in the Russian Arctic.

The total area of wetlands in the Russian Arctic is approximately 0.35 mln square km. They occupy 50%-80% of land in the West Siberia, and much smaller fraction in other permafrost regions. Estimated annual net flux of methane from the Russian northern wetlands is 28.5 mln tons, of which 22.2 mln tons come from the West Siberian wetlands. Results from permafrost model indicated that the largest increase in the depth of seasonal thawing, up to 50%, is expected in the relatively dry northernmost locations along the Arctic coast and in the East Siberia, while in the West Siberia projected increase is relatively small, within 10%-15%. As follows from the results of carbon modeling, projected by the mid-21^{st} century changes in the volume of the seasonally thawing organic rich soils and higher soil temperatures may increase the annual net flux of methane from Russian permafrost regions by 6-10 mln tons. This estimate is compatible with the current balance between the global source (450 mln tons) and sink (430 mln tons) of methane, which has important implication for the global radiative forcing.

Results of this study have been obtained under the assumption that the soil hydrological regime, and particularly the water table in the Arctic wetlands will not be changed. Drying or wetting of tundra is concurrent with warming and may have significant effect on greenhouse emission and radiative forcing. Better drainage conditions and enhanced evapotranspiration under warmer climate may lower the water table and improve soil ventilation, ultimately shifting the currently existing balance in favor of CO2 rather than CH4 production. More studies are needed to narrow the range of uncertainties associated with the soil hydrology.