6. Landscape controls of CH_4 fluxes in a catchment of the forest tundra at the lower Yenissej

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Abstract

Soils of boreal ecosystems store an essential part of the total terrestrial carbon pool and they affect atmospheric methane concentration by net-CH_4 exchange. Climate warming will have a great impact on carbon storage and CH_4 production in high-latitude soils, especially in areas where melting of permafrost is induced. Permafrost soils can act as a sink for atmospheric CH_4 but they can also show CH_4 emission. The seasonal thaw depth, the dynamics of soil moisture as well as the amount, composition, and bioavailability of organic matter stored in permafrost soils are important factors determining the net-fluxes of CH_4 at the soil surface. The knowledge how climate warming will change these factors and how these changes will influence the emission of CH_4 is of decisive importance for the prediction of the future role of these ecosystems in the global CH_4 cycle. The objectives of our study are i) to determine the variability of net-CH_4 fluxes in a small catchment of the forest tundra in Siberia, ii) to determine the soil and landscape controls of the net-exchange of CH_4, and iii) to analyze the bioavailability and potential trace gas emission of soil organic matter stored in this area.

CH_4 fluxes were measured in summer and autumn 2003 using the soil cover method. Nearly all soils of the catchment showed a net-CH_4 uptake with flux rates between 10 and 60 µg CH_4 m^{-2} h^{-1}. CH_4 uptake rates were larger for soils without permafrost than for permafrost soils. The estimated mean CH_4 uptake was 1.5 kg CH_4 ha^{-1} a^{-1} for soils with a seasonal thaw depth > 90 cm and 0.5 to 1.0 kg CH_4 ha^{-1} a^{-1} for soils with an active layer < 90 cm. Large CH_4 emission (3 mg CH_4 m^{-2} h^{-1}) occurred from thermokarst ponds induced by permafrost degradation. The results show that permafrost distribution and the depth of the active layer are important controls of CH_4 fluxes and they suggest that the ongoing formation of thermokarst ponds changed the area from sink to a source of atmospheric CH_4. Large stocks of organic carbon were found in the soils of the catchment (8 to 320 kg C m^{-2} down to a depth of 2 m). The major part of this carbon was located in the frozen subsoils. Our incubation studies reveal that these old, frozen C stocks will become bioavailable after thawing. Thus, they may fuel CH_4 emission if they are decomposed under anoxic conditions in thermokarst ponds.