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Assessing the net impact of long-term drainage disturbance on a permafrost ecosystem through multi-disciplinary observations

Mathias Goeckede (1), Min Jung Kwon (1), Fanny Kittler (1), Ina Burjack (1), Martin Heimann (1), Nikita Zimov (2), and Sergey Zimov (2)

(1) Max-Planck-Institute for Biogeochemistry, Biogeochemical Systems, Jena, Germany (mgoeck@bgc-jena.mpg.de), (2) Northeast Science Station, Chersky, Russia

This study presents findings from a multi-disciplinary disturbance experiment established on the floodplain of the Kolyma River near Chersky, Northeast Siberia. Parts of our site have been artificially drained by ditches since 2004 to study shifts in biogeochemical and biogeophysical ecosystem properties following a sustained lowering of the water table. In particular, we are interested in changes in carbon and energy flux patterns, and resulting effects on the sustainability of the permafrost carbon pool.

We conduct a paired experiment with two uniformly instrumented sites representing drained and reference tundra, respectively. Year-round fluxes of carbon (CO_2 and CH4) and energy are available from two eddy-covariance towers, supplemented by a comprehensive monitoring of surface layer meteorology. These tower datasets are supplemented by observations targeting microsite flux rates with flux chamber transects, microbial and vegetation community structures, radiocarbon signals, nutrient availability and seasonal dynamics in phenology.

Through our multi-disciplinary observations we can document that the drainage triggered a suite of secondary changes in ecosystem properties, including e.g. vegetation structure (more tussocks and shrubs), snow cover regime (earlier buildup, earlier snow melt), soil temperature (warmer soils throughout the year) and thaw depth (reduced). Concerning the energy budget, this results in an intensification of energy transfer to the lower atmosphere, particularly in form of sensible heat. The CO_2 exchange between ecosystem and atmosphere is intensified as well, with drainage leading to both higher assimilation (taller vegetation) and respiration (warmer topsoils) rates. Increases in respiration dominate here, thus the net sink strength of the ecosystem for CO_2 is reduced as a consequence of lowering the water table. CH4 emissions are reduced by more then 50% following the drainage, since in the disturbed area conditions for both production (dryer soils) and transport (less plant-mediated transport due to shifts in vegetation) have negative impacts on flux rates. Summarizing, drainage results in complex effects with both positive and negative contributions to the net global warming potential of this ecosystem, with the long-term effect most likely leading to a positive feedback with global warming.