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Carbon Exchange in the Northern High Latitude Terrestrial Ecosystems Over the Last Three Decades

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The dynamics of carbon fluxes in the permafrost region is likely to have tremendous impacts for the future global climate. Recently, several ecosystem and land surface models have demonstrated improved permafrost modeling capabilities by incorporating deep soil layers, organic soils, and parameterizing the effects of wind compaction and depth hoar formations, which influence high latitude soil biogeophysics. However, no global study has yet incorporated the combined effects of these biogeophysical improvements. Additionally, the primary focus has been on modeling biogeophysical fluxes rather than on how biogeochemical processes and feedbacks are impacted.

In this study, we evaluate how biogeochemistry (carbon and nitrogen dynamics) responds to improved biogeophysics in the high latitudes. We employ a land surface model, the Integrated Science Assessment Model (ISAM), to model the fluxes of water, energy and carbon, as well as the change in active layer depths during the historical period. The ISAM represents fully prognostic carbon and nitrogen cycles, coupled with biogeophysics schemes.

Additionally, biogeophysical improvements such as the inclusion of deep soils, organic soils, wind compaction and depth hoar formation effects, which are critical for high-latitude soil thermal dynamics, have been incorporated into the model. The performance of the model is evaluated using observations for active layer depths and carbon fluxes, together with recent estimates for total soil carbon amount in the permafrost region. The soil decomposition module in the ISAM was calibrated with field experiment data, which includes representation of nitrogen mineralization processes.The ISAM modeled carbon, nitrogen and energy fluxes were evaluated for several flux tower sites representative of the tundra and the boreal ecosystems as well as for the northern high latitude region.

This is one of the first studies to explore the combined effects of improvements in biogeophysics, coupled with a detailed model of soil carbon and nitrogen dynamics, for the entire northern high latitude region.

The initial results of the model simulations suggest that the northern high latitude ecosystems were acting as a sink for atmospheric CO_2 for the period 2000-2009. However, model results suggest that strength of the sink has weakened over the past three decade due to climate change.