Biogeochemical Consequences of the Hydrologic Connection Between Permafrost-Thaw Bogs and Surrounding Peat Plateaus: Advective Heat Transport in Permafrost Landscapes

Rebecca B. Neumann[1*], Joel F. Eklof[1], Jing Tao[1,2], Qing Zhu[2], William J. Riley[2]

[1]University of Washington, Seattle, WA;
[2]Climate and Ecosystem Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA

(rebneum@uw.edu)

Project Lead Principal Investigator (PI): Rebecca B. Neumann
BER Program: TES
Project: University project

When ice-rich permafrost thaws, the ground subsides, creating thermokarst features such as thaw bogs. While this type of landscape transformation releases carbon stored in permafrost into the atmosphere, on longer time scales, it facilitates sequestration of atmospheric carbon in plant biomass because permafrost thaw releases plant-available nutrients and wetlands are highly productive. However, wetlands also generate methane, which is a potent greenhouse gas. Methane emissions from thermokarst bogs can cause these carbon-sequestering systems to have a positive global warming potential.

Data previously collected by the research team from a thaw bog in Interior Alaska demonstrated that rainfall early in the growing season notably increased CO_2 uptake and CH_4 emissions by the bog. Water from the surrounding permafrost-peat-plateau flowed through the peat soils and penetrated into the bog, rapidly warming bog soils down to deep depths (~80 cm). The warm, deep bog soils early in the growing season supported microbial and plant processes that enhanced CO_2 uptake and CH_4 emissions. Thaw bogs often represent topographically low points in the landscape, and thus they receive and collect runoff from the surrounding landscape. However, the hydrologic connection between bogs and the surrounding permafrost plateaus (the bog-watershed connection), and the ability of this connection to impact biogeochemical processes in the bog, is not traditionally recognized in field studies nor included in models.

Our project is advancing understanding of the bog-watershed connection, clarifying the conditions under which it results in the transport of thermal energy into bog and impacts land-atmosphere exchange of carbon. We are conducting fieldwork at a well-instrumented, thawing bog complex in Interior Alaska and performing Earth System modeling. Field data thus far indicate that bogs that receive proportionately more water from the surrounding watershed emit more methane. Through coupled modeling of lateral water and heat transport with Energy Exascale Earth System Model (E3SM) land model (ELMv1-ECA), we have confirmed the important role of advective heat transport in affecting bog soil temperatures and CH_4 emissions. Specifically, results show that incorporating lateral advective heat transport improved simulated soil-temperature and moisture profiles, active layer thickness, and bog area inundation dynamics along two simulation transects that extend from the peat-plateau to the bog, aligning with major sensor locations at the field site.

Northern latitudes are expected to get warmer and wetter, and initiation and expansion of thermokarst thaw is expected to increase. In this context, the influence of the bog-watershed connection is likely to increase.