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ABSTRACT TITLE: Linking Permafrost Hydrology and Biogeochemistry: Using Stable Isotopes to Support Conceptual and Quantitative Modeling in the NGEE Arctic Project

ABSTRACT: As part of the DOE Next Generation Ecosystem Experiment – Arctic (NGEE-Arctic) project we are examining the lateral- and vertical- connectivity of water, nitrogen, and carbon systems in permafrost areas. Complex Arctic drainage networks can potentially lead to significant redistribution of water and biogeochemically important species over the landscape. Topographic features of arctic landscapes, especially polygonal ground, thaw ponds and lakes, comprise a complex and tortuous drainage network. In addition, a dynamic active layer and variations in soil- and ice-hydraulic properties act as important controls on vertical fluxes. Climate driven warming and degradation of permafrost may lead to changes in the low relief features as well as active layer thickness in low gradient regions like the North Slope of Alaska. Thus, it is necessary to develop a firm conceptual and quantitative understanding of the relationship between microtopography, larger-scale features such as rivers, and active layer dynamics to define and model how hydrological and biogeochemical processes feed-back to climate and Arctic ecosystems. In 2012 we conducted a synoptic isotope and geochemical survey at the Barrow Environmental Observatory (BEO) in Alaska. We tested a combination of methods including piezometers, drive points, and diffusion cells at multiple depths in the saturated zone and installed passive wicks and macrorhizons to sample the unsaturated zone. The analysis suite included cations, anions, DOC, TOC, DON, dissolved methane, and isotopes of water, DIC and DOC. Geochemical results show strong correlations with microtopographic units such as polygon type, and a wide range of redox conditions occur over the site. Thus, methane source and sink areas are likely strongly linked to these small-scale features. A limited set of samples from larger-scale hydrologic features such as major drainage channels shows significant chemical shifts from the small scale suggesting that it is important to understand multi-scale controls on where/how water is moving and the biogeochemical transformations that are occurring. Stable isotope data (^{2}H and ^{18}O) also show some important differences at the microtopographic scale indicating that water sources (e.g., rainfall or ice melt) and hydrological residence times can vary with depth and type of microtopographic unit. Carbon and nitrogen chemistry-and isotope-data demonstrate how biogeochemical cycling is strongly linked to the presence or absence of surface water ponding. For example, nitrogen production appears to be limited to high-centered polygons. High-centered polygons tend to develop more under degraded permafrost conditions. Thus, as degradation progresses, low-centered polygons become converted to high-centered polygons which could significantly impact nitrogen cycling and vegetation shifts in these Arctic systems. Overall, our findings suggest that the BEO system is a heterogeneous and dynamic hydrological and biogeochemical system with strong temporally- and spatially-driven variability at multiple scales.