Implementing Field Eh Measurements to Illuminate Controls on Methane Oxidation in Sedge-Dominated Sites in Discontinuous Permafrost Peatlands

Introduction: Rising temperatures in the subarctic are accelerating thaw of organic-rich permafrost peatlands, liberating organic carbon (C) from long term storage through microbial decomposition, and increasing methane (CH_4) emissions[1,2]. Methanotrophic bacteria can oxidize (consume) CH_4 in thawing peatlands, producing carbon dioxide (CO_2)[3,4]. Recent biogeochemical research has elucidated the controls of CH_4 production and flux in thawing peatlands; however, CH_4 oxidation and its controls remain significantly less understood than CH_4 flux.

Both CH_4 flux and CH_4 oxidation vary along the gradient of permafrost thaw. As thaw occurs, hydrology, plant communities, and geochemical characteristics will all vary spatially and exert controls on the carbon dynamics of thaw[5]. Methane and CO_2 are both greenhouse gases, but CH_4 has a >30x larger warming potential than CO_2. Thus, it is critical to gain further insight into the factors determining the ratio of CH_4 flux and CH_4 oxidation in thawing peatlands to produce accurate emissions projections for climate change models.

Preliminary data from July 2015 from Stordalen Mire in Abisko, Sweden (68°21'N, 18°49'E) provides evidence for permafrost thaw-induced methane oxidation at open-water sedge sites adjacent to collapsing permafrost palsas (Fig. 1). Sedges contain aerenchymous tissues that enable gas transport in and out of the water column[4]. Sedges act as a conduit for CH_4 out of the water column and transport oxygen (O_2) into the rooting zone (rhizosphere), enabling CH_4 oxidation below the water table[4].

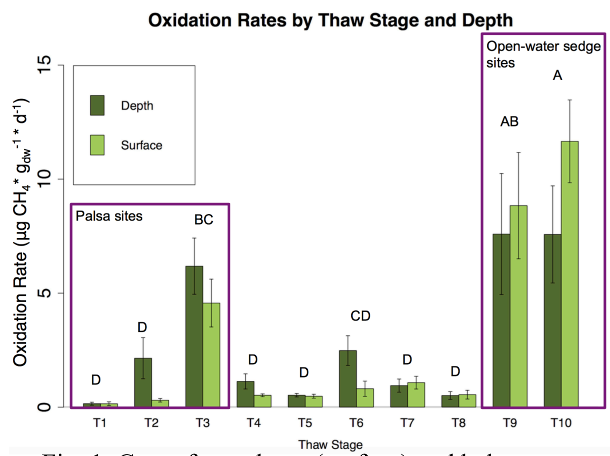

Fig. 1. Cores from above (surface) and below (depth) the water table were extracted from 10 sites over a permafrost thaw gradient. Bars represent mean oxidation rate across replicates ± standard error; n=4. By thaw stage: $F = 19.75$, $p < 0.001$, by depth and thaw stage*depth: $p > 0.05$.

One major gap in validation of biogeochemical models of wetland CH_4 emissions is the lack of Eh or redox potential measurements. Field measured Eh of pore water in sedge rooting zones in thawing peatlands should show the extent of O_2 diffusion into the water column and indicate whether aerobic (CH_4 oxidation) or anaerobic (CH_4 production) processes are the dominant microbial metabolic pathways in thawing permafrost[6,7]. Little data is available on the redox state of peatland pore waters because reliable field Eh measurements have previously been difficult to attain and reproduce. Carefully calibrated field Eh electrodes will enable more accurate *in situ* redox potential measurements[8]. In addition to field Eh measurements, laboratory incubations of peat from these locations may link redox potential and areas of CH_4 oxidation, particularly in the rhizosphere.

Measuring changes in redox potential through the water column of open-water sedge sites will enable more accurate modeling of carbon dynamics in thawing subarctic peatlands, as it will indicate the zones in which CH_4 production or CH_4 oxidation dominate. Current research at Stordalen Mire uses the DeNitrification-DeComposition Model (DNDC) to test CH_4 production pathways and flux[9]. Further monitoring of CH_4 oxidation and its relationship to redox potential will enable DNDC to better integrate CH_4 oxidation and validate wetland CH_4 emissions predictions. Understanding the connection between pore water redox potential and oxidation rates in open-water sites is critical to understanding how permafrost thaw will influence carbon dynamics and geochemical characteristics in transitional thaw stages in peatlands as thaw progression advances.

Hypotheses: By pairing *in situ* Eh measurements in open-water sedge sites and laboratory incubations of biomass from sedge sites at each Eh measurement depth, I will test the following hypotheses. **1.** A positive correlation exists between redox potential and potential oxidation rate. **2.** Redox potential and potential oxidation rate will be highest in the rhizosphere relative to the rest of the water column in open-water sedge sites. **3.** Incorporation of redox potential and CH_4 oxidation rates to DNDC will improve modeling of wetland CH_4 emissions.

Methods: My research will focus on open-water sedge sites in Stordalen Mire, a thawing subarctic permafrost peatland complex in northernmost Sweden containing palsas, semi-wet *Sphagnum* sites, wet sedge-dominated sites, shallow lakes, and thaw ponds. As part of my REU experience, I collected preliminary oxidation data using incubations of peat from across a permafrost thaw gradient in July 2015, which revealed high potential oxidation rates in open-water sedge sites proximal to thawing palsas.

I will measure redox conditions (Eh) with a platinum electrode[8] through the water column in wet sedge areas in Stordalen Mire throughout the course of the snow-free season (June-September). I will also measure environmental correlates including CH_4 flux, water table depth, thaw depth, pH, and plant community composition to examine potential relationships between redox potential and other environmental variables. I will couple Eh measurements with aerobic incubations[10] of sedge biomass to determine the relationship between redox potential and potential oxidation rates in sedge areas. Incubations will occur at *in situ* temperatures and CH_4 concentrations, as determined by field measurements from the preceding field season. Incubation protocol will be held constant across all replicates. After collection, redox potentials, oxidation rates, and environmental data can be incorporated into DNDC to test their effect on emissions scenarios from Stordalen Mire and other similar permafrost peatland complexes. I will work with my advisor's (R. Varner) collaborators at UNH to integrate these data to DNDC.

Intellectual Merit: This project will provide some of the first empirical data on *in situ* O_2 diffusion through the water column in thawing peatland complexes and its effects on carbon dynamics. As previous models rely on hypothesized values for Eh and O_2 diffusion, these data are essential to developing more accurate biogeochemical models of thawing peatlands to yield more reliable estimates of CH_4 emissions from wetlands as climate changes.

Broader Impacts: I am committed to better understanding climate change and biogeochemical systems to both further scientific understanding and to guide mitigation of future carbon emissions and climate change effects. Elucidating less-understood aspects of carbon dynamics, like CH_4 oxidation, and their effect on future emissions is key to creating effective mitigation.

I will participate in programs facilitated by the Joan and James Leitzel Center for Mathematics, Science, and Engineering Education (R. Varner, Director) to educate the wider community about global environmental change. Programming from the Leitzel Center aims to engage teachers, high school students, and undergraduates in STEM activities. I will implement educational outreach in regional schools and mentor undergraduate students on research projects, with particular interest in encouraging female and low-income students to pursue their interests in the STEM field.

References: [1]Turetsky, M.R., et al. (2014), *Global Change Biol.,* 2183, [2]Callaghan, T.V. et al. (2010), *Geophys. Res. Letts.,* [3]Kip, N., et al. (2010), *Nature Geosci.,* 617, [4]Ström, L. et al. (2005), *Biogeochem.,* 65, [5]Malhotra, A. and Roulet, N.T. (2015), *Biogeosci.,* 3119, [6]de Mars, H. and Wassen, M.J. (1999), *Plant Ecol.,* 41, [7]Popp, T.J., et al., (2000), *Biogeochem.,* 259, [8]Hagris, T.J. and Twilley, R.R. (1994), *Res. Methods Papers,* 684., [9]Deng, J., et al., (2014), *Biogeosci,* 4753., [10]Larmola, T., et al., (2013), *Eco. Soc. of America,* 2356.