**Limnology & Oceanography Research Exchange (LOREX) Application**

**Project Title:** Spatial Variability of Carbon Fluxes in a Subarctic Catchment  
**Student Name and Email:** Cheristy Jones, cheristy.jones@unh.edu

Current Institution: University of New Hampshire  
Program (MS, PhD, other) and Year in Program: PhD, 3rd year  
Advisor(s) Name: Ruth K. Varner  
Thesis Title: Missing Carbon: Quantifying lateral carbon fluxes across Arctic ecosystems

**ASLO Member ID:** 14498

**Potential exchange site and collaborator:** Abisko, Sweden (Umeå University’s Climate Impacts Research Centre), Dr. Jan Karlsson
Abstract (300 words maximum):

As the climate continues to warm, permafrost thaw is increasing lateral fluxes of carbon (C) into aquatic systems. However, most studies characterize these fluxes from only one point in a catchment thus the spatial variability of lateral C fluxes from river networks in heterogeneous landscapes is not well quantified. The transformation of this C as it flows throughout the catchment is also not well understood. To investigate how C quality and quantity vary across the terrestrial-aquatic interface, I will sample surface water across a subcatchment that includes three different land-cover types. The study subcatchment is 15 km² and includes the permafrost peatland Stordalen Mire in Sweden (68°21’ N 18°49’ E). The catchment has four stream branches and the landscape transitions from alpine tundra at the upper elevations, then to birch forest before draining into a discontinuous permafrost peatland. I will sample the catchment at high spatial frequency in July-August 2024 and determine the relative contribution of the varying landcover types to watershed C cycling. I will measure dissolved methane, dissolved carbon dioxide, dissolved organic carbon concentrations and composition (i.e., quality) along each stream branch across varying slopes within each landcover type. To partition sources of carbon from landcover sources, I will perform isotopic analyses of dissolved gases ($\delta^{13}$C-CO$_2$, $\delta^{13}$C-CH$_4$, $\delta^{13}$D-CH$_3$D). This spatially resolute sampling will allow us to identify lateral flux patterns across the terrestrial-aquatic interface within river networks and determine the relative contribution of different landcover types to watershed-scale fluxes. Understanding how landcover type affects the spatial variability of C cycling across a watershed is crucial for understanding watershed-scale lateral C flux as well as C transformation in these climate sensitive ecosystems.

Key words: rivers, carbon, biogeochemistry, Arctic, catchments
Project Description (3-page maximum):

**Background**

Streams carry biogeochemical signals of the landscape and are thus important indicators of landscape change. As the Arctic continues to warm, shifting hydrological flow paths and permafrost thaw can move highly biodegradable (i.e., labile) carbon (C) into streams, potentially increasing carbon dioxide (CO$_2$) and methane (CH$_4$) emissions. Most studies characterize these C fluxes and signals from only one point in a catchment, usually at large river outlets (e.g., Raymond et al., 2007; Tank et al., 2016; Toohey et al., 2016). While this can provide information on overall catchment dynamics and processes occurring in both the terrestrial and aquatic systems, this does not provide an understanding of lateral C fluxes across the terrestrial/aquatic interface and the mechanisms controlling these fluxes, particularly in heterogeneous landscapes. Different patches across the landscape can serve as “control points”, disproportionally contributing solutes, including dissolved organic carbon (DOC), CO$_2$, and CH$_4$, to the stream and affecting climate forcing trace gases. For example, changes in dominant vegetation can control the lability of DOC that enters stream networks. However, once material from these control points has entered the stream, the instream processing of this carbon is similarly not well characterized throughout the landscape, potentially leading to underestimates of CO$_2$ and CH$_4$ emissions from aquatic systems. In particular, CH$_4$ concentrations can be highly spatially variable, due to changes in physical stream structures (i.e., differences in sediment, groundwater connectivity, etc.).

**Objectives**

I will conduct a synoptic sampling campaign to better understand C transport and transformation in a small, sub-Arctic catchment. This spatially resolute sampling will allow us to identify lateral flux patterns across the terrestrial-aquatic interface within river networks and determine the relative contribution of different land-cover types to watershed-scale fluxes. High-frequency CO$_2$, DOC, and CH$_4$ measurements will illuminate mechanisms driving these fluxes in a permafrost peatland, which are particularly high C emitters (Miner et al., 2022; Varner et al., 2021). Specifically, I aim to address the following questions: 1) How does C quantity and quality change throughout the catchment (i.e., spatially)? 2) What are the ecosystem patches that control CO$_2$ and CH$_4$ concentrations along a peatland corridor? My hypotheses are:

- **H1a**: C concentrations (DOC, CO$_2$, CH$_4$) will increase from the headwaters to the mouth of the catchment as the drainage area of terrestrial C input increases. **H1b**: Stream branches draining a higher percentage of organic matter rich peatlands will disproportionally contribute high concentrations of labile C to the catchment, making vegetation the biggest driver.

- **H2**: The highest concentration of DIC and CH$_4$ will be found in stream reaches draining areas with more permafrost because permafrost thaw releases labile OM.
Approach

The study catchment is 15 km$^2$ and includes the permafrost peatland Stordalen Mire in Abisko, Sweden (68°21’ N 18°49’ E; Fig. 2). The catchment is alpine tundra at the upper elevations (600-770 m.a.s.l) characterized by dwarf shrubs and heaths. At lower elevations (330-600 m.a.s.l), the catchment transitions to birch forest before draining into discontinuous permafrost peatlands (including Stordalen Mire) which are dominated by sphagnum mosses and sedges\textsuperscript{17}. There are four mainstream branches in the catchment that begin at the upper elevations as small, mountain streams (<1 m wide). When they enter the relatively flat peatland systems, they become deeper and wider (up to 4.5 m wide). The catchment has 27 lakes of varying sizes, most post-glacial. Only one lake is in the alpine tundra.

The synoptic sampling campaign will take place in late July 2024 to August 2024, at the height of the growing season. Along each main stream branch, I will collect surface water samples at three varying slopes in each landcover type (i.e., alpine tundra, birch forest, and peatland) and at the transition zone between each landcover (i.e., alpine tundra to birch forest interface). Samples will also be collected at the lake inlets and outlets. Discharge measurements will be taken at all sampling locations. Analysis of water samples for DOC, CO$_2$, and CH$_4$ will allow me to quantify the types of carbon in the streams. Dissolved CO$_2$ and CH$_4$ will be sampled using the headspace equilibration method and ran in the Umeå University’s Climate Impacts Research Centre (CIRC) laboratories at the Abisko Scientific Research Station to calculate surface water gas fluxes. C quality will be measured using a light absorbance method (Suva$^\text{254}$), a proxy for C lability. The C quality samples as well as the DOC$^\text{6}$ samples will also be analyzed in the CIRC laboratories. In addition to C, samples will also be analyzed for nitrogen and phosphorus as they are important regulators of ecosystem processes. I will collect additional dissolved CO$_2$ and CH$_4$ samples for stable isotope ($\delta^{13}$C-CO$_2$, $\delta^{13}$C-CH$_4$, and $\delta^{13}$D-CH$_3$D) to partition sources. These samples will be stored in glass vials and run in Dr. Ruth Varner’s (advisor) Trace Gas Biogeochemistry Laboratory at the University of New Hampshire (UNH), my home institution. GIS will be used to link landscape characteristics to measured C quantity and quality. Ancillary data (e.g., air temperature, precipitation data, etc.) will be collected from the SITES (https://www.fieldsites.se/en-GB) monitoring equipment located in Stordalen Mire.

Scientific Significance

The data from this work will provide crucial insight into the drivers of lateral carbon transport and emissions in freshwater systems as well as the spatial variability of these emissions in a particularly vulnerable ecosystem. This will provide important insights into the necessary spatial sampling resolution to better assess CO$_2$ and CH$_4$ emissions and can be used to scale
emissions more accurately across watersheds. These findings will become increasingly important as climate change continues to alter these vulnerable landscapes.

**Project Feasibility and Timeline**

Field work for this project will begin at the height in the growing season, in **late July 2024, through late August 2024 (four-weeks total)**. I anticipate that field sampling will take approximately two-weeks, laboratory work in Sweden will take an additional week, and an extra week for incidentals (e.g., weather, travel delays, instrument malfunction, etc.; Table 1). Following field work, I will return to UNH to run water samples at the UNH Water Quality Analysis Laboratory and isotopic samples at the UNH Trace Gas Biogeochemistry Laboratory. I anticipate a publication and a dissertation chapter to be submitted by the end of Spring 2025.

As a third-year PhD student at UNH, I spent two summers in Arctic Sweden quantifying C fluxes and transport in Stordalen Mire, a permafrost wetland. I measured vertical CO$_2$ and CH$_4$ fluxes via manual chamber methods and characterized belowground and aquatic C composition and flow which has given me the skills to successfully complete this project, especially with the additional guidance of Dr. Jan Karlsson from the Climate Impacts Research Centre (CIRC), Umeå University. I also conducted a pilot study for this work in the Stordalen Mire catchment in 2023 to ensure the success of this project.

**Table 1.** Project timeline for work to be completed at UNH and Abisko, Sweden from Spring 2024 to Spring 2025

<table>
<thead>
<tr>
<th>2024-2025</th>
<th>Spring 2024</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>Fall-Spring 2025</th>
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<tbody>
<tr>
<td>Online preparation for fieldwork, UNH</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
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<tr>
<td>ASLO summer meeting &amp; orientation, UNH</td>
<td></td>
<td></td>
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<tr>
<td>Prepare field supplies, UNH</td>
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<td></td>
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<td></td>
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<tr>
<td>Collect water, dissolved CO$_2$, CH$_4$ samples, Sweden</td>
<td>x</td>
<td></td>
<td>x</td>
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<td></td>
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<tr>
<td>Analyze CO$_2$,CH$_4$, water samples, Sweden</td>
<td></td>
<td></td>
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<td>x</td>
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<tr>
<td>Analyze isotope samples, UNH</td>
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<td>x</td>
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<tr>
<td>Data analysis, UNH</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
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<tr>
<td>Prepare manuscript and dissertation chapter, UNH</td>
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<td></td>
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<td>x</td>
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</table>

**Dissemination of Results**

I expect that this study will result in a peer-reviewed publication as well as presentations of this research at the European Geophysical Union, American Geophysical Union, and ASLO meetings. I will also strive to participate in the CIRC research symposium, an annual meeting where CIRC researchers share their work. I will share the data from this work in the standard academic publications and place data in free and open repositories like Github. I will also work with Dr. Karlsson and CIRC to ensure I adhere to data sharing guidelines for CIRC. Throughout my participation in the LORAX program, I will also document my experiences on my social media accounts to reach a broad audience.
**Project Justification (1-page maximum):**

**Significance**

The results of this study will form the third chapter of my dissertation as well as a peer-reviewed publication. The LORAX program offers a unique opportunity to grow my skills in measuring greenhouse gas fluxes to the catchment level, which will expand the scale of my current work which has focused on carbon cycling across a permafrost thaw gradient at the tens of meters scale. I will gain skills in not only carbon characterization, but also carbon transformation which will provide me with the tools to take a mechanistic approach to my research, significantly increasing its impact. As a woman in STEM and first-generation college student, the LORAX program will provide an important steppingstone in my career to build new skills and collaborations. Ultimately, I plan to become a professor to continue researching terrestrial-aquatic connections in the Arctic and the LORAX program will allow me to form lasting, international collaborations that I hope continue to foster throughout my career. In addition, this collaboration will bring new perspectives to my work that will help to drive my research questions and my PhD to new directions.

**Affiliation**

I am looking forward to expanding my connections with world-renowned Arctic researchers at CIRC, including the project supervisor Dr. Jan Karlsson. Dr. Karlsson is an esteemed Arctic researcher affiliated with CIRC. He has been conducting research in the Abisko region for several decades and can provide a unique perspective on this dynamic ecosystem. I am looking forward to learning how to scale carbon fluxes with him and grow my skills as a trace gas biogeochemist. In addition, Dr. Karlsson is currently leading efforts to create a framework to predict carbon dioxide and methane emissions in aquatic systems, making this the perfect time to implement my work as it will complement ongoing research at CIRC by providing a mechanistic understanding of emissions in aquatic systems. Dr. Karlsson will provide invaluable guidance on site selection as well as how to scale the C emission measurements. The Stordalen Mire Catchment also has extensive background information, making it an ideal location to conduct a mechanistic study. He will also assist in manuscript preparation. Additionally, the CIRC research laboratory provides a unique opportunity to conduct field work and laboratory work in a remote Arctic environment that I otherwise would not have access too.
References (1-page maximum):
January 2, 2024

Dear Selection Committee:

I am writing this letter in support of Ms. Cheristy Jones’ application to the LOREX program. Ms. Jones is currently enrolled in her third year of the University of New Hampshire’s Natural Resource and Earth System Science PhD program where I serve as her advisor. For background, I am a Professor of Biogeochemistry at the UNH’s Institute for the Study of Earth, Oceans and Space and in the Department of Earth Sciences. Over the past 27 years I have mentored five postdoctoral researchers, five Ph.D. students, 17 Masters students and over 50 undergraduate students in their research.

I am fully supportive of Ms. Jones’ application for LOREX for several reasons. The first being the mature development of a research focus for her PhD work. In Arctic biogeochemical research, there is a pressing need to understand the linkage between terrestrial and aquatic ecosystems. This is where the transfer and transformation of carbon can occur and aquatic and terrestrial researchers often work in silos, using different technical approaches and terminology. Ms. Jones recently defended her PhD proposal identifying this as a clear research need in our community. Her dissertation will be one of only a handful that will take this integrated approach across a watershed that includes a thawing permafrost landscape to help us understand not only the one-dimensional processes in each habitat but will be able to provide validation data for models of horizontal transport of carbon, nutrients and other trace elements in these climate sensitive ecosystems.

I have personally witnessed and participated in research that Ms. Jones’ has planned and implemented. I see this project as having a very high potential for success and considerably enhanced by her collaboration with Dr. Jan Karlsson. His extensive expertise not only in Arctic ecosystems but in aquatic C cycling will ensure that Ms. Jones’ work will have a very high impact. In her work previously in the Stordalen Mire, Ms. Jones’ was a positive role model for more junior researchers and a positive representative of my research group, UNH and the US scientific community. Ms. Jones has navigated two long field seasons (each greater than 3 months) in northern Sweden during which she led her own PhD research campaign, mentored undergraduate students doing their first research projects, planned and led a team based (7+ people) synoptic survey and supported our NSF EMERGE Project field sampling campaign. I cannot say that I have ever worked with a student who is more driven or more dedicated to field work. Ms. Jones also has an incredible attention to detail, so I am confident in her ability to collect the data she needs but also to be safe when she is doing this. After successfully navigating two summers with COVID outbreaks and having Wilderness First Responder training, she prepared for any safety situation that could arise in remote field work.

I submit this letter with my highest level of support for Ms. Jones’ application. Her work on the linkages between terrestrial and aquatic ecosystems is at the cutting edge of our understanding in these ecosystems that transport and transform carbon into potent climate forcing gases.

Sincerely,

Ruth K. Varner, PhD
Faculty Fellow for DEI, College of Engineering and Physical Sciences
Professor of Biogeochemistry
Department of Earth Sciences and Institute for the Study of Earth, Oceans and Space
Co-Director, EMERGE Biological Integration Institute
To whom it may concern

Letter of support

This letter is to support the LOREX application by Cheristy Jones, PhD student at the University of New Hampshire.

Cheristy proposes a project to characterize methane and carbon dioxide fluxes of the Stordalen Mire catchment in northern Sweden. The Stordalen mire experience rapid thawing of permafrost and the aquatic systems adjacent to the mire is releasing important quantities of greenhouse gases to the atmosphere. Yet, there is a lack of detailed studies on the controlling mechanisms of carbon cycling and greenhouse gas dynamics across the land-water interface. The proposed project is a very interesting and I anticipate it would result in valuable contribution to understanding the carbon cycle in permafrost regions.

I see major opportunities for Cheristy to carry out an interesting collaborative project with my group and with other people at the Climate Impacts Research Centre (CIRC). Land-water interactions is a central research theme at CIRC and in my group we work with questions related to how mobilization and export of carbon from soils and wetlands affect key biogeochemical and ecological processes in streams and lakes. In short, I will be happy to host Cheristy and collaborate with her on the proposed project.

Sincerely,

Jan Karlsson
Prof. in Aquatic Biogeochemistry
Director of CIRC
Umeå University, Sweden