Linking terrestrial and aquatic carbon cycling in an Arctic catchment

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I. Significance

The results from the work conducted under my New Hampshire Space Grant Fellowship will form the third chapter of my dissertation as well as a peer-reviewed publication. This award allowed me to expand my skills in measuring greenhouse gas fluxes to include flux tower data which will expand the scale of my current landscape work. In addition, I was able to collaborate with researchers at Aarhus University in Denmark as well as at the Greenland Institute of Natural Resources whom I hope to continue to work with throughout my career.

II. Background

As glacial melt accelerates due to climate change, low-glacially fed catchments (i.e., areas where most surface water does not come from glacial sources and all surface water flows to one point, such as the ocean) are becoming increasingly prevalent throughout the Arctic[1]. Glacial retreat exposes landscapes to vegetation colonization, and erosion, fundamentally altering carbon (C) cycling in these catchments[1,2]. In glacier-draining catchments, C and nutrient (i.e., nitrogen (N) and phosphorus (P)) transport often increases which can lead to higher carbon dioxide (CO_2) and methane (CH_4) emissions from aquatic systems (i.e., streams and lakes) and increased transport of nutrient loads to marine systems[3]. However, C and nutrient transport in catchments with low glacial glacier drainage are not well characterized, despite these types of catchments increasingly becoming the main water supply for Greenlandic settlements[4]. Further, many studies characterize C and N export from only one point in a catchment ignoring the complex and heterogeneous network of streams and channels that lead to these outlets. **The proportions of different C species transported to streams is poorly quantified and they are rarely linked to vertical CO_2 fluxes across the landscape.[2]**

III. Objectives

Coupling lateral and vertical C fluxes in terrestrial and aquatic environments will provide a holistic understanding of the C balance of Arctic catchments and critical data for integrated modeling of these dynamic and vulnerable ecosystems. I aim to address three primary questions essential to understanding C cycling within low-glacially fed catchments: **1) How does C and nutrient quantity change throughout the catchment (i.e., spatially)? 2) How does C type differ throughout the catchment and 3) What are the relationships between vertical CO_2 emissions and aquatic C content?** I hypothesize that C concentrations will increase throughout the catchment as increasing drainage areas will transport more organic material. I further predict that C will become less likely to be degraded into CO_2 lower in the catchment as it will be degraded by microbes in the upper sections of the catchment. Nutrient concentrations will also likely decrease throughout the catchment as they are utilized quickly. I hypothesize that higher terrestrial CO_2 emissions will also correlate to higher aquatic C concentrations and emissions as these areas will correlate with more labile C.

IV. Field Work Conducted

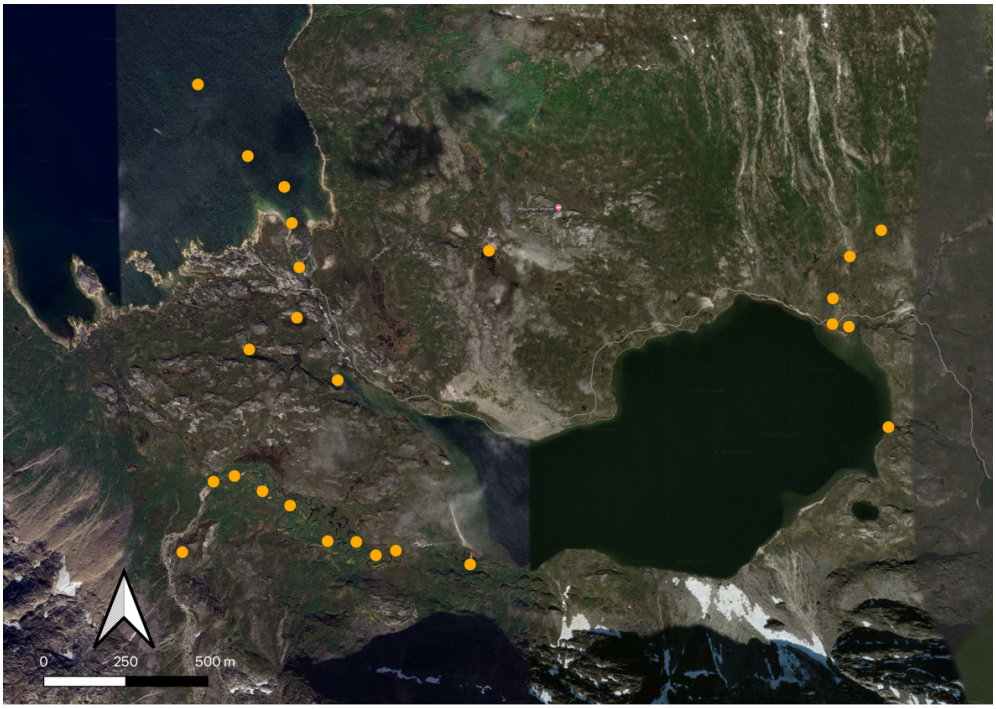
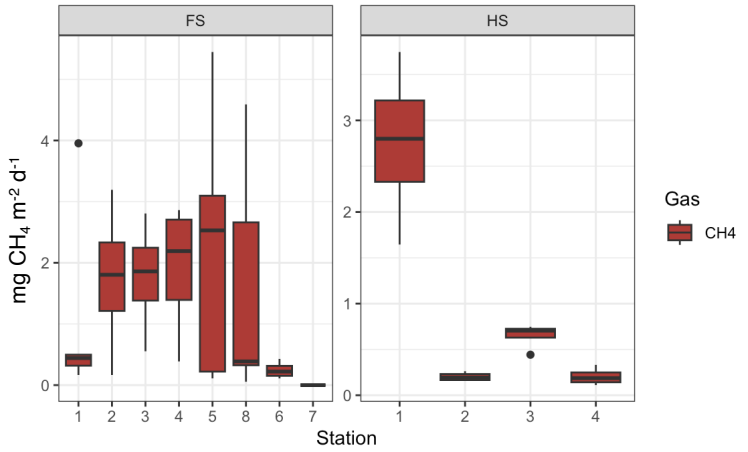


Figure 1. Map of Kobbefjord catchment (64° N, 51° W). Orange dots indicate sampling locations.

During my fellowship, I conducted weekly sampling for one month in the Kobbefjord catchment (32 km^2, 64° N, 51° W), an Arctic tundra ecosystem located near Nuuk, Greenland (Fig. 1). Within the catchment are two mid-order streams, one that flows through a heathland and one that flows through a fen, that both drain into a glacial lake. I sampled these streams at high spatial frequency (every ~200m) in June-July 2024 to compare the differences of landcover type on stream C exchange and investigate the implications this variability has on catchment C budgets. I characterized dissolved organic C quantity and quality, terminal electron acceptors, dissolved inorganic C, dissolved CO_2, dissolved CH_4, and CO_2 and CH_4 fluxes from both streams and the lake outlet. To partition sources of carbon, I analyzed the stable carbon isotopes of dissolved CO_2 and CH_4. Additionally, I used the eddy covariance flux method to compare stream C emissions to terrestrial C emissions and estimated lateral C fluxes from terrestrial to aquatic environments both in the heath and the fen.

V. Preliminary Results

a)



b)

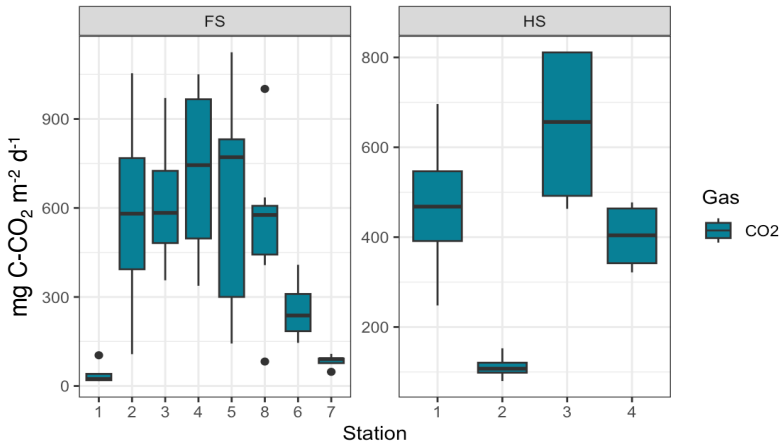


Figure 2. Diffusive emissions of a) CH_4 (mg CH_4 m^{-2} d^{-1}) and b) CO_2 (mg C-CO_2 m^{-2} d^{-1}) from the fen stream reach (FS) and the heath stream reach (HS). Stations are ordered from the stream mouth to upstream sampling locations.

Although both the heath and fen stream reaches were sources of CO_2 (median= 449 & 381 mg CO_2 - C m^{-2} d^{-1}, respectively) and CH_4 (median= 0.39 & 0.44 mg CH_4 m^{-2} d^{-1}, respectively) to the atmosphere (Fig. 2), preliminary results show that stream reaches adjacent to a fen emit non-significantly higher amounts of CO_2 ($p= 0.99$) and CH_4 ($p= 0.95$), suggesting that the terrestrial productivity of the fen is not reflected in stream C dynamics. Further investigation of the control points of lateral C transport using porewater and surface water isotopic analysis paired with landscape C emissions will help elucidate the causes and implications of this potential decoupling on aquatic C flux upscaling and catchment C budgets.

VI. On-going Work and Future Products

Following the conclusion of my fellowship, I will continue to conduct sample processing and data analysis. This work will be presented at the American Geophysical Union Fall Meeting in December 2024. Ultimately, this work will form a chapter of my dissertation along with peer reviewed publication (expected spring 2025).

VII. References

1. Hawkings, J. R. *et al.* The effect of warming climate on nutrient and solute export from the Greenland Ice Sheet. *Geochem. Persp. Let.* 94–104 (2015) doi:10.7185/geochemlet.1510.
2. Musilova, M. *et al.* Microbially driven export of labile organic carbon from the Greenland ice sheet. *Nature Geosci* **10**, 360–365 (2017).
3. Bröder, L. *et al.* Contrasting Export of Particulate Organic Carbon From Greenlandic Glacial and Nonglacial Streams. *Geophysical Research Letters* **49**, e2022GL101210 (2022).
4. Abermann, J., Langley, K., Myreng, S. M., Rasmussen, K. & Petersen, D. Heterogeneous timing of freshwater input into Kobbefjord, a LOW-ARCTIC fjord in Greenland. *Hydrological Processes* **35**, e14413 (2021).