Integrating ABoVE airborne datasets and field campaigns to identify hotspots of surface water inundation and carbon flux across Arctic-Boreal ecosystems

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Introduction and Rational:

Inland waters represent greater than 3% of the total continental surface of the pan-Arctic. High latitude lake ecosystems are estimated to be net sources of atmospheric carbon dioxide (CO_2), releasing between 74-347 Tg-C yr^{-1}(Hastie et al. 2018). For the boreal region, this emission has been postulated to be one of the largest carbon fluxes from northern latitude aquatic environments (Hastie et al. 2018). Arctic-boreal regions maintain one of the largest pools of legacy carbon susceptible to mineralization due to changing climate conditions (Schuur et al. 2015, Olefeldt et al. 2016).

The input of carbon to aquatic systems requires hydrologic connectivity, whether across the surface or within the subsurface. Aquatic boundaries are not static in space or time. Lake areas and perimeters can change annually (Rover et al. 2011) and seasonally (Cooley et al. 2017); both may be influenced by the underlying distribution of permafrost soils (Karlsson et al. 2015). ***The magnitude and extent of seasonally inundated lands remains unknown, and we hypothesize that the region of regularly inundated soils as well as terrestrial soils inundated during transitory events are hotspots for the cycling of carbon and represent a component of the landscape highly vulnerable to change.***

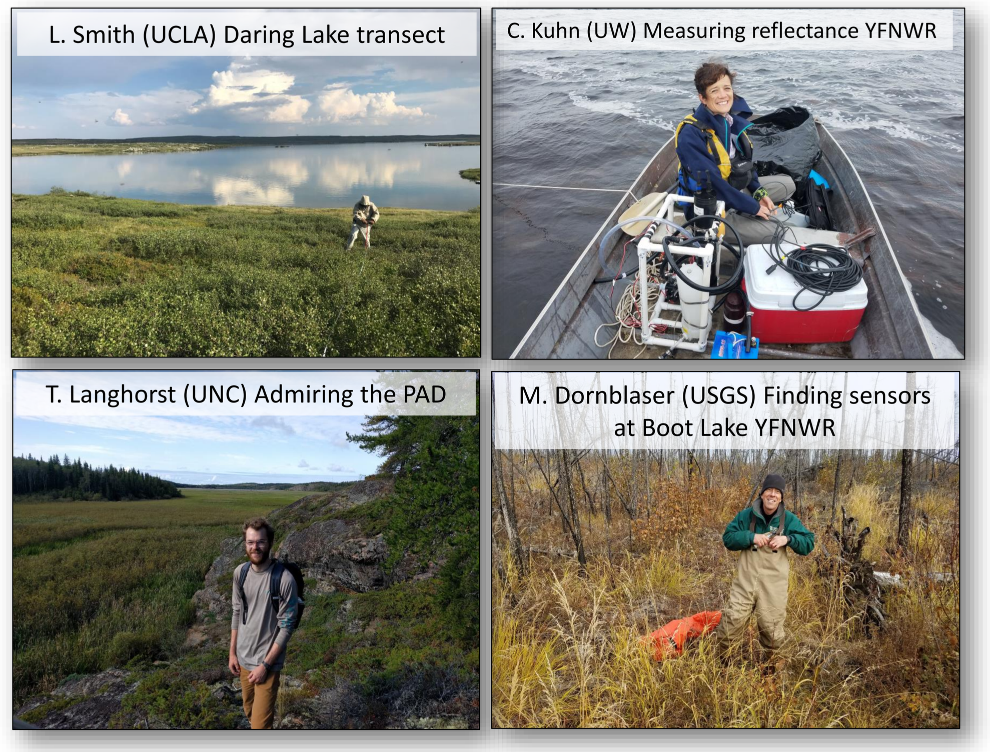
Science Objectives:

O1: Utilize UAVSAR, AirMOSS, AirSWOT, LVIS, and AVIRIS-NG to identify inundation extent and water surface elevation across northern latitude lake ecosystems.

O2: Identify and measure the connectivity of terrestrial ecosystems to lake ecosystems with changing inundation extent and quantify the signature and concentrations of terrestrial and aquatic carbon sources.

O3: Quantify the fluxes of CO_2 and CH_4 to the atmosphere across a gradient from unsaturated to saturated soils and vegetation.

Tier 2 Science Questions: This proposal addresses questions 3.4, 3.5 and 3.6 focusing on the intersection of changing hydrology, species composition, and carbon cycling across both terrestrial and aquatic domains.



Methodology

Airborne and field data collections are designed to vary from low terrestrial-aquatic connectivity through the hydrologic systems (YFNWR) to high hydrologic connectivity (Peace Athabasca Delta)

Sporadic permafrost exists in the Yukon Flats. The Peace Athabasca Delta has extreme patterns of inundation and evaporation each year. The Yellowknife – Daring Lake system sits within the Canadian shield, with shallow surface and ground water flow paths

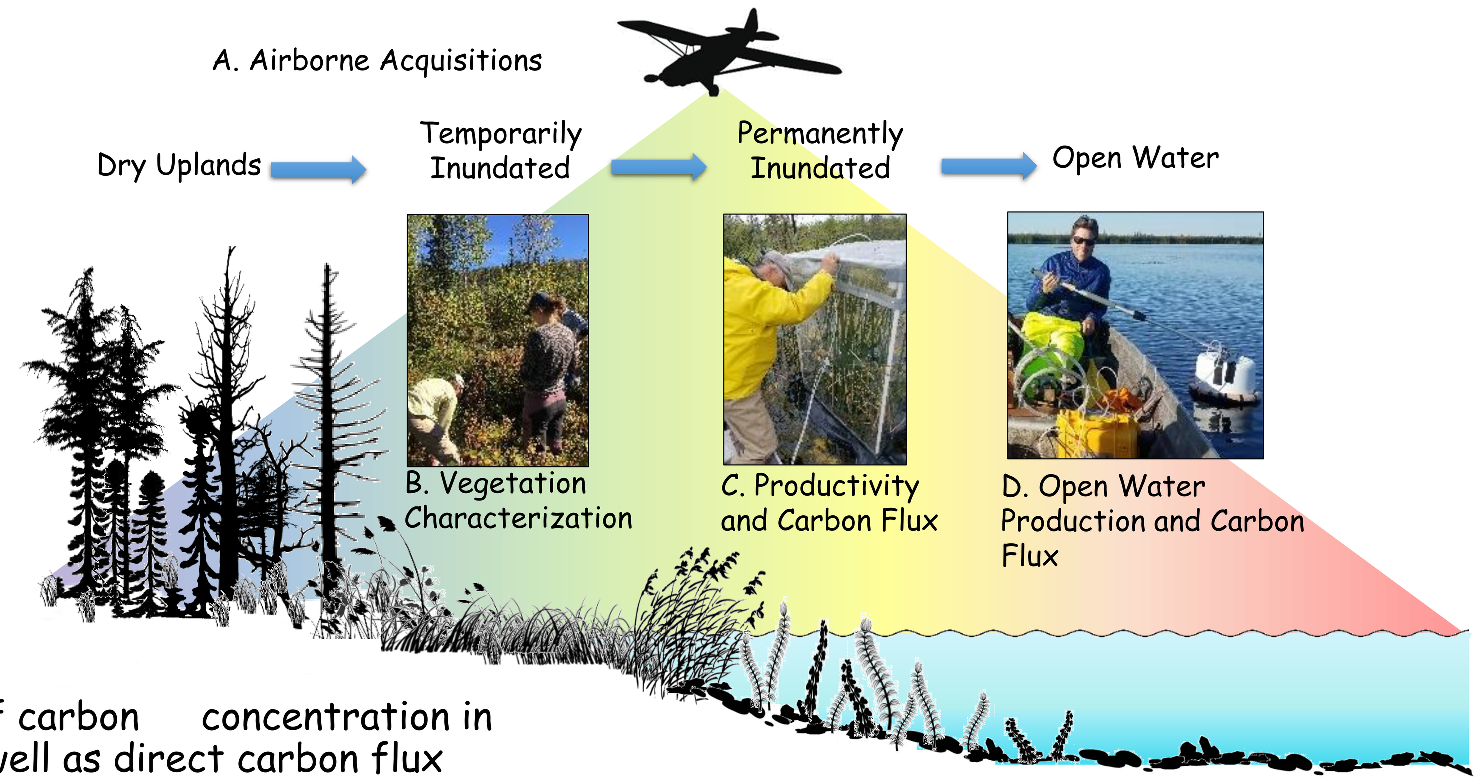


Figure 2. Methodological Approach

A. Airborne data from UAVSAR, LVIS, AirSWOT and AVIRIS-NG will be utilized to identify vegetation composition and structure for mapping and inundation extent.
B. Field based site validation will be conducted summer 2019, 2020 for species composition,
C. Field measurements across the domain of inundation of carbon concentration in water, chemical composition of organic matter, as well as direct carbon flux summer 2019, 2020
D. Open water carbon measurements of chemical composition, ecosystem productivity, and carbon flux. Integration of carbon cycling and AAC data will be done across each of the 4 defined zones.

Impacts on ABoVE Science:

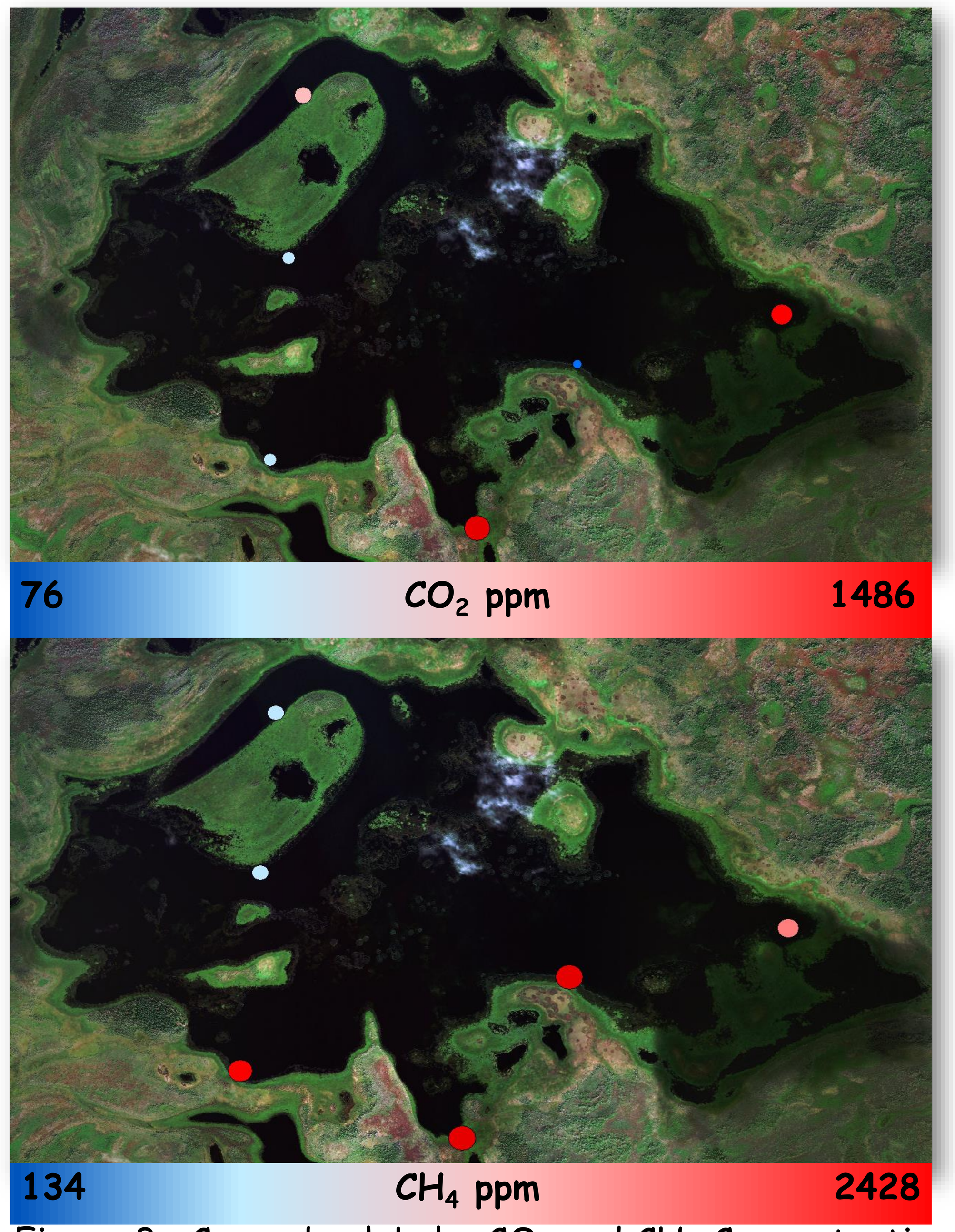


Figure 3. Canvasback Lake CO_2 and CH_4 Concentrations summer 2018

We will directly measure both the CO_2 and CH_4 flux from these potential hotspots in direct collaboration with ABoVE2 project "**Characterizing Microtopgraphic Hot-spots and Landscape-scale Methane Emissions Across the ABoVE Domain" PI's, C. Miller, K. Walter Anthony, and C. Elder**

Location matters when considering the role that water plays in the cycling of carbon in Arctic-boreal landscapes. Lakes historically have been thought of as atmospheric carbon sources, but results from ABoVE1 within the Yukon Flats National Wildlife Refuge (YFNWR) indicate that open waters remain under-saturated throughout the open water season (Bogard et al. 2019), furthermore, lakes are highly variable.

CO_2 and CH_4 concentrations can differ by orders of magnitudes from the littoral zone to areas of open water. Measurements from ABoVE 1 suggest that the littoral zone – or the area of inundation maintains high concentrations of carbon gases. **Are these hotspots within arctic and boreal ecosystems?**

Figure 4: 12-Mile Lake in the Yukon Flats National Wildlife Refuge recently inundated forested land from ice jams on the Yukon River (D. Butman)

Beyond Phase I:

ABoVE2 will build on NESSF recipient Catherine Kuhn's findings that GPP scales across Airborne and satellite remote sensing platforms with the potential to scale to the ABoVE domain (Figure 5).

Results from ABoVE2 will include high resolution and field validated maps of inundation extent, and carbon flux derived from data presented in Figure 6. Further collaboration and validation of AirSWOT will be included with this effort.

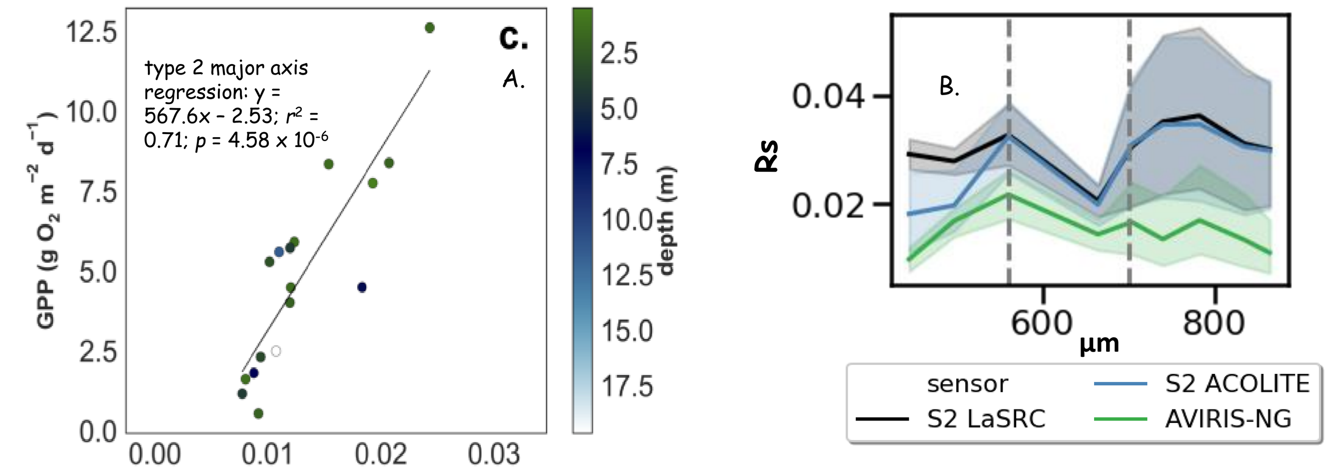


Figure 5: A. Correlation between Gross Primary Production derived from estimate of ecosystem metabolism from ^{18}O, and the OLI Band 3(Green). Points colored by depth. B. Reflectance comparisons for arctic lakes across field – Airborne – Sentinel-2 scales (Kuhn et al. in prep).

Anticipated results include:

1. Baseline assessments of the potential importance of inundated lands for the scaling of terrestrial and aquatic fluxes of carbon controlled by hydrologic variability.
2. Comprehensive chemical and flux dataset in underrepresented regions for boreal/arctic monitoring of aquatic systems.
3. Strong and lasting collaboration between USFWS, ECCC, NWT and Canadian Academic partners focused on management of changing hydrology in arctic systems.

Collaborators:

Mark Bertram, U.S. Fish and Wildlife Service, Fairbanks, AK
Dr. Daniel Peters, Environment & Climate Change Canada
Mr. Bruce Hanna, Government of the NWT
Dr. Sherry Schiff, University of Waterloo
Dr. Charles Miller, NASA J.P.L
Dr. Clayton Elder, NASA J.P.L
Dr. Colin Gleason, University of Massachusetts, Amherst.

Environment and Climate Change Canada
Environnement et Changement climatique Canada

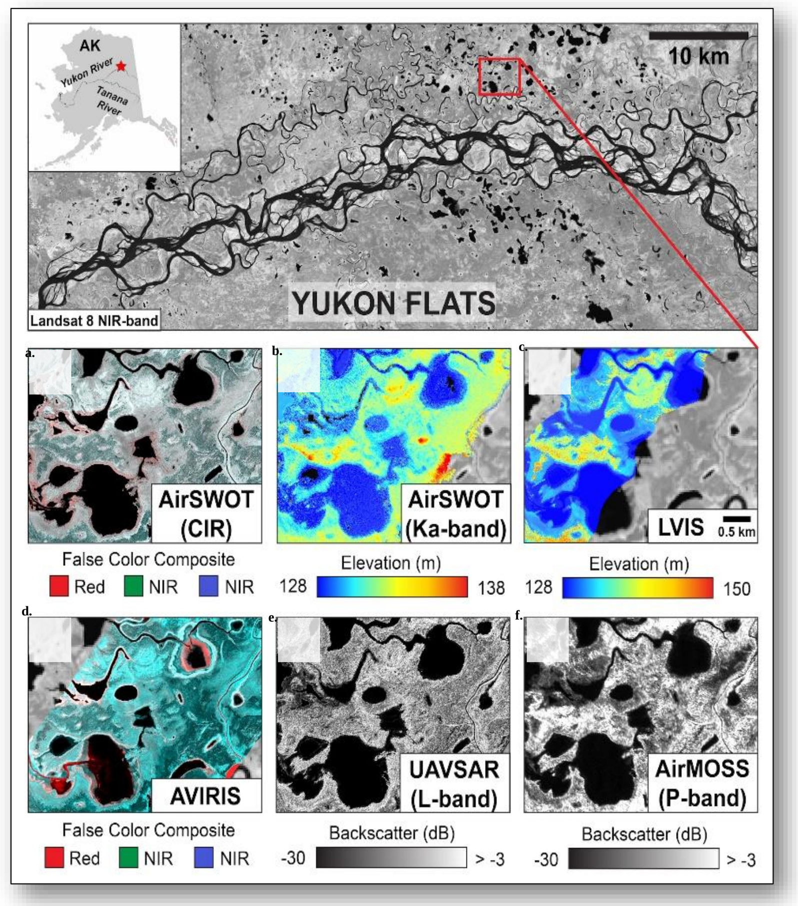


Figure 6: Example datasets to be used for inundation extent – vegetation class and structure, and mapping of regions for carbon flux. The Yukon Flats are depicted here.

Citations

Bogard, M. J., and Coauthors, 2019: Negligible cycling of terrestrial carbon in many lakes of the arid circumpolar landscape. *Nature Geosci*, **12**, 180-185.; Cooley, S., L. Smith, L. Stepan, and J. Mascaro, 2017: Tracking Dynamic Northern Surface Water Changes with High-Frequency Planet CubeSat Imagery. *Remote Sensing*, **9**, 1306.; Hastie, A., R. Lauerwald, G. Weyhenmeyer, S. Sobek, C. Verpoorter, and P. Regnier, 2018: CO2 evasion from boreal lakes: Revised estimate, drivers of spatial variability, and future projections. *GLOBAL CHANGE BIOL*, **24**, 711-728.; Karlsson, J. M., F. Jaramillo, and G. Destouni, 2015: Hydro-climatic and lake change patterns in Arctic permafrost and non-permafrost areas. *J Hydrol*, **529**, 134-145.; Olefeldt, D., and Coauthors, 2016: Circumpolar distribution and carbon storage of thermokarst landscapes. *Nature Communications*, **7**, 13043.; Rover, J., L. Ji, B. K. Wylie, and L. L. Tieszen, 2011: Establishing water body areal extent trends in interior Alaska from multi-temporal Landsat data. *Remote Sensing Letters*, **3**, 595-604.; Schuur, E. A. G., and Coauthors, 2015: Climate change and the permafrost carbon feedback. *Nature.*, **520**, 171