Implications of Thermokarst Landforms on Carbon Cycling in the Yukon Kuskokwim Delta, Alaska

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Introduction

Thermokarst processes are an often-underrepresented component of the carbon permafrost dynamic, partly due to the challenges of quantifying their emissions, which can be highly heterogeneous at small spatial scales and variable over time as thermokarst development progresses or stabilizes.

How do thermokarst features in burned and unburned shrub-tussock tundra impact active layer development and CO_2 release?

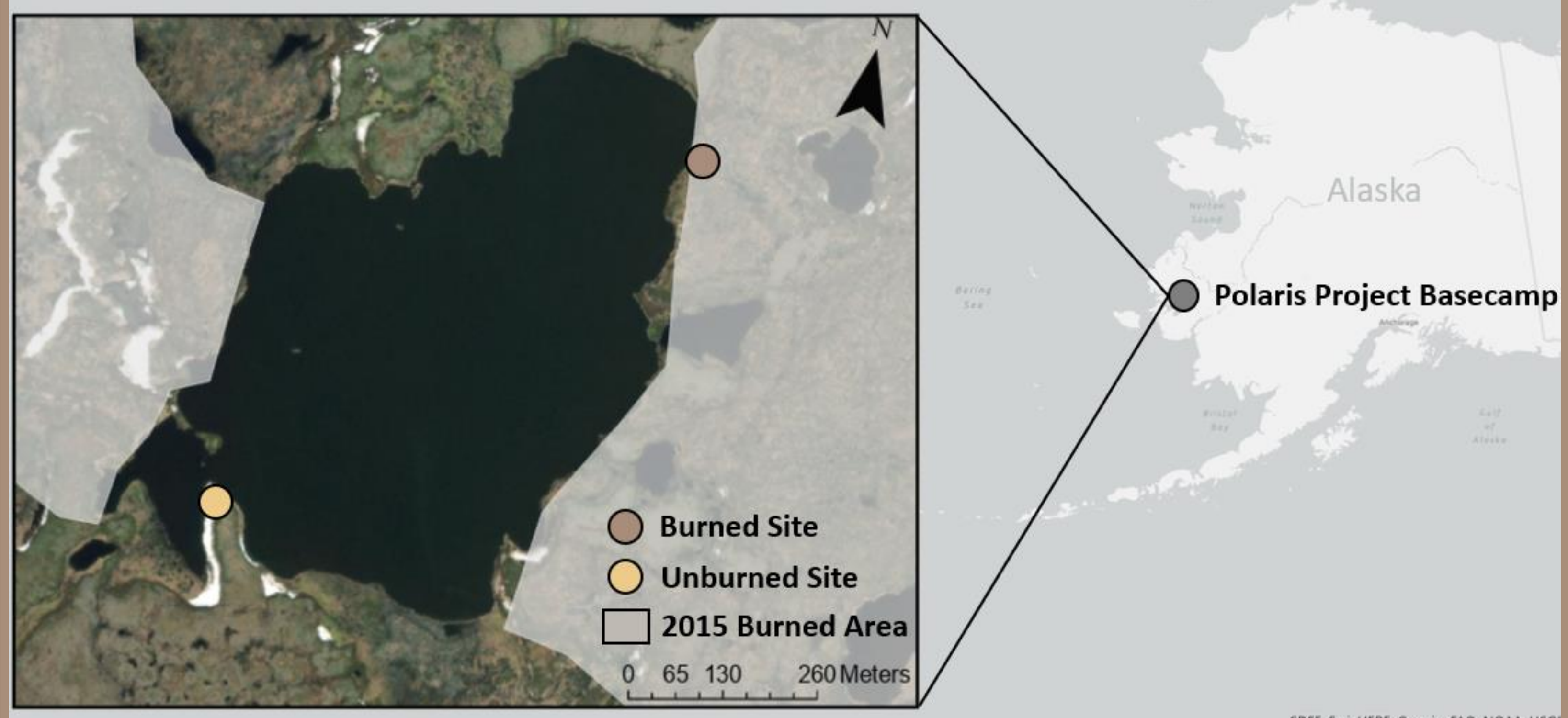

Figure 1: Map of study area within the Yukon Kuskokwim Delta, AK.

Methods

- Sampling took place over a 2-week field campaign in July 2022.
- Measured net ecosystem exchange (NEE) and ecosystem respiration (R_{eco}) at "disturbed" (within 1-2m of ground cracking) and "control" (within 2-10m of cracking) plots using an LI-7810. Gross primary productivity (GPP) determined by the difference between NEE and R_{eco}.
  - Burned (2015) site had 3 disturbed and 3 control plots.
  - Unburned site had 2 disturbed and 2 control plots.
- Thaw depth/soil temperature was measured at flux plots and along a transect that ran perpendicular to the ground crack.
- Analysis of variance (ANOVA) and Tukey post hoc tests were used to determine site differences.
- Significance ($p<0.05$) is noted by different letters on the figures.

Figure 2: A tarp was used to cover the chamber to measure CO_2 R_{eco}.

Results

a)

b)

Thaw Depth (cm)

Burned/ Control	Burned/ Disturbed	Unburned/ Control	Unburned/ Disturbed
30 ± 0.73	37 ± 2.91	36 ± 1	72 ± 8

Figure 3: a) To-scale diagram of a thaw depth transect at the burned site. b) Across both sites, thaw depth was greatest at disturbed plots.

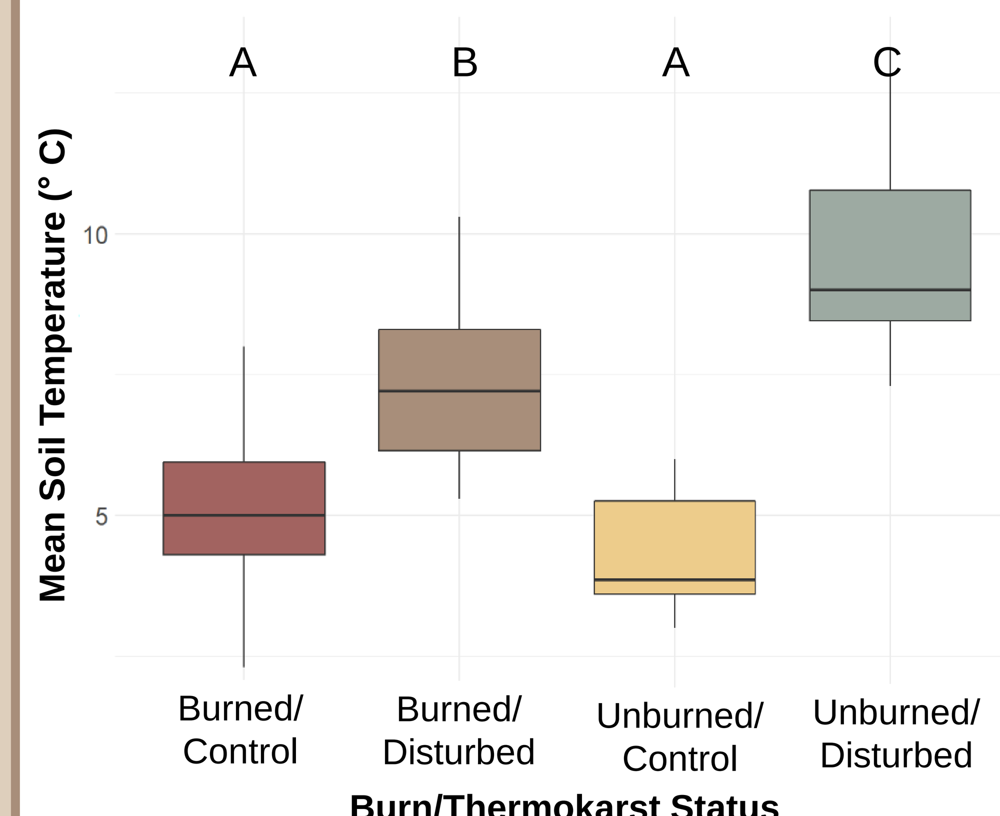

Figure 4: Disturbed plots at both sites had significantly higher soil temperatures than the respective control plots.

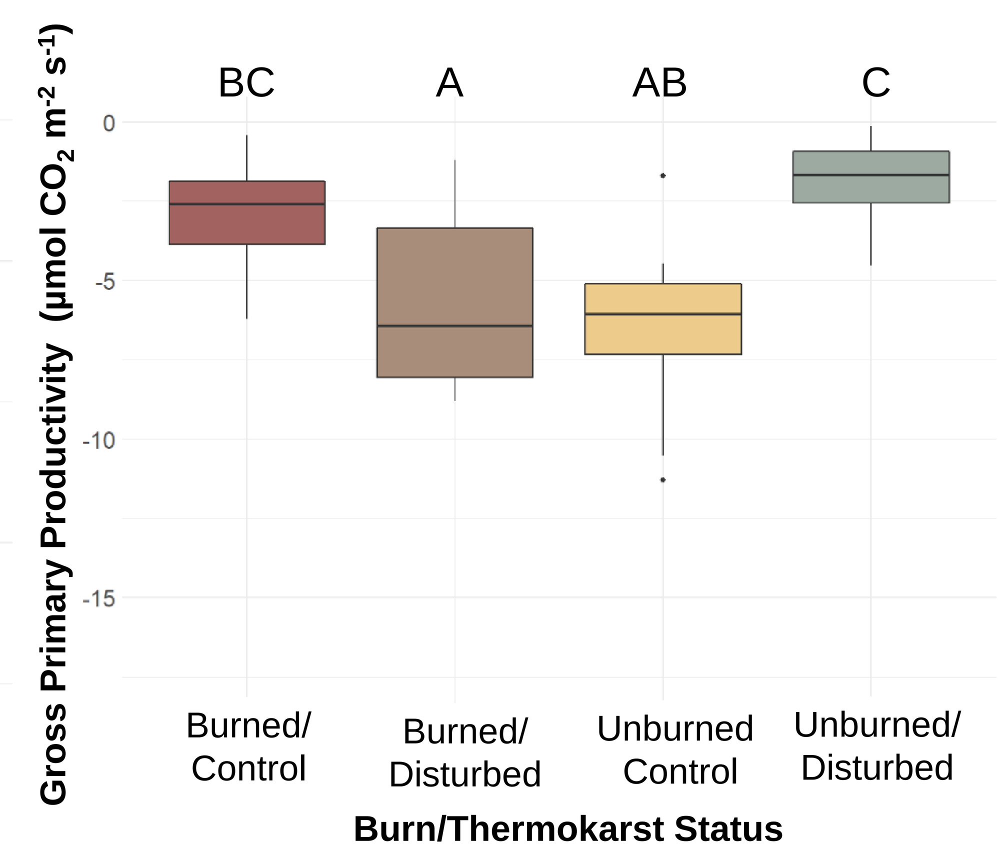

Figure 5: In burn impacted areas, disturbed plots had significantly higher CO_2 uptake than control plots. At the unburned site, the reverse is true as control sites had significantly higher CO_2 uptake than disturbed areas.

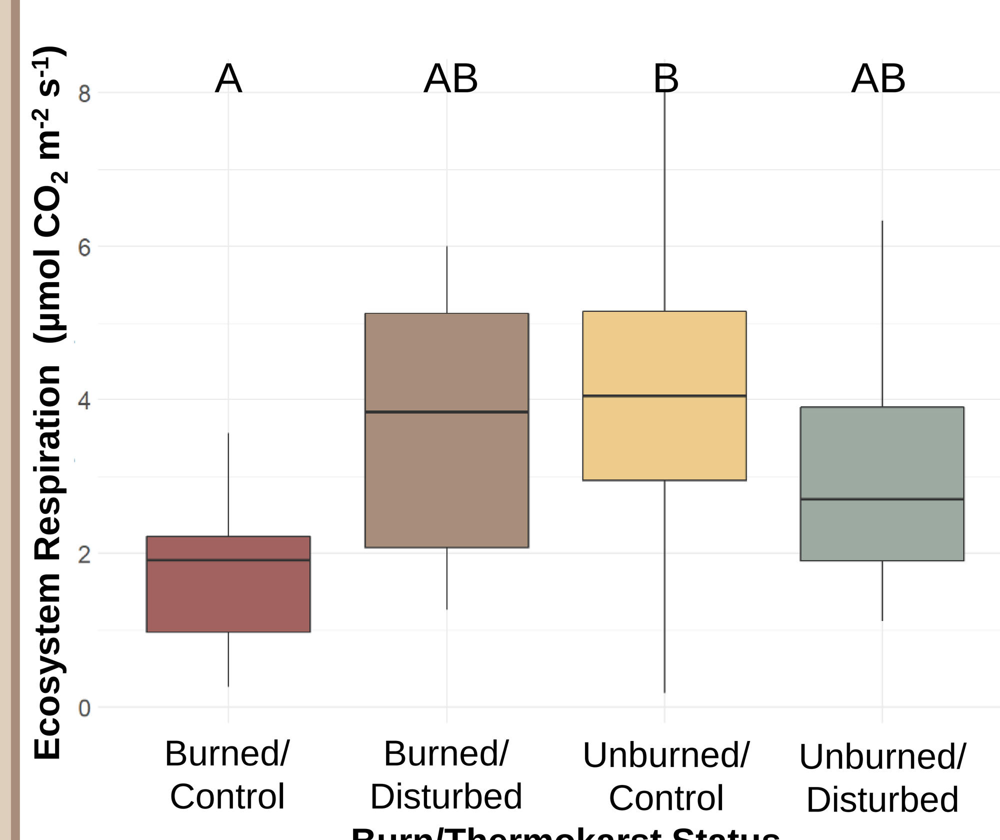

Figure 6: CO_2 respiration at the unburned control site was significantly higher than respiration at the burned control site.

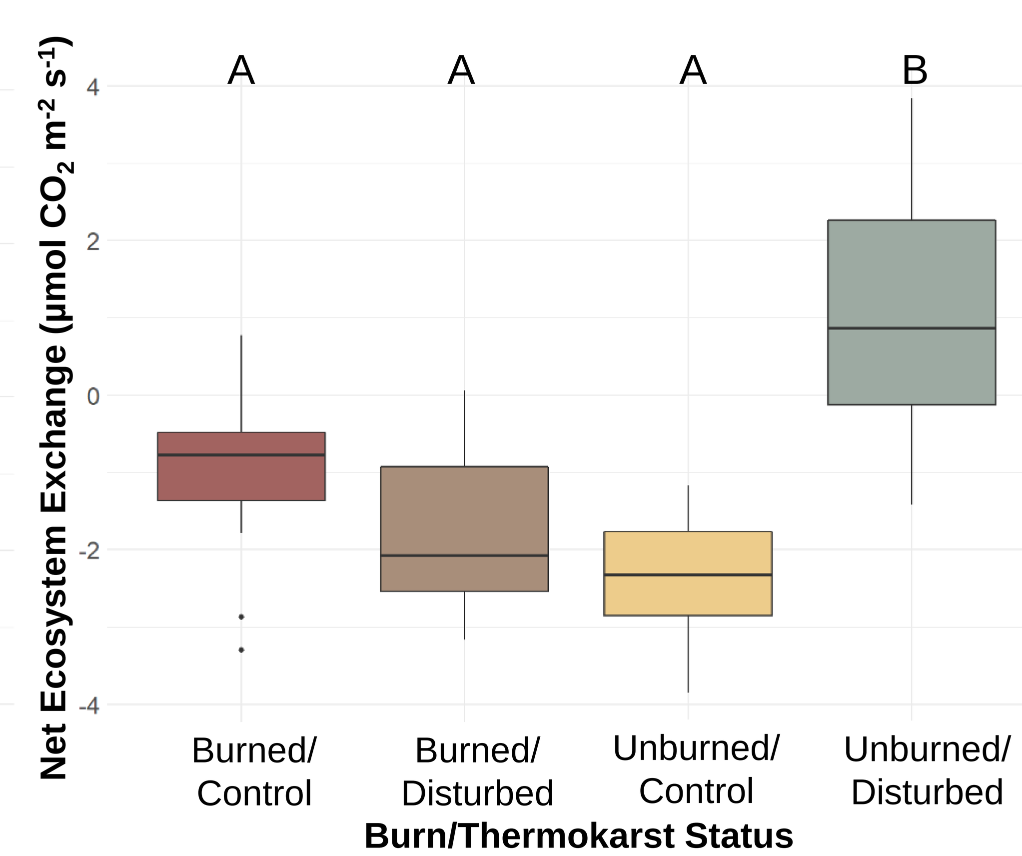

Figure 7: At the burned site, all plots had net uptake. At the unburned site, control plots had a net uptake of CO_2, whereas disturbed plots had net emissions.

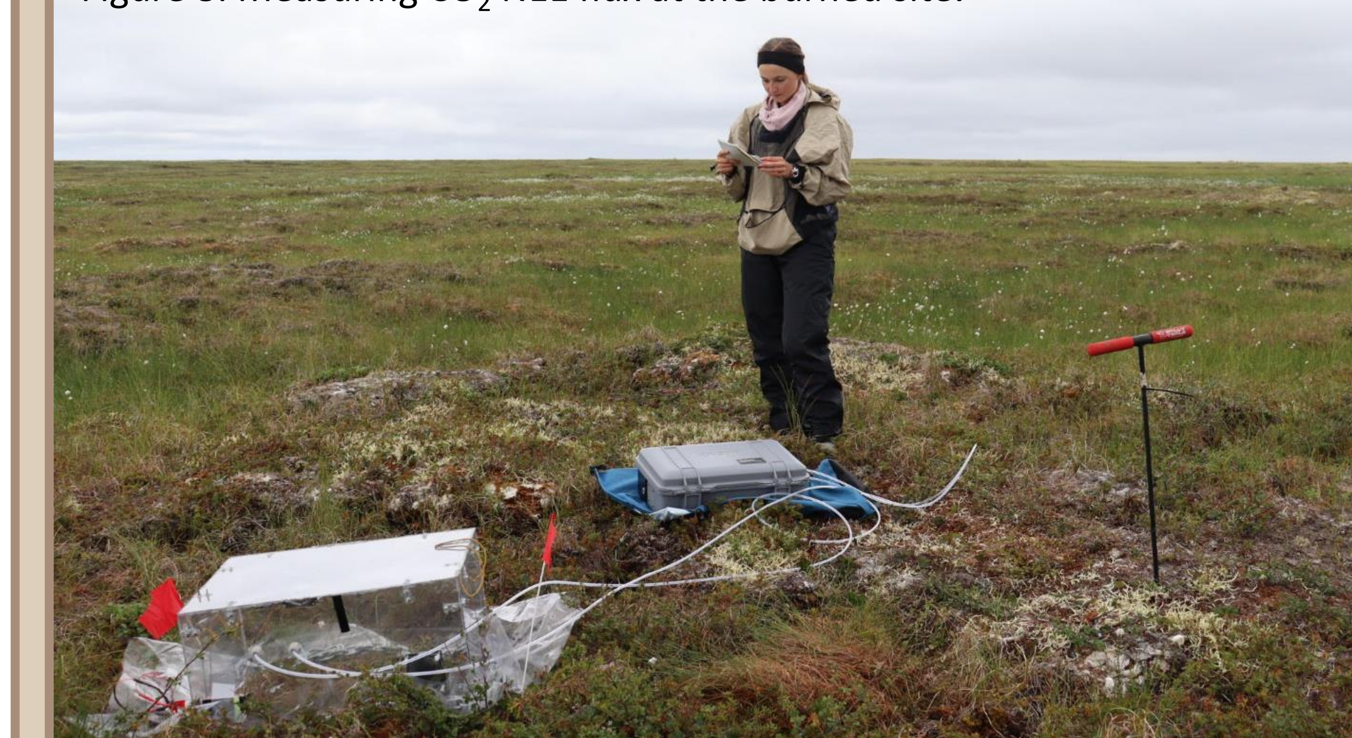

Figure 8: Measuring CO_2 NEE flux at the burned site.

Results and Discussion

- The warmer and deeper active layer observed at disturbed sites indicate the potential for thermokarst events to induce lateral thaw thereby initiating a positive feedback which further warms and thaws the area (figures 3 & 4).
- At the burned site, we observed more CO_2 uptake at disturbed sites compared to control sites (figure 5), likely due to the recovery of the feature which points to the potential of recovering vegetation at thermokarst disturbances to offset some of the initial gasses emitted.
- Increased nutrient availability due to the fire could help explain the differences in carbon fluxes, GPP and R_{eco}, (figures 5 & 6) at the burned vs. the unburned sites. Vegetation cover was also an important driver of fluxes, as the burn impacted control sites had not fully recovered yet and had less vegetation than at the unburned control sites.
- The impacts of wildfire and recovery combined with the heterogeneous nature of thermokarst disturbances both likely contribute to the difference in NEE at the unburned disturbed site compared to the other plots (figure 7).

Conclusion/Future Work

- The Arctic is warming disproportionately to the rest of the world and is being impacted by thermokarst formations and wildfires, whose combined disturbance have a heterogeneous impact on CO_2 fluxes. Incorporating disturbance and recovery are critical to understanding carbon cycling in Arctic landscapes.
- Future work includes expanding this research spatially and temporally.

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