The Effects of Tundra Wildfires on Soil Carbon Fluxes

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Introduction

This study aimed to investigate the consequences of fire on carbon-rich Arctic tundra ecosystems. Our focus centered on a comparative analysis of soil carbon fluxes within the peat plateaus in Alaska's Yukon-Kuskokwim Delta (YKD), specifically examining areas that have been affected by fires versus those that have remained undisturbed. Our hypothesis was that burned lowland soils release lower quantities of carbon dioxide (CO_2) and methane (CH_4) than unburned soils, even years after fire events occur. Monitoring and anticipating the role of peat and permafrost in global climate change is of extreme import, as amplified warming in the Arctic enables the decomposition or combustion of prehistoric organic materials and, consequently, the release of a massive repository of carbon (Rantanen, M., *et al.*).

Methods

- Examined 72 plots across 6 tundra plateaus:
  - 3 burned plateaus (affected by 2015 wildfires)
  - 3 unburned plateaus
- Selected 4 plots of each vegetation type at each site, where dominant vegetation type covered ≥ 80% of a 50cm x 50cm quadrat (below)
- Dominant vegetation categories were lichens (*Cetraria cucullata, Cladina Mitis*), forbes and shrubs (usually rubus-dominated (*Rubus chamaemorus*)), and sphagnum mosses (*Sphagnum fuscum, Polytrichum strictum*).


Burned Lichens

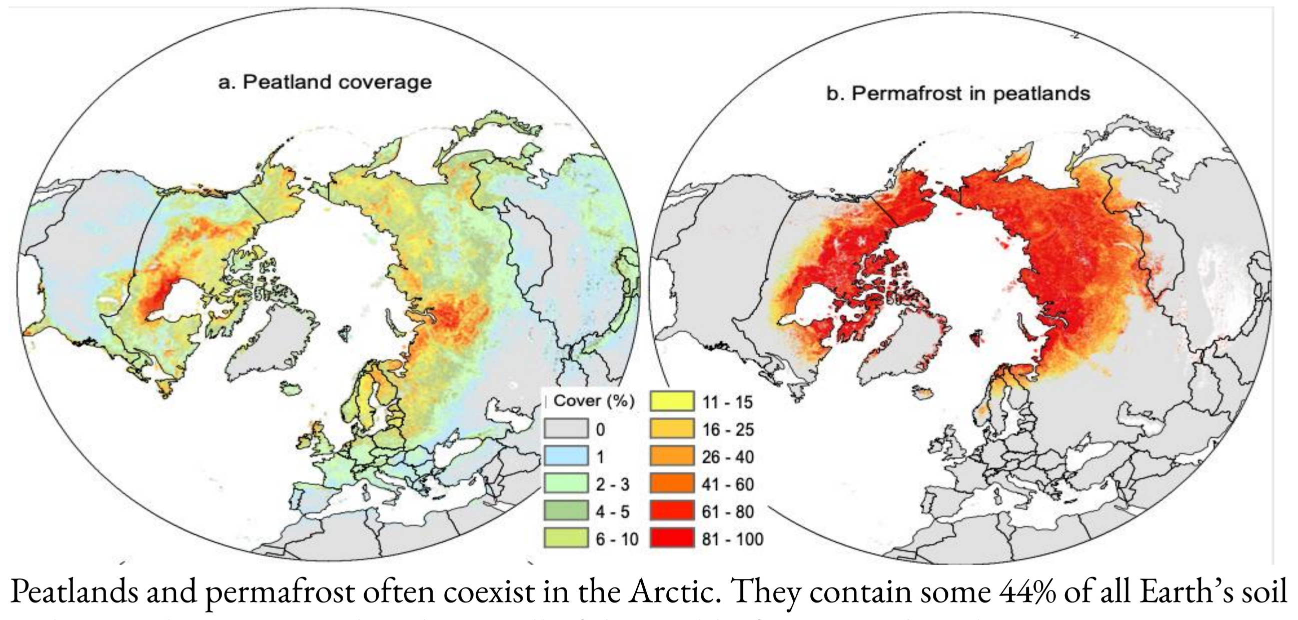

Unburned Lichens


Unburned Rubus


Unburned Sphagnum

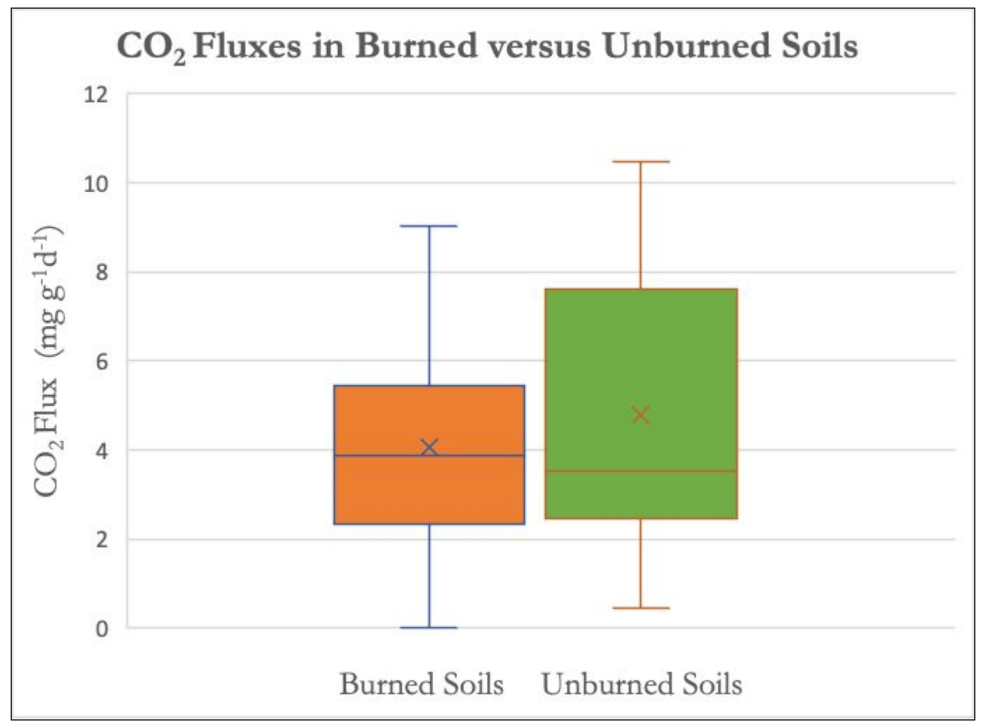
- At each plot, recorded permafrost thaw depth, soil temperature, and soil moisture; removed living vegetation; extracted soil core; and recorded core dimensions
- Incubated top 5cm of non-living soils in LI-COR trace gas analyzer for 3 minutes/sample, to calculate rate of linear soil carbon gas fluxes
- Homogenized, weighed, and dessicated 18 representative soil subsamples (9 burned, 9 unburned, 6 of each dominant vegetation type)
- Completed a loss on ignition to calculate carbon gas fluxes in relation to soil organic matter (SOM) content in burned versus unburned sites.
- Conducted an independent two sample t-test to identify statistical differences between fluxes from burned versus unburned areas.

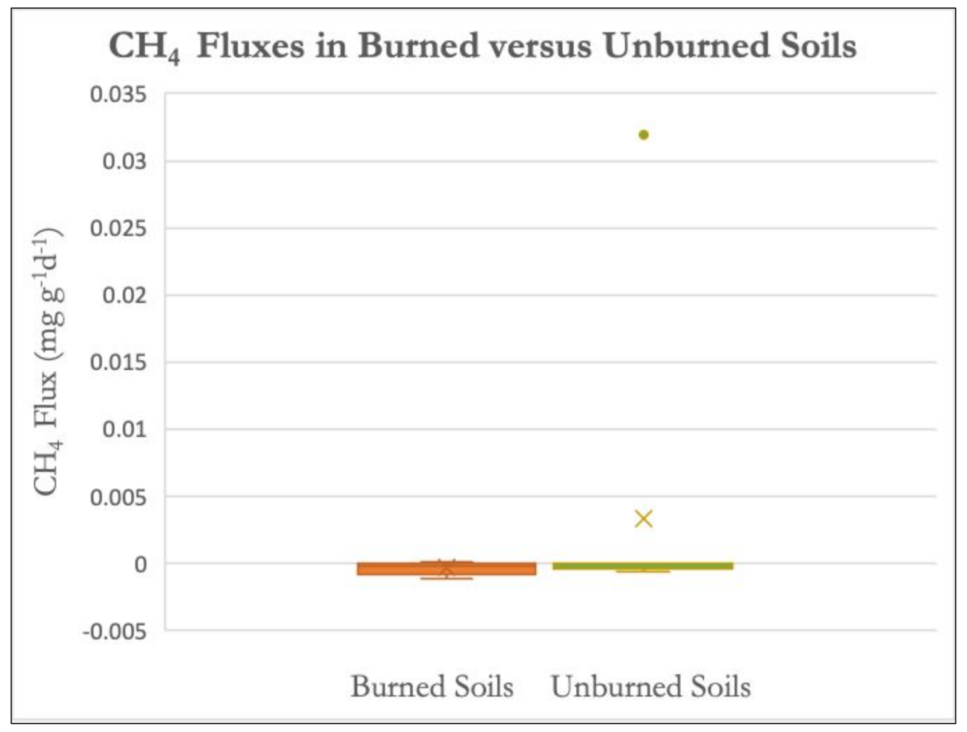
Study Area



Peatlands and permafrost often coexist in the Arctic. They contain some 44% of all Earth's soil carbon, and twice as much carbon as all of the world's forests combined.

Results





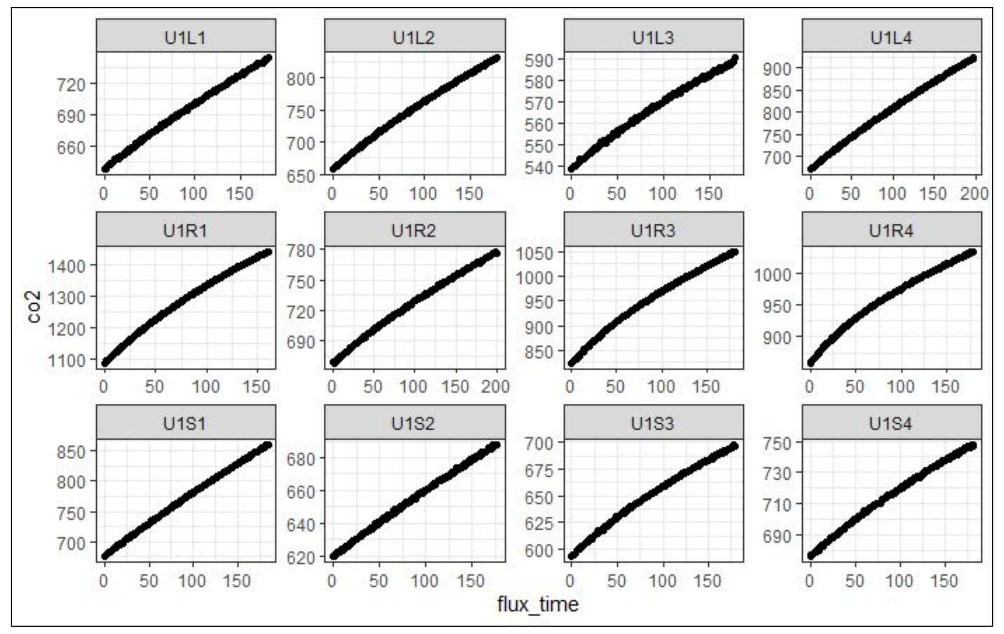
Figures 1 and 2 (Above): Box-and-Whisker plots show mean, median, and quartiles of carbon dioxide and methane gas production from burned versus unburned tundra soils. Mean CO_2 and CH_4 production was higher from unburned soils, although a statistical difference was not detected (Table 2).

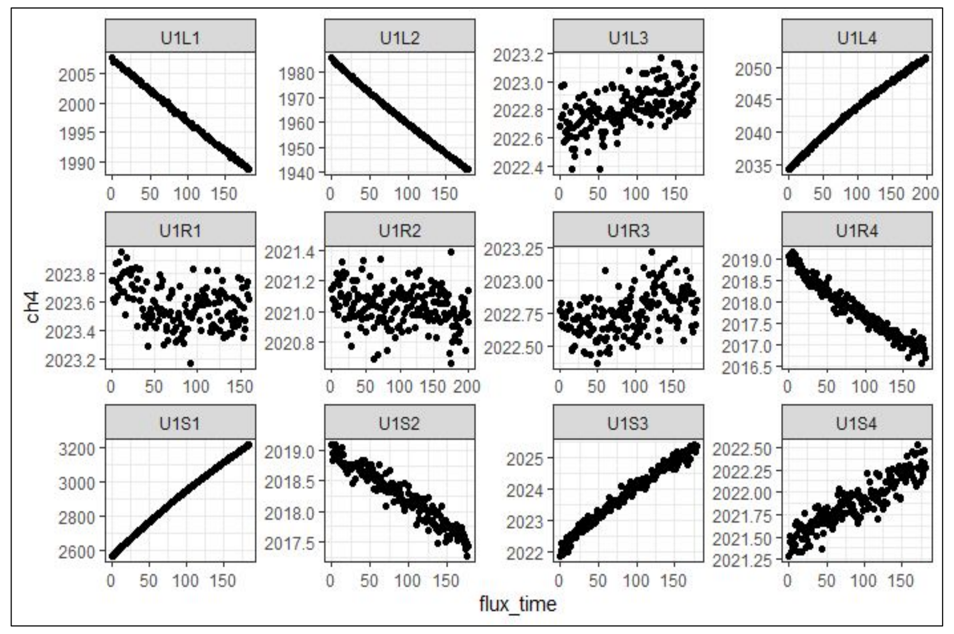
Table 1: Mean gaseous soil carbon fluxes are compared from burned versus unburned tundra soils, assessing both carbon dioxide (CO_2) and methane (CH_4) fluxes.

	CO_2 flux: burned soils	CO_2 flux: unburned soils	CH_4 flux: burned soils	CH_4 flux: unburned soils
Mean Flux Rates of soils (mg $g^{-1}d^{-1}$)	4.50	4.80	-0.0003	0.0034

Table 2: A statistical analysis was completed using an independent two-sample t-test, assessing differences in carbon flux rates between burned and unburned tundra soils.

	CO_2	CH_4
Difference in Mean Flux Rate of burned versus unburned soils (mg $g^{-1}d^{-1}$)	0.2955 (unburned > burned)	0.00373 (unburned > burned)
P(T<=t) two-tail	0.8312	0.3265





Figures 3 and 4 (Above): Examples of CO_2 and CH_4 flux graphs observed during trace gas analysis.

Findings

- Statistically significant differences were not found between the CO_2 (0.8312) and CH_4 (0.3265) emission rates of burned versus unburned sites, by running an independent t-test.
- Mean CO_2 outputs from observed unburned plateaus were slightly higher than those from observed burned sites.
- Microbial communities in burned soils consume more CH_4 than those in unburned soils.
- CH_4 was observed to be consumed in most burned and unburned plateaus, across all vegetation types, indicating that the chosen peat plateaus are methane sinks.

Discussion

- Contrary to the initial hypothesis, there is not a significant difference between carbon fluxes from burned and unburned soils.
- Past wildfire events may not affect soil carbon flux behaviors from Arctic tundra peatland ecosystems, 8 years after fire events.
- Due to time constraints, only 25% of soil samples were analyzed; vegetation type, soil and ambient temperature, and saturation were not analyzed after desiccation but showed little impact upon wet soil analysis.
- In the future, this experiment can be replicated with additional burned and unburned sites, with all samples being dried and measured for a more representative sample pool. Such replications can help draw more accurate conclusions about acquired CO_2 and CH_4 fluxes, along with comparing organic matter consumption between burned and unburned areas, over various vegetation types.
- Measurements of soil organic matter and microbial biomass are impending to draw further connections to recorded fluxes.

Acknowledgments: We acknowledge and respect the Yup'ik and Cup'ik communities as traditional stewards of the lands, waters, and rich biodiversity in western Alaska. Financial support for this project was provided by NSF-1915307.
We would also like to thank the Woodwell Climate Research Center for this phenomenal opportunity, along with Susan Natali for inspiring us with her endless wisdom and passion for Arctic geosciences, Seeta Sistla for advising us on soil biogeochemistry, Nigel Golden and Tiffany Windholz for organizing our tundra adventures, and the entire Polaris Project team for their grit, zeal, and humor in the field.