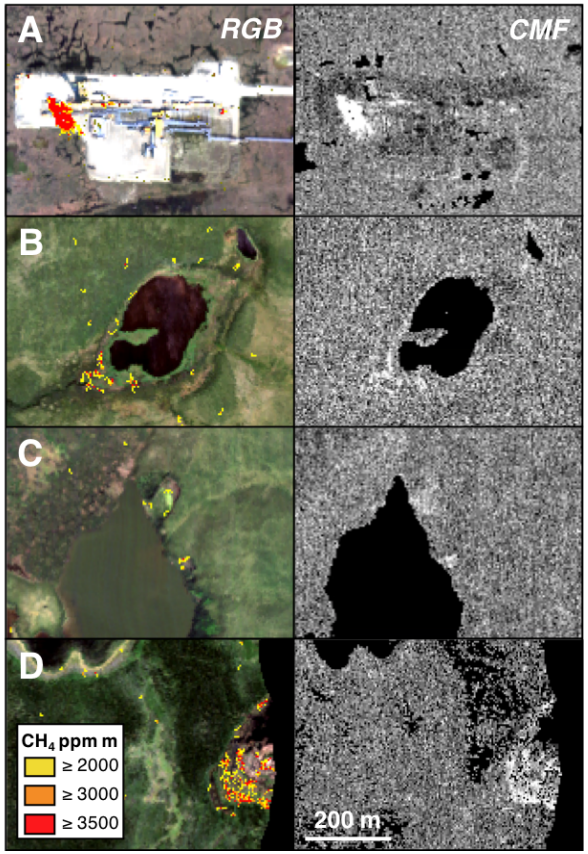
# Airborne mapping reveals emergent power law of Arctic methane emissions

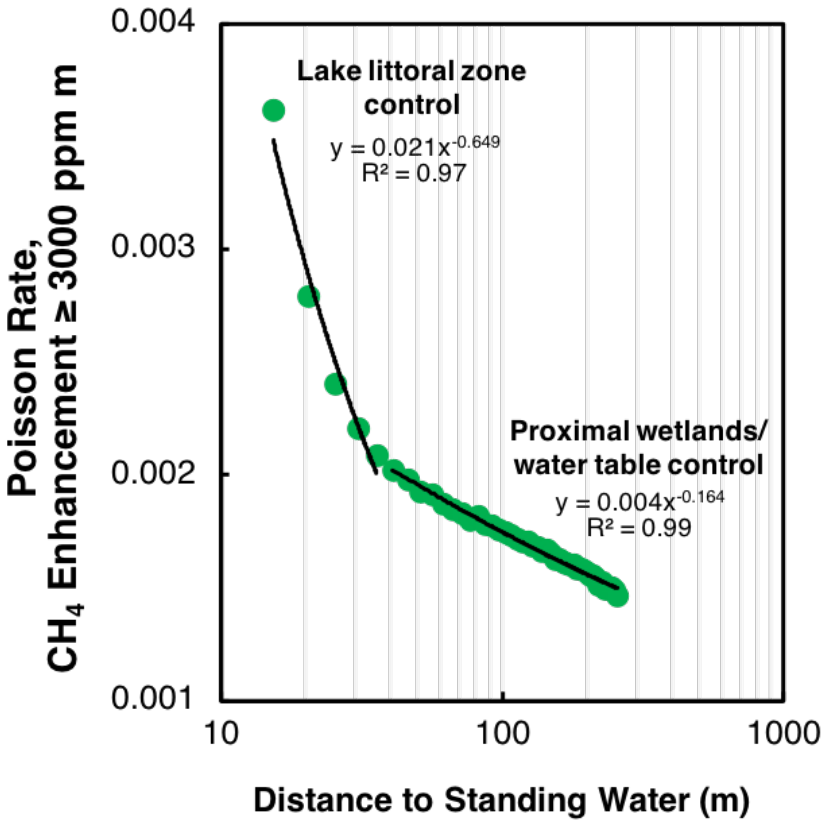
C.D. Elder, D.R. Thompson, A.K. Thorpe, P.J. Hanke, K.M. Walter Anthony, C.E. Miller. (2020),
*Geophys. Res. Lett.* (2020). DOI:10.1029/2019GL085707

**Highlight:** Airborne mapping of millions of methane hotspots, at unprecedented spatial resolution and coverage, elucidated the fine-scale spatial distribution of intense emission sites proximal to water bodies across the broad N. American high-latitude permafrost domain.

**Example anthropogenic (A) and ecological (B-D) hotspot detections in the study domain**




**Domain-wide, fine-scale spatial pattern in $CH_4$ hotspot probability proximal to open water**



# Airborne mapping reveals emergent power law of Arctic methane emissions

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## Background

- Arctic $CH_4$ emissions from permafrost sources could fuel a significant positive feedback to further climate warming.
- Despite their potential impact, Arctic $CH_4$ emissions and their sources are highly uncertain due to our inability to observe complex biogeochemical processes across heterogenous landscapes.

## Analysis

- We conducted an airborne survey (unprecedented spatial resolution and coverage) mapping $CH_4$ emission hotspots across Alaska and w. Canada, revealing process-level spatial patterns, on the domain-scale, that were mirrored in flux observations at two ground validation sites.

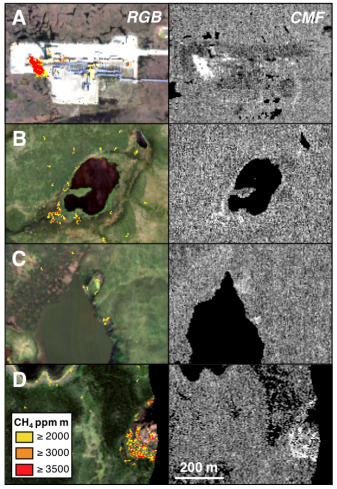
## Findings

- NASA's Next Generation Airborne Visible/Infrared Imaging Spectrometer (AVIRIS-NG) observed roughly 2 million $CH_4$ emission hotspots at an individual element resolution of 5 m across a 30,000 $km^2$ study domain -resulting in nearly 1 billion samples total.
- Hotspots followed two spatial power laws, where 40m from water was a threshold for occurrence, and a novel parameter for emissions upscaling.
- The geomorphic factors that regulate the distribution of domain-wide, remotely-sensed hotspots are the same that control wide-ranging $CH_4$ fluxes observed at the site-level.

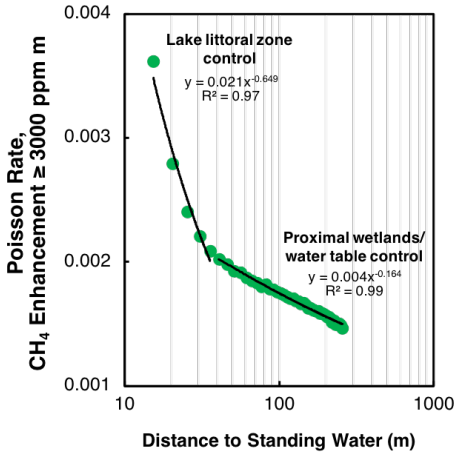
## Significance

Our observations have enabled statistical upscaling of meter-scale, process-level $CH_4$ dynamics across a broad and diverse study domain. We showed that relatively fine-scale distance thresholds from standing water have a significant impact on the occurrence of $CH_4$ hotspots, producing valuable metrics for improving the accuracy of regional emissions upscaling, model validation, and emission forecasting.

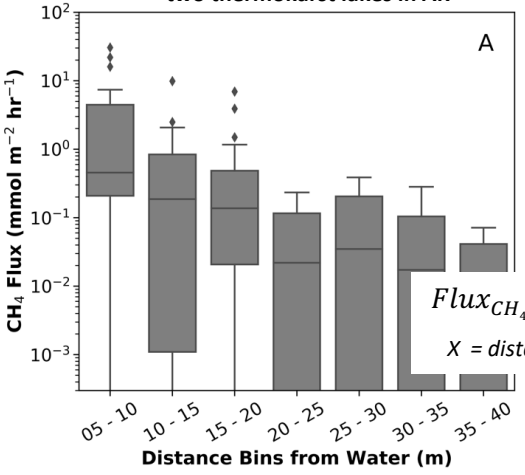
**Anthropogenic and ecological hotspot detections in the study domain**




**Domain-wide spatial pattern in $CH_4$ hotspots proximal to water**



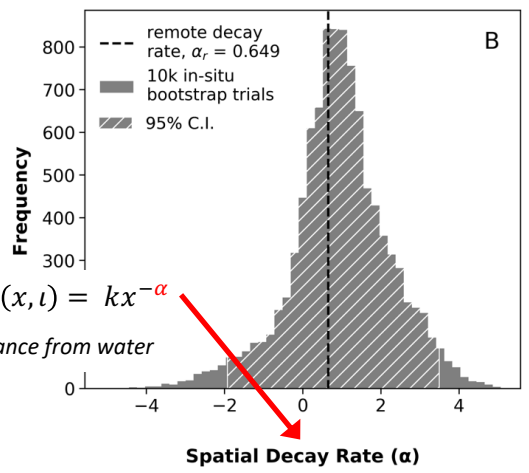

**In-situ $CH_4$ flux validation data from two thermokarst lakes in AK**




$$Flux_{CH_4}(x, \iota) = kx^{-\alpha}$$

*X = distance from water*

**Agreement in remote vs. in-situ spatial decay rate**



# Full Citation & Abstract

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## Abstract

Methane ($CH_4$) emissions from thawing permafrost amplify a climate warming feedback. However, upscaling of site-level $CH_4$ observations across diverse Arctic landscapes remains highly uncertain, compromising accuracy of current pan-Arctic $CH_4$ budgets and confidence in model forecasts. We report a 30,000-$km^2$ survey at 25-$m^2$ resolution (~1 billion observations) of $CH_4$ hotspot patterns across Alaska and northwestern Canada using airborne imaging spectroscopy. Hotspots covered 0.2% of the surveyed area, concentrated in the wetland-upland ecotone, and followed a two-component power law as a function of distance from standing water. Hotspots decreased sharply over the first 40-m from standing water ($y = 0.21x^{-0.649}$, $R^2 = 0.97$), mirroring in-situ flux observations. Beyond 40-m, $CH_4$ hotspots diminished gradually over hundreds of meters ($y = 0.004x^{-0.164}$, $R^2 = 0.99$). This emergent property quantifies the distribution of strong methanogenic zones from site to regional scales, vastly improving metrics for scaling ground-based $CH_4$ inventories and validation of land models.