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California Institute of Technology

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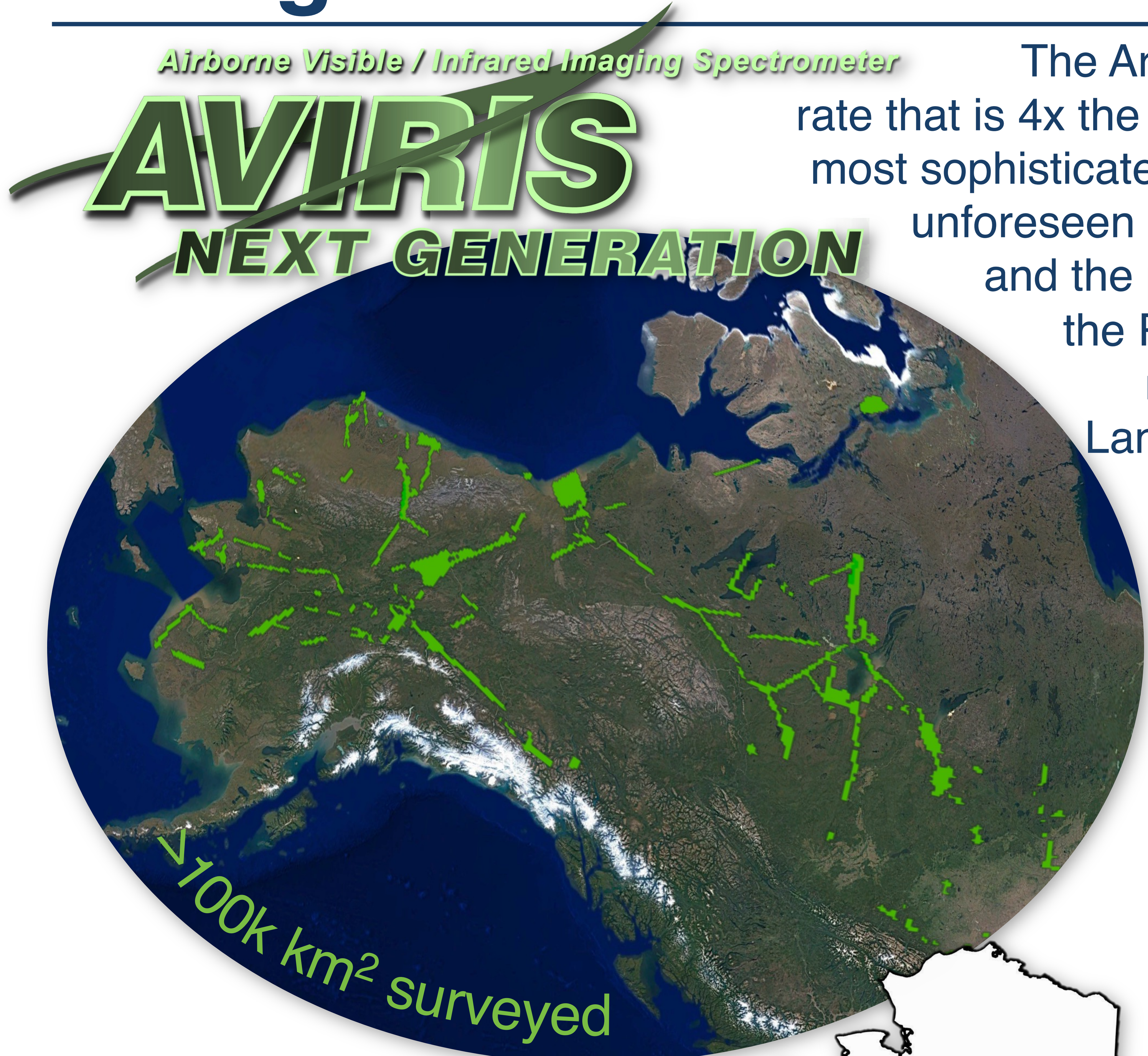
Regional scale patterns of remotely sensed methane hotspots with respect to Arctic lake change and thermokarst geomorphology

Clayton D. Elder (clayton.d.elder@jpl.nasa.gov), D.R. Thompson, L. Baskaran, I. Nitze, G. Grosse, N. Hasson, M.J. Engram, N. Tyler, K.M. Walter Anthony, and C.E. Miller

ARCTIC – BOREAL VULNERABILITY EXPERIMENT

Background



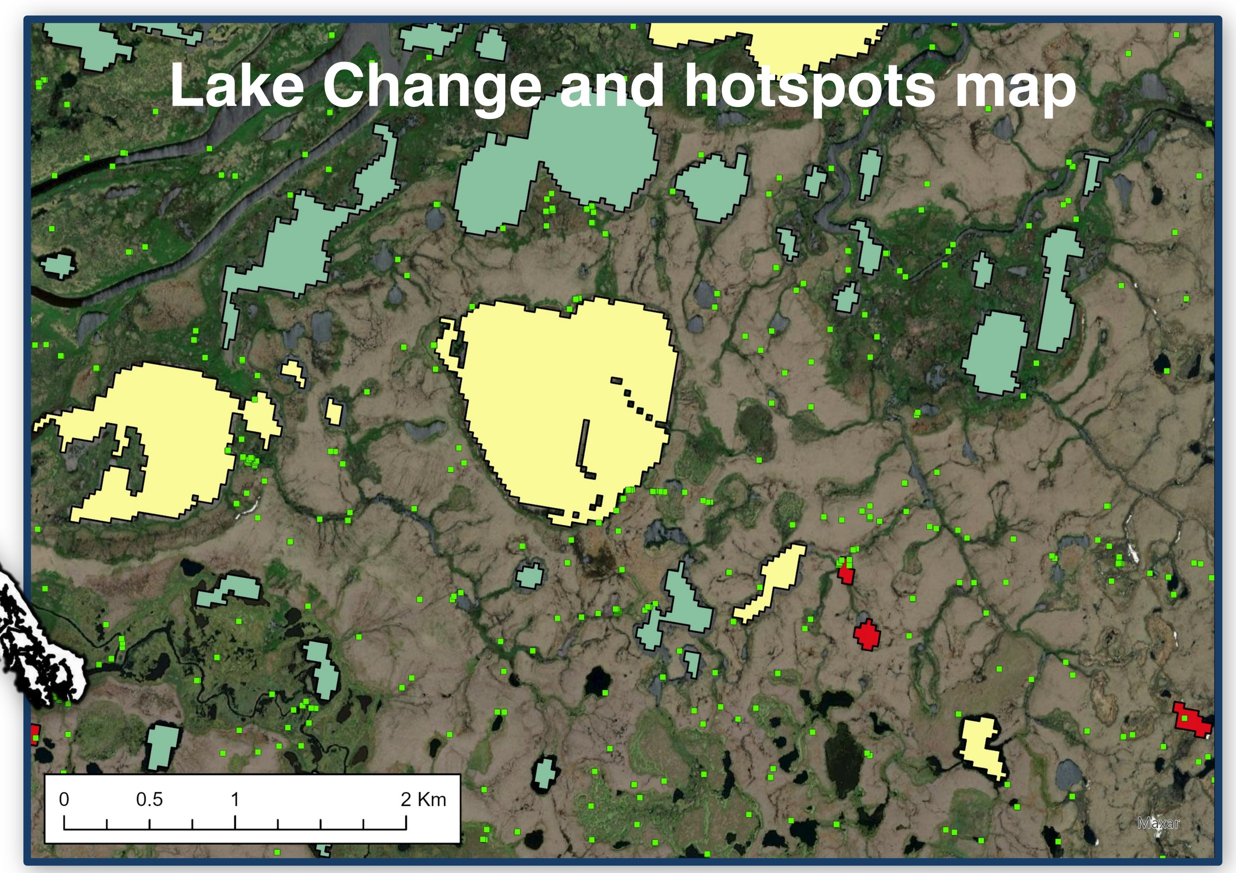
The Arctic is the fastest warming region on the planet, a rate that is 4x the global average and almost never predicted in our most sophisticated earth system models[1]. This rapid change holds unforeseen consequences for diverse permafrost landscapes and the permafrost carbon (PC) reservoir. The strength of the PC feedback depends largely on the proportion of mobilized PC that is emitted as methane (CH_4)[2,3]. Landscape heterogeneity, complex biogeochemistry, and high spatiotemporal variability challenge accurate scaling of high latitude CH_4 emission estimates. Thus, **we used scale-bridging satellite[4] and airborne[5,6] observations to determine whether the observed trend in thaw-driven lake shrinkage[7] affects CH_4 emissions in the thawing Arctic.**

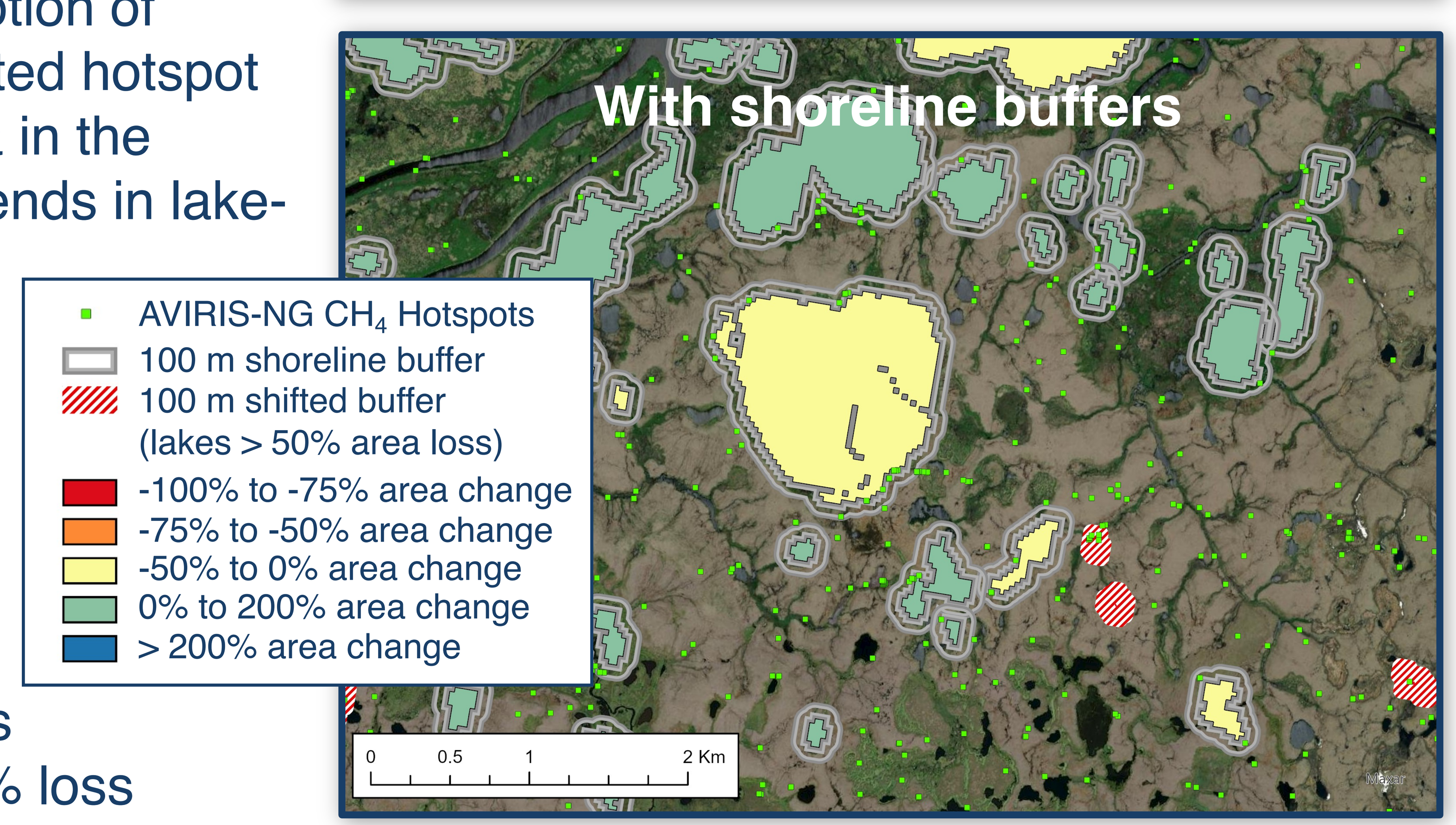
Approach

How does lake area change effect CH_4 emissions in the YK Delta, Alaska?

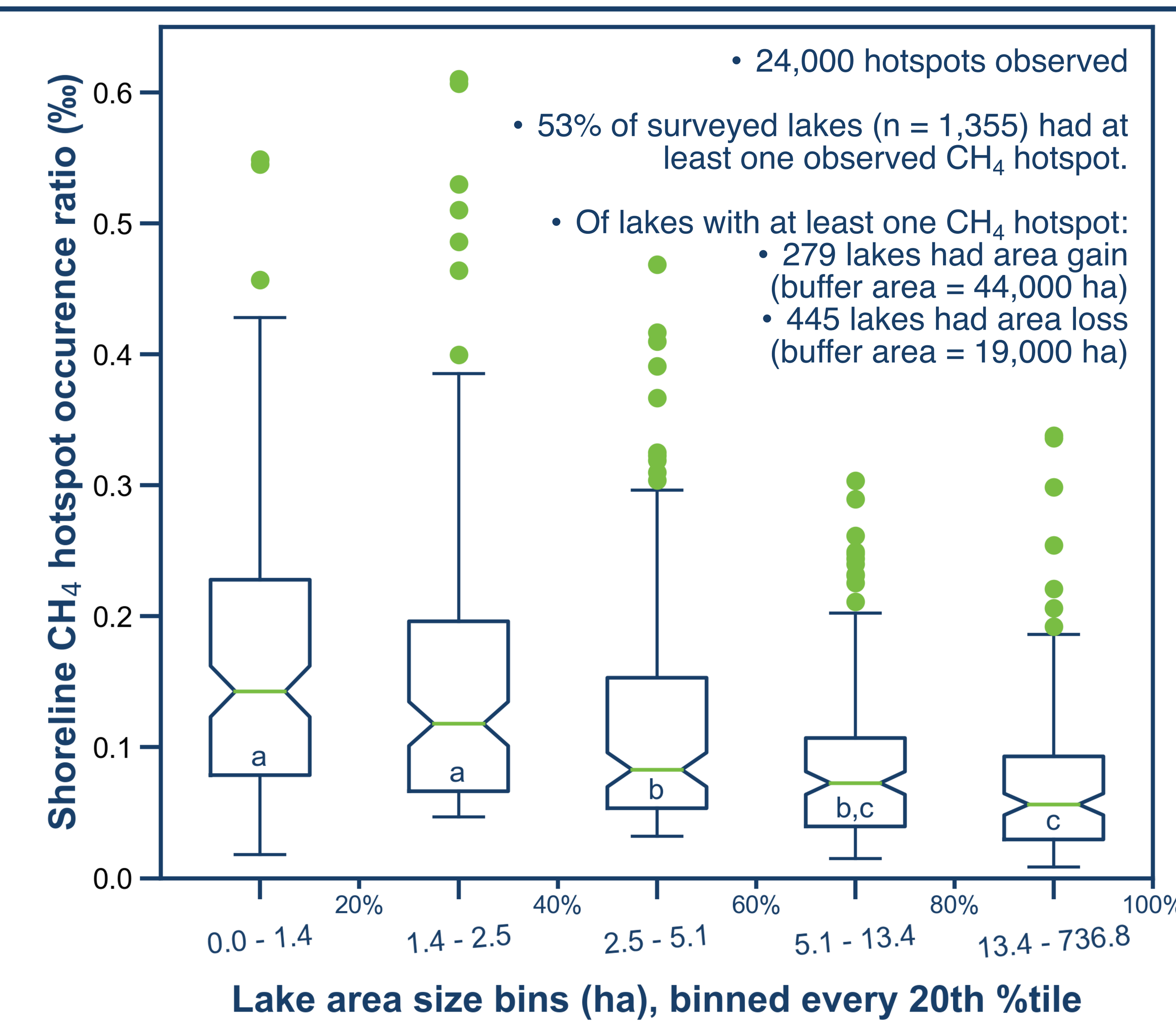
NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS-NG) observes CH_4 emission hotspots as enhancements of CH_4 in the air between the ground and the aircraft via absorption of photons in SWIR wavelengths. This study related hotspot detections in 2018 in a 1,800 km² imaged area in the Yukon Kuskokwim Delta to Landsat-derived trends in lake-area change.

- Landsat-derived lake area change analysis (1999 – 2014) by Nitze et al. 2018[4]
- 1 hectare minimum lake size
- 1,355 lakes analyzed
- CH_4 hotspot occurrence rates (hotspot area/buffer area) were determined in a 100 m terrestrial buffer around the lakes
- Buffer shifted 50m inward for lakes w/ > 50% loss

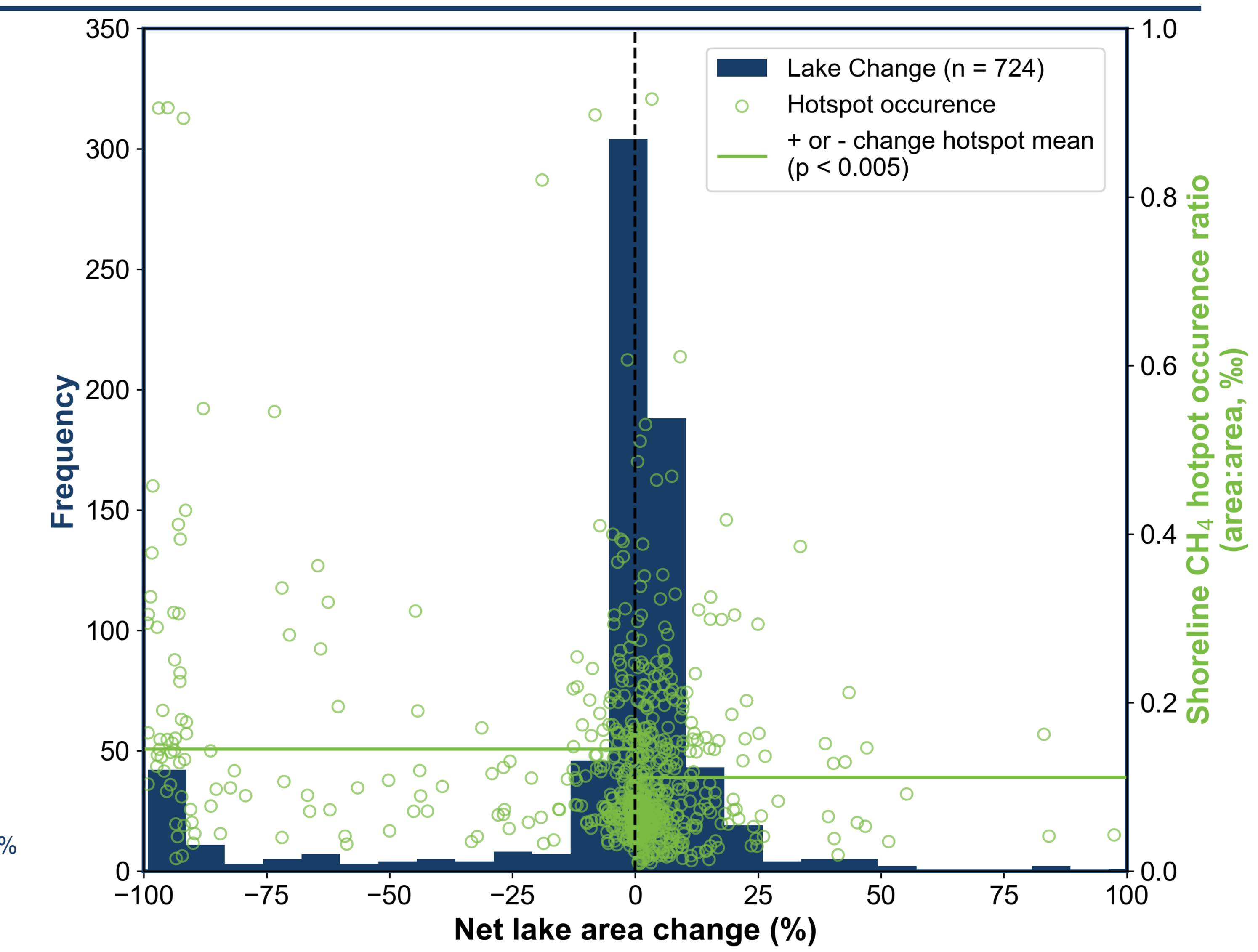




Preliminary Findings



FINDING A) CH_4 hotspots were more likely surrounding the smallest lakes. Lakes were binned equally in 20%tile increments. Letters represent statistically significant ($\alpha = 0.05$) size groups with respect to CH_4 hotspot occurrence.



FINDING B) CH_4 hotspot occurrence was 25% more likely on shorelines of lakes that have shrank in area from 1999 - 2014 ($p < 0.005$). Histogram = distribution of lake change. Scatter plot = hotspot occurrence by feature.

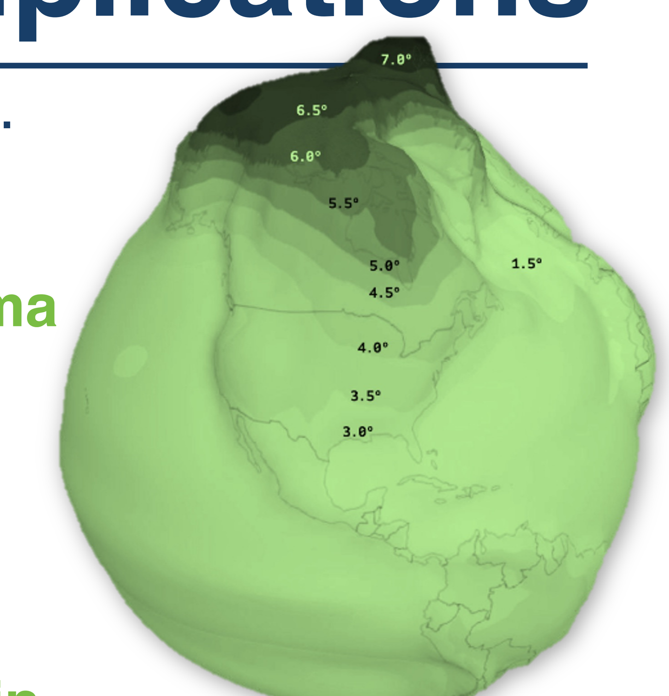
Implications

FINDING A) CH_4 hotspots were more likely surrounding the smallest lakes.

IMPLICATION A) If lake size is a proxy for lake age in thermokarst environments, expanding lakes in the YK Delta may behave more like Yedoma lakes in terms of thermokarst succession and subsequent CH_4 emissions[8].

FINDING B) CH_4 hotspot occurrence was 25% more likely on shorelines of lakes that have shrank in area from 1999 - 2014 ($p < 0.005$)

IMPLICATION B) Lake surface water decline may promote wetland creation in draining lake basis with conditions favorable for greater CH_4 emissions. (Organic rich lowland successional pathway)[2]



Projected 2040-2060 temps shown as elevation (relative to 1880–1920). Map by G. Fiske Woodwell Climate

Key Takeaways

1. Arctic CH_4 emissions are difficult to quantify, but **AVIRIS-NG** is providing a novel perspective on their key environmental drivers.
2. In a survey of 1,400 lakes in the YK Delta, Alaska, **CH_4 hotspots are more likely to occur near lakes that have shrank during the last 23 years.**

References

1) Rantanen, Mika, et al. *Communications Earth & Environment* (2022). 2) Turetsky, Merritt R., et al. *Nature Geoscience* (2020). 3) Miner, Kimberley R., et al. *Nature Reviews Earth & Environment* (2022). 4) Nitze, Ingmar, et al. *Nature communications* (2018). 5) Elder, Clayton D., et al. *Geophysical Research Letters* (2020). 6) Elder, Clayton D., et al. *Global Biogeochemical Cycles* (2021). 7) Webb, Elizabeth E., et al. *Nature Climate Change* (2022). 8) Walter Anthony, Katey M., et al. *Environmental Research Letters* (2021).