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EARTH SCIENCES DIVISION

Association between permafrost degradation and soil greenhouse gas fluxes in the Alaskan Arctic

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OBJECTIVES

Improve understanding of soil greenhouse gas fluxes in the Arctic coastal tundra, as part of the DOE NGEE-Arctic project. Specifically:

- How do soil CO_2 and CH_4 fluxes change over the growing season?
- How does microtopography affect the seasonal pattern of CO_2 and CH_4 fluxes?
- How well can soil CO_2 and CH_4 variance be explained by soil water content and soil temperature?
- How much variance in soil CO_2 and CH_4 flux are explained by microtopography?

MATERIALS & METHODS

Field Site: Barrow Environmental Observatory (BEO) in Barrow, AK located at 71°17'44"N 156°45'59"W

Figure 1 – Map of Alaska showing the location of Barrow circled in red.

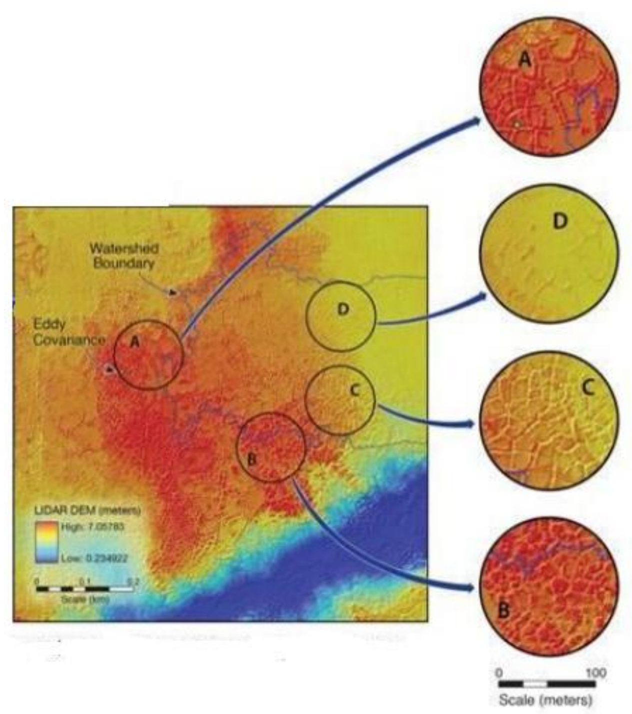

Figure 2 – LiDAR image of BEO showing the study's intensive sampling areas[1].

Figure 2 identifies four different polygonal structure types seen on the BEO:

- A – Low centered polygons
- B – High centered polygons
- C – Flat centered polygons
- D – Low centered poorly defined polygons

Each polygon structure is comprised of 3 features:

- C – Center
- E – Edge
- T – Trough

Measurements:

- 4 replicates for each combination of polygon structure and feature for a total of 48 biogeochemical (BGC) sampling plots.
- 3 field campaigns in summer 2012: June/July (43 measurements), Aug. (54 measurements; all BGC plots), and Sept. (56 measurements; all BGC plots).
- CO_2 and CH_4 concentration over time from static chambers; fluxes calculated from numerical curve fitting method[2].
- Soil temperature at 5 cm taken concurrently with chambers
- Soil water content of top 8 cm taken concurrently with chambers
- Thaw depth measured weekly

RESULTS – Greenhouse Gas Time Series

CO_2 Flux June to September

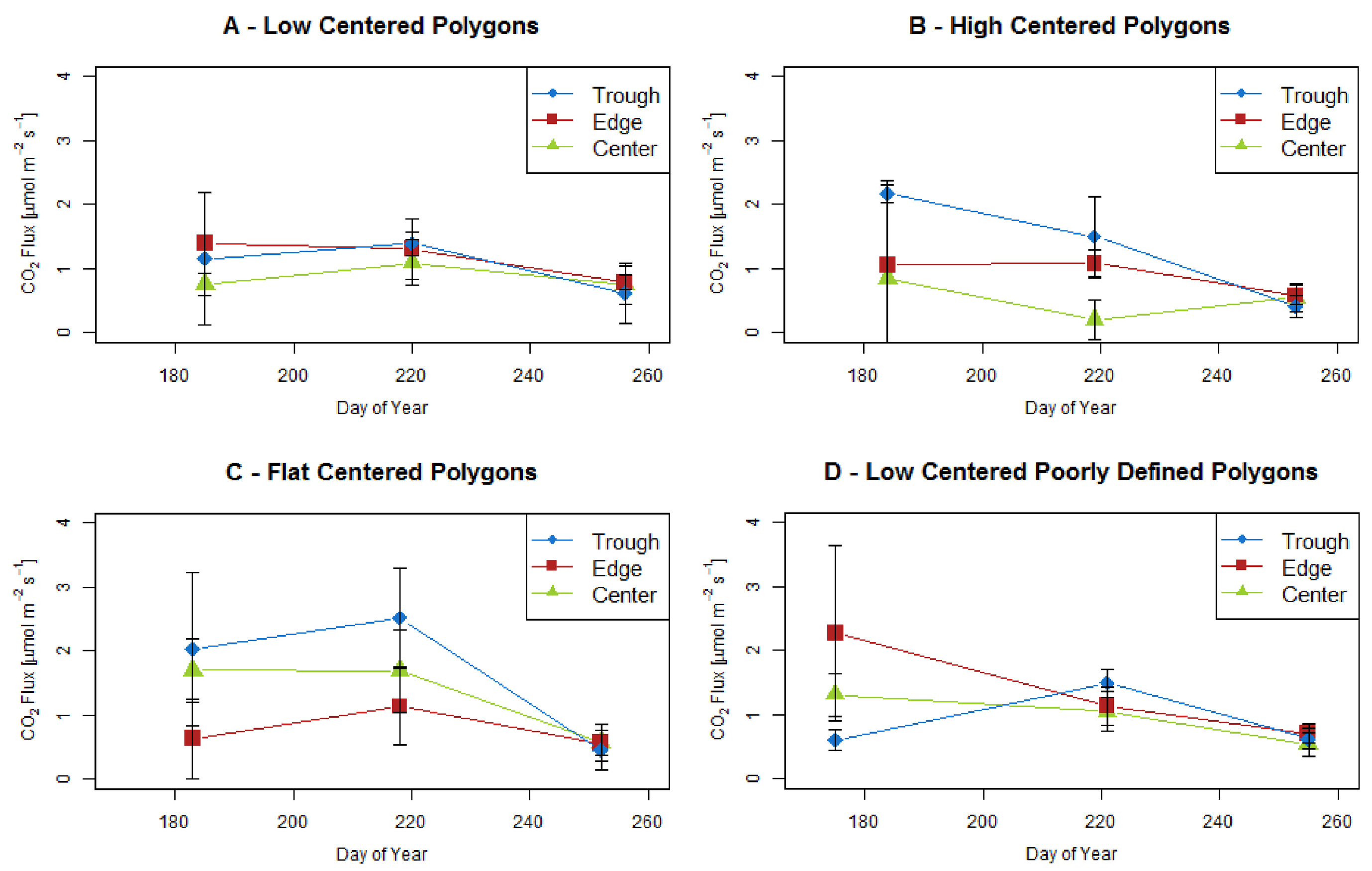

Figure 3- Carbon Dioxide Flux over the growing season for all four polygon types.

- CO_2 fluxes decrease in September when temperatures decrease, plants senesce and (we hypothesize) autotrophic respiration decreases.
- CO_2 flux is more affected by polygon position (*center, edge, trough*) in the dry areas (B & C) than in the wet areas (A & D).

CH_4 Flux June to September

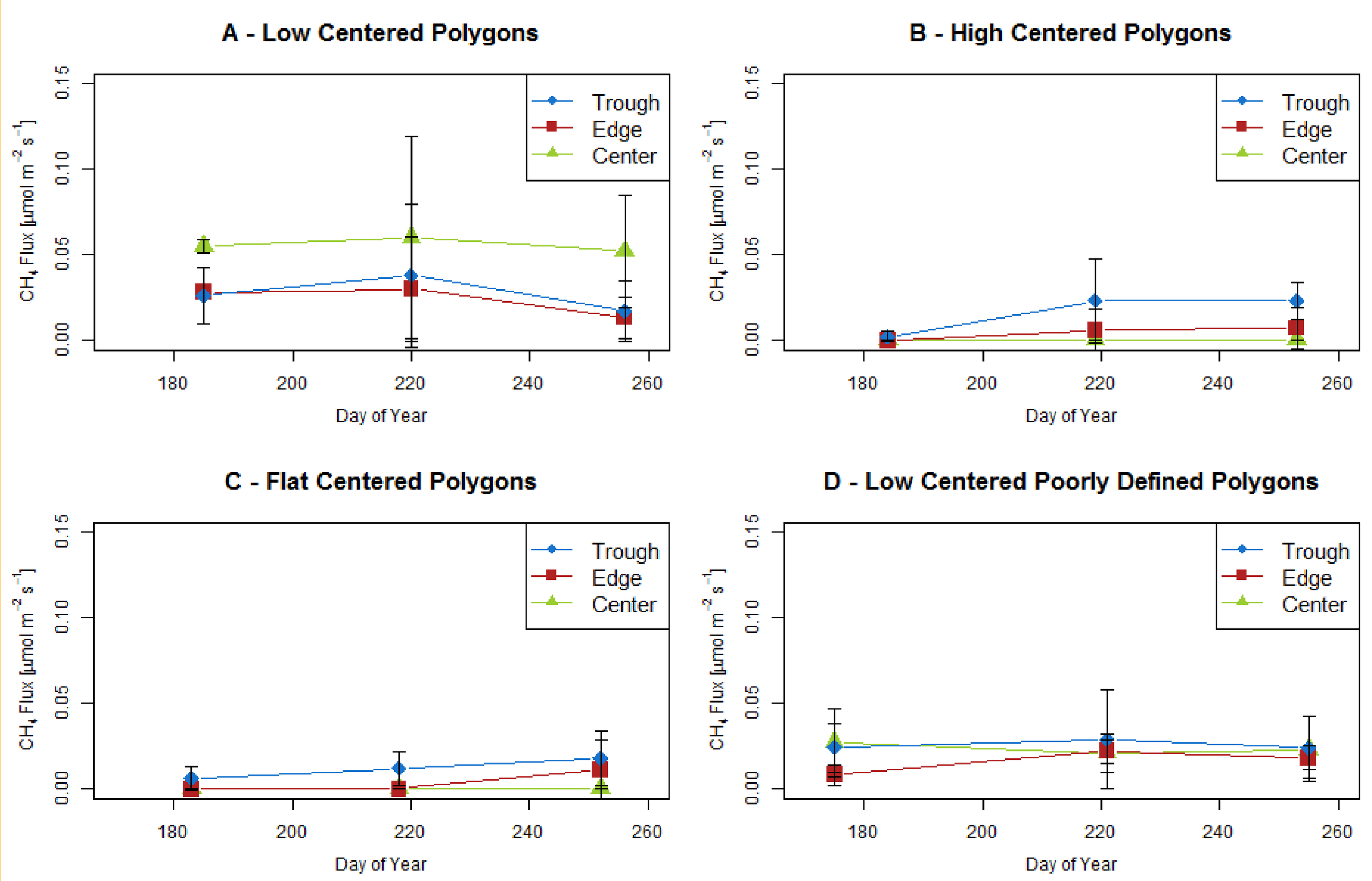

Figure 4- Methane Flux over the growing season for all four polygon types.

- CH_4 fluxes are stable or increase in September, reflecting increased thaw depth, warmer soil, and more surface water.

RESULTS – Explaining CO_2 Flux Patterns

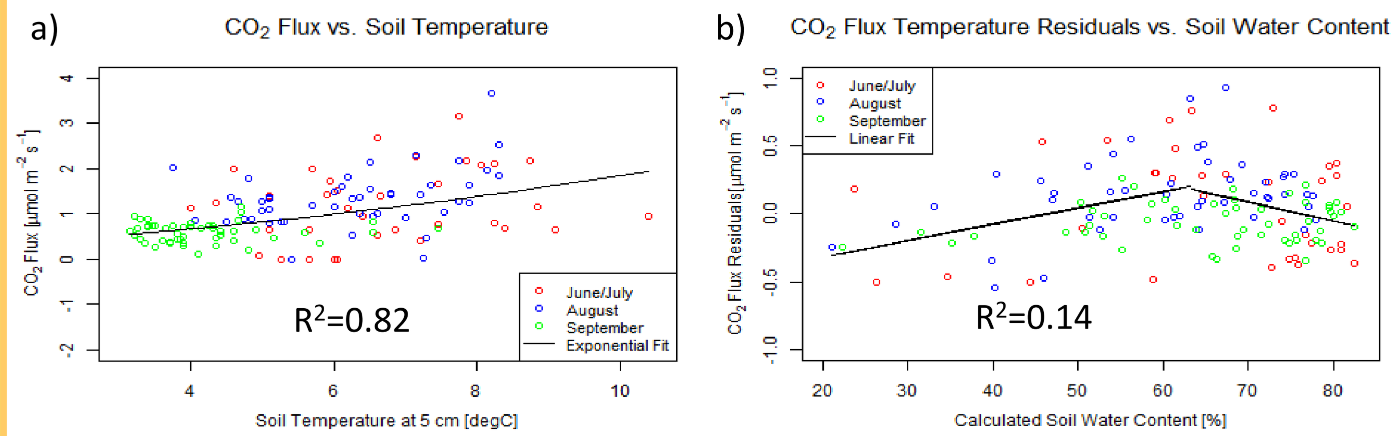

Figure 5 – a) Soil temperature vs. CO_2 flux with showing an exponential dependence of CO_2 on temperature; b) Soil water content vs. temperature CO_2 model residuals.

- Exponential relationship between soil temperature at 5 cm and CO_2 flux accounts for 81.5% of the variance of the data.
- The BEO Q_{10} relationship for soil respiration is 5.1 at 3 °C and 4.2 at 5 °C.
- Figure 5b shows that CO_2 residual fluxes are water limited below a soil water content of 63% and are diffusion limited above 63%.
- Soil temperature and water content account for 84.4% of the CO_2 variance seen in the summer 2012.

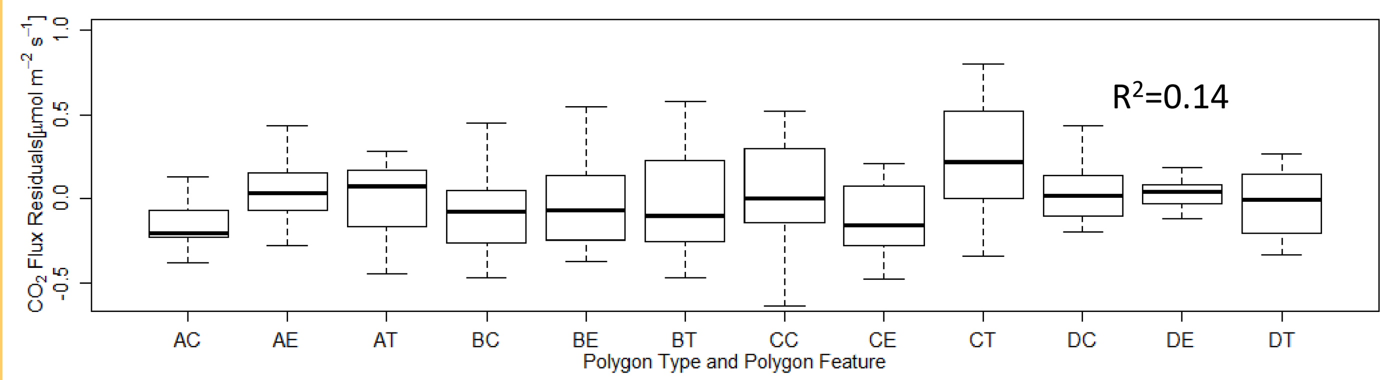

Figure 6 - Sampling location vs. soil temperature and water content CO_2 model residuals. The variables on the x-axis are described in the methods section.

- Sampling location can explain 13.8% of the leftover variance of the CO_2 data..
- The Troughs of Area C had the largest impact on CO_2 flux and this is reflected by the largest summer CO_2 fluxes being seen there
- Soil temperature, soil water content, and sampling location accounted for 86.5% of the variance seen in the data.

RESULTS – Explaining CH_4 Flux Patterns

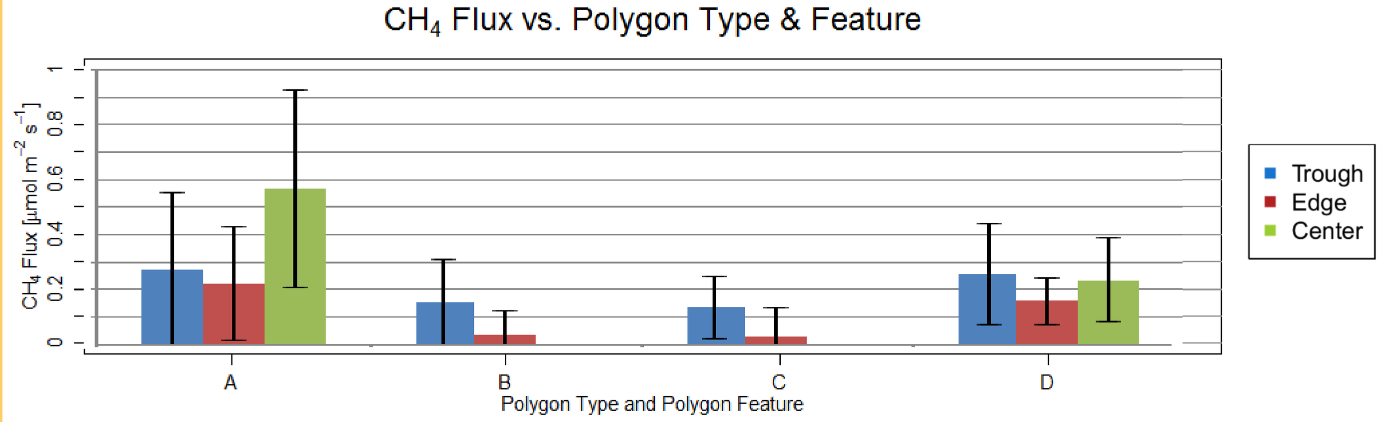

Figure 7 – Average CH_4 fluxes over summer 2012

- CH_4 flux is higher in the wet areas (A & D) , with highest fluxes in the Centers of Area A.
- In Areas B and C, troughs are the only polygon feature with significant methane efflux.

RESULTS – Explaining CH_4 Flux Patterns continued

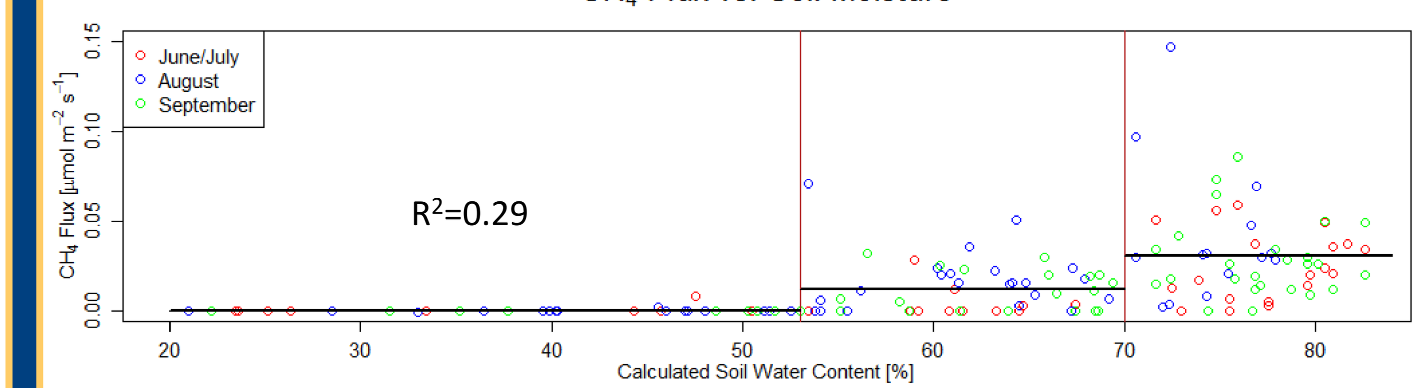

Figure 8 – Soil water content vs.CH_4 flux

- The site measurements show three distinct regions of CH_4 flux with soil moisture:
  - Almost no CH_4 flux for θ < 53%
  - Moderate CH_4 flux for 53% ≤ θ < 70%
  - Highest CH_4 flux for θ ≥ 70%
- Soil water content range explains 29.3% of the variance of the data.

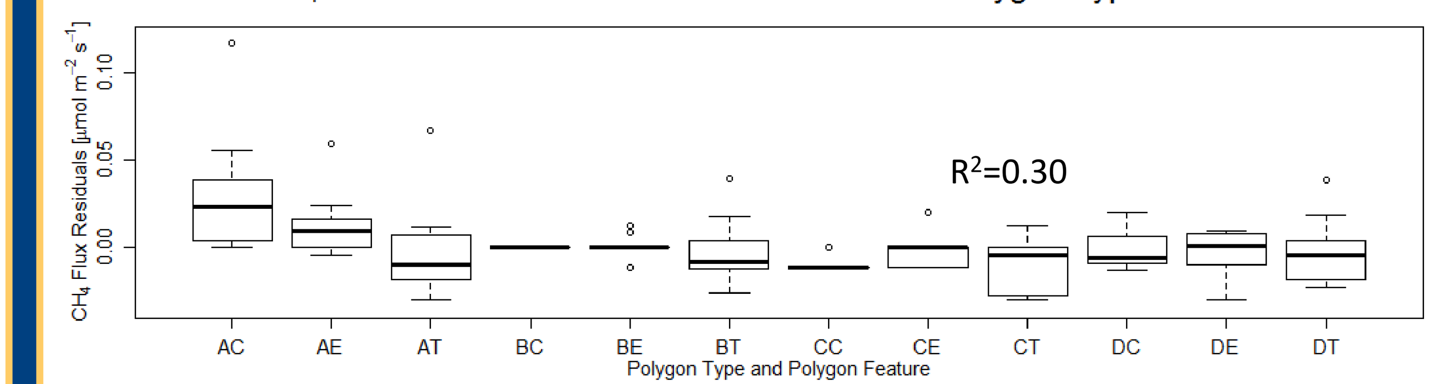

Figure 9- Sampling location vs. water content CH_4model residuals. The variables on the x-axis are described in the methods section.

- Sampling location explains 29.7% of the remaining variance of the CH_4 data.
- The Centers of Area A had the largest impact on CH_4 flux not explained by soil water content. The Edges of Area A had the 2nd largest impact on CH_4 flux not explained by water content.
- Soil water content range and sampling location accounted for 50.3% of the variance seen in the CH_4 data.

SUMMARY AND CONCLUSIONS

- Polygon feature has a greater influence on soil CO_2 flux in the dry areas (B & C) and earlier in the growing season
- Soil CO_2 fluxes in September decrease as a result of soil temperature and possibly decreased autotrophic respiration.
- Polygon feature has an increased influence on soil CH_4 flux in the dry areas as the season progresses.
- Most locations show that soil CH_4 flux remains constant or increases in September possibly from increased thaw depth and inundated areas.
- Soil temperature, soil water content, and sampling location accounts for 84.4% of the variance of soil CO_2 flux.
- Soil water content range and sampling location account for 50.3% of the variance in soil CH_4 flux.

ACKNOWLEDGMENTS

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REFERENCES

1. Image provided by Craig Tweedie, University of Texas El Paso
2. Matthias, D., Yarger, D. N., & Weinbeck, R. S. (1978). A numerical evaluation of chamber methods for determining gas fluxes. *Geophysical Research Letters*, *5*(9), 765–768.