Effect of thaw depth on fluxes of CO_2 and CH_4 in manipulated Arctic coastal tundra of Barrow, Alaska

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ABSTRACT

The manipulation treatment consisted of draining, controlling, and flooding treated sections by adjusting standing water. Inundation increased CH_4 emission by a factor of 4.3 compared to non-flooded sections. This may be due to the decomposition of organic matter under a limited oxygen environment by saturated standing water. On the other hand, CO_2 emission in the dry section was 3.9-fold higher than in others. CH_4 emission tends to increase with deeper thaw depth, which strongly depends on the water table; however, CO_2 emission is not related to thaw depth. Quotients of global warming potential ($GWPCO_2$) (dry/control) and $GWPCH_4$ (wet/control) increased by 464 and 148 %, respectively, and $GWPCH_4$ (dry/control) declined by 66 %. This suggests that CO_2 emission in a drained section is enhanced by soil and ecosystem respiration, and CH_4 emission in a flooded area is likely stimulated under an anoxic environment by inundated standing water. The findings of this manipulation experiment during the autumn period demonstrate the different production processes of CO_2 and CH_4, as well as different global warming potentials, coupled with change in thaw depth. Thus the outcomes imply that the expansion of tundra lakes leads the enhancement of CH_4 release, and the disappearance of the lakes causes the stimulated CO_2 production in response to the Arctic climate change.

1. Site Description & Methods

- *Barrow Environmental Observatory (BEO) Station;*
- *Three 300-m Tramlines of Manipulation Experiment;*
- *South (Drained), Middle (Control), North (Flooded);*
- *Measuring items: CO_2 and CH_4 flux-measurements with portable chamber (50 cm OD; 50 cm high), Thaw depth, Temperatures of air and soil;*
- *Observation period: September 13-18, 2007*

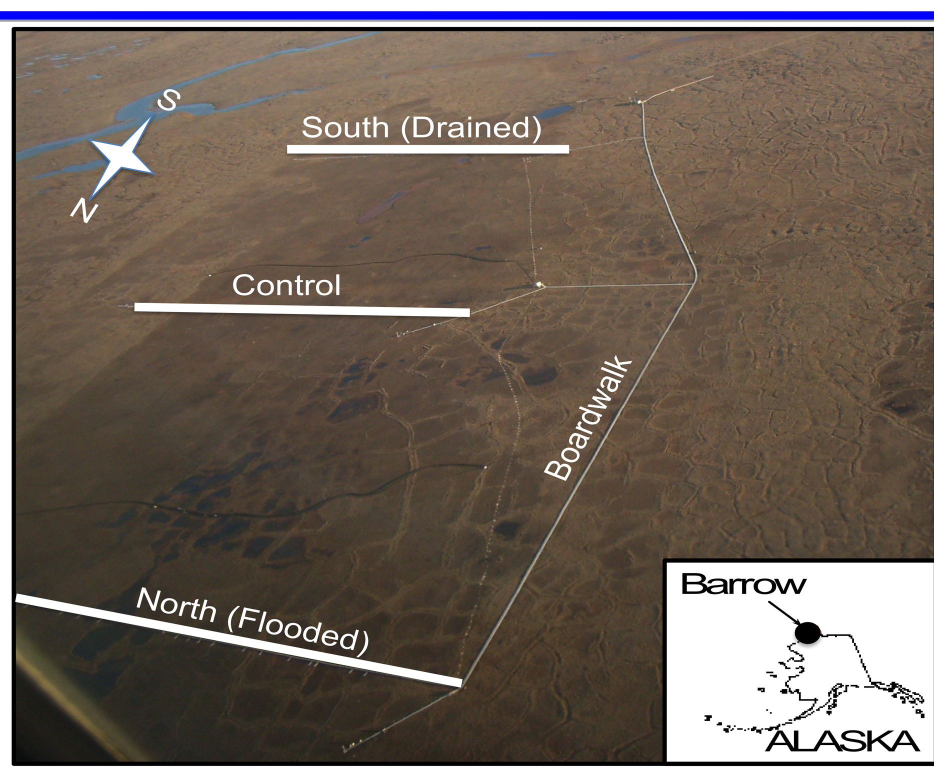
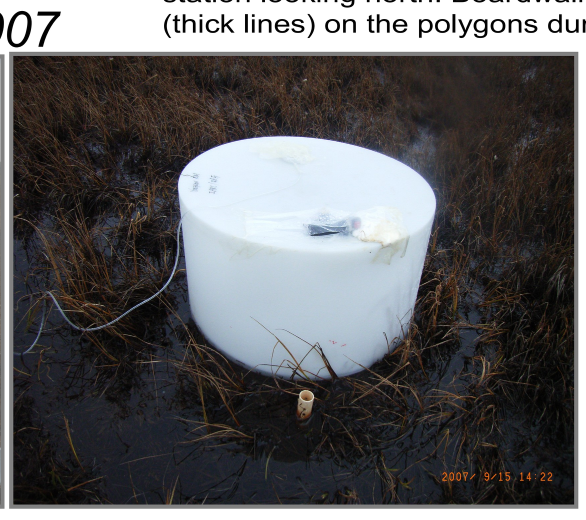
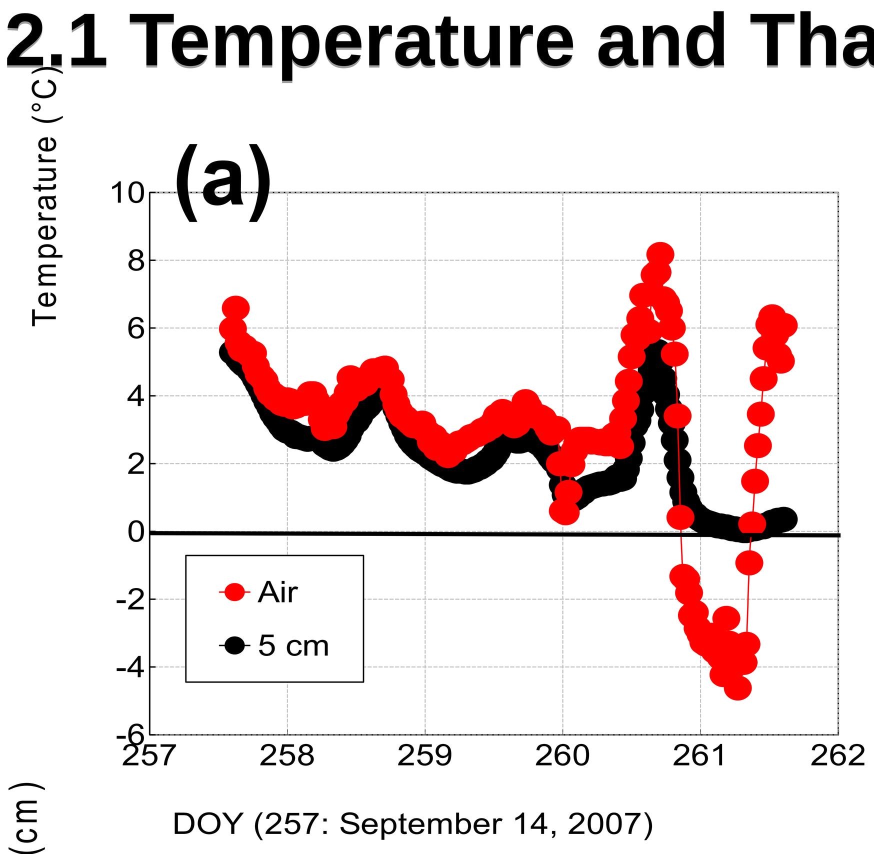


Figure 1. Aerial oblique photograph of the Biocomplexity Experiment station looking north. Boardwalks (thin lines) and three 300-m tramline (thick lines) on the polygons during the autumn period of 2007.



2. Results and Discussion

2.1 Temperature and Thaw Depth



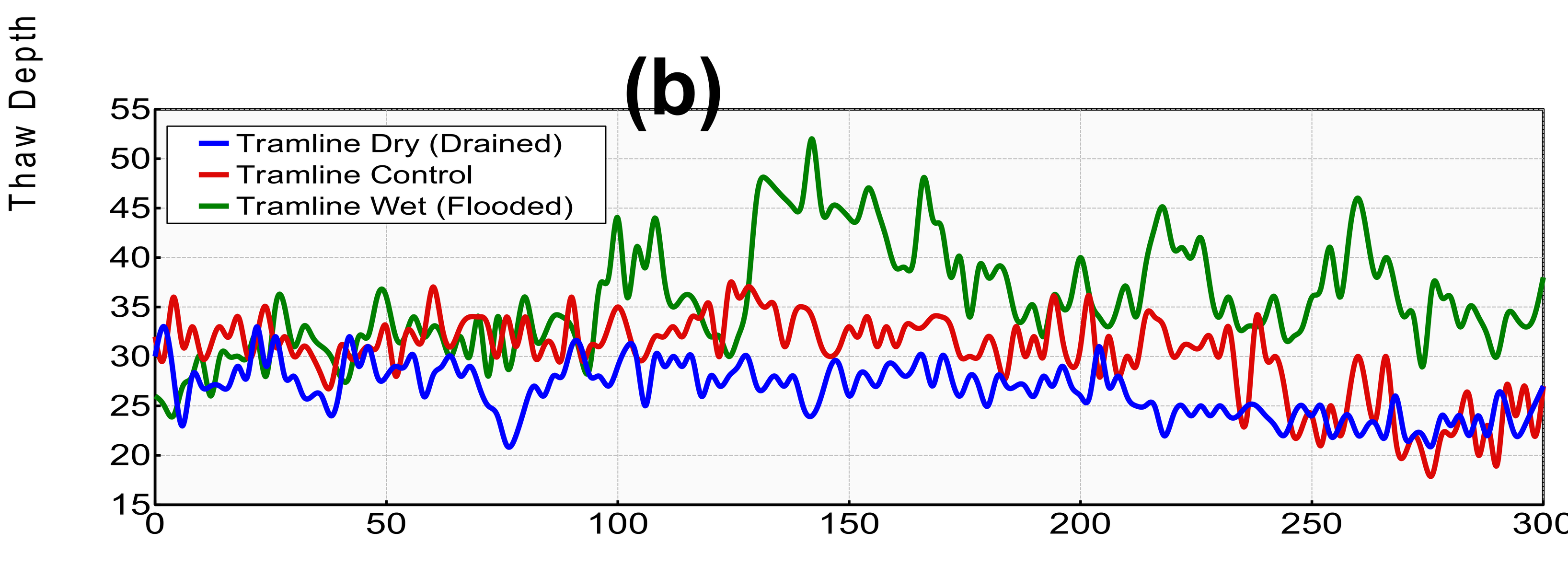


Fig 2. Temporal variation of **(a)** temperatures in air (red) and soil (blue), and **(b)** spatial pattern of thaw depth in dry (blue), control (red), and wet (green) treatment sections during the autumn period of 2007. Blue circle denotes temperature below the zero.

2.2. Spatial Variations of CO_2 and CH_4

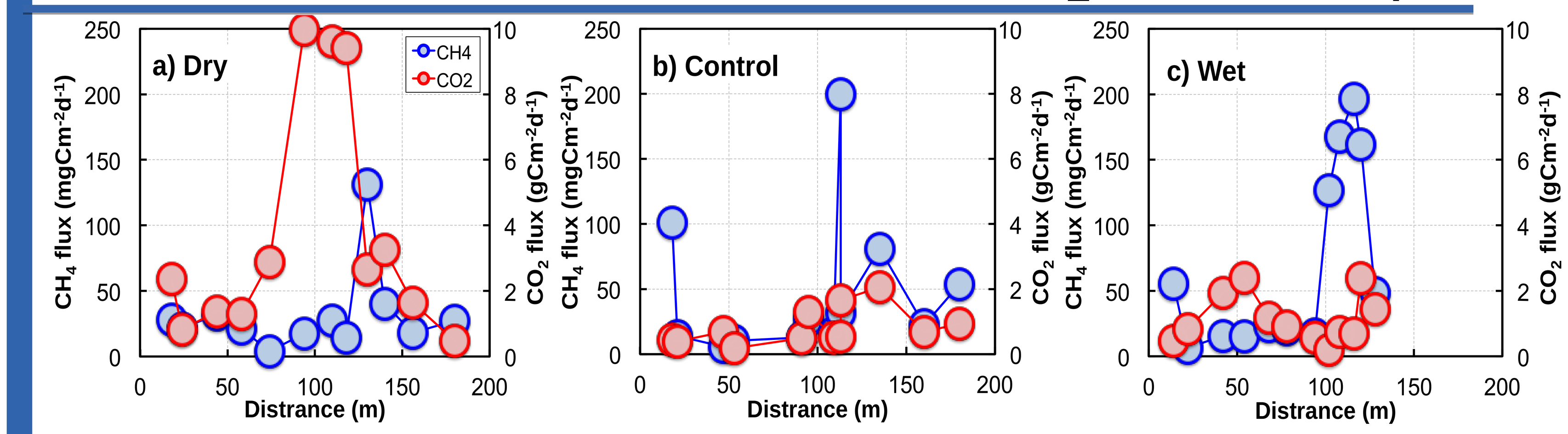


Fig. 3. Spatial variations in CH_4 and CO_2 fluxes in (a) dry, (b) control, and (c) wet treatments along each manipulation experiment tramline. Higher CH_4 emission was produced when soil was saturated and showed deeper thaw depth. On the other hand, higher CO_2 emission showed in dry tramline, suggesting the *differences in production processes of CO_2 and CH_4 in different condition of standing water in manipulation experiment*.

2.3. CO_2/CH_4 and Environmental factors

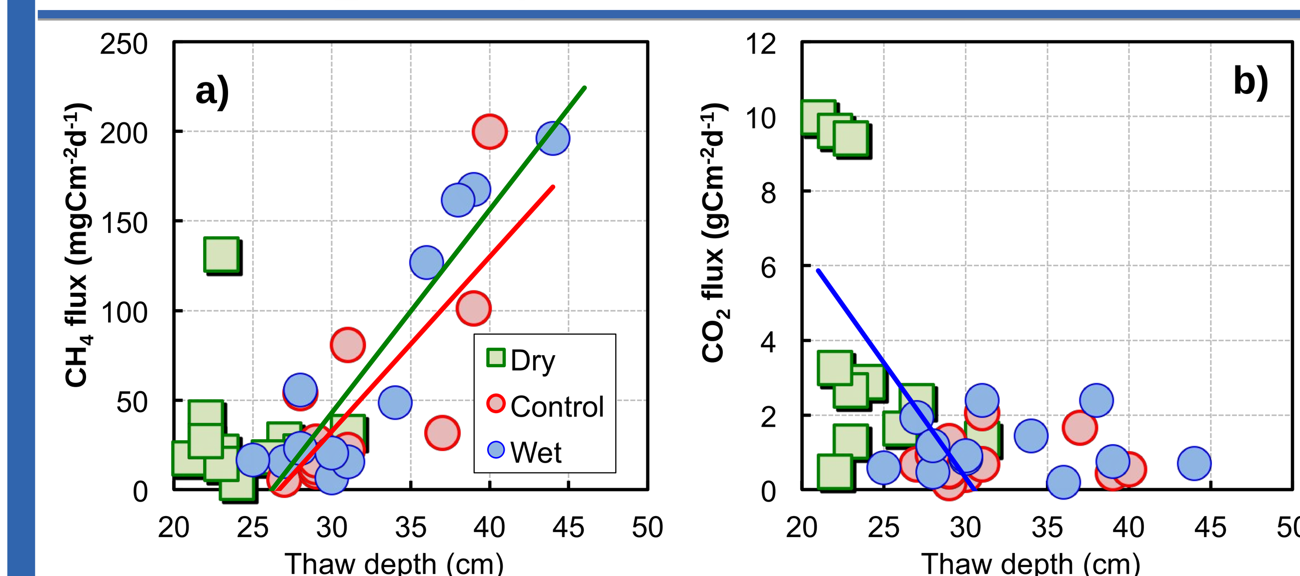


Fig 4. Responses from (a) CH_4 and (b) CO_2 fluxes to thaw depth (cm, TD), for which the equations show $CH_4 = 9.7\ TD - 260$ ($R^2 = 0.59$; $p = 0.482$) and $CH_4 = 11.3\ TD - 297$ ($R^2 = 0.84$; $p = 0.003$) under control (solid line) and wet (dashed) treatments, respectively, and $CO_2 = -0.62\ TD + 18.8$ ($R^2 = 0.28$; $p = 0.482$) in dry treatment.

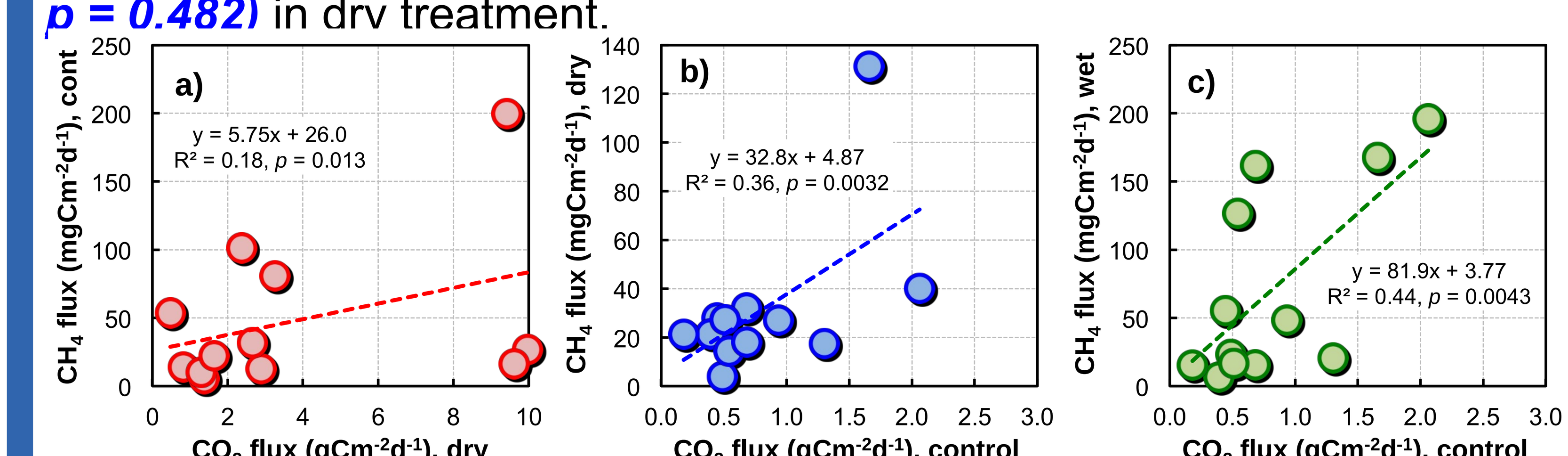


Fig 5. Responses of (a) CH_4 flux under control for CO_2 flux under dry treatment, and of CH_4 flux under (b) dry and (c) wet treatments for CO_2 flux under control treatment.

1. **CO_2 and CH_4 from trapped bubbles: 5,150 and 53,630 ppmv,**
   \>>> **CH_4 ebullition as a process of CH_4 release within the wet treatment** (Walter et al., 2008),
2. **CH_4 abundance from area and freezing period: ca. 2.57 gC/m²/day,**
   \>>> **1.98 gC/m²/day in Greenland during onset of freezing** (Mastepanov et al., 2008),
3. **□^{13}C and D of CH_4: -73.1 and -329 ‰,**
   \>>> Similar to those from ebullition events with ice koshkas in lakes,
   \>>> **Main source is CO_2 reduction** (Walter et al., 2008),

1. **Estimation of GWP (global warming potential) for 61-day of autumn,**
   \>>> GWP (global warming potential) of CH_4 at 25-time that of CO_2 (IPCC., 2014),
2. **Quotients of GWP-CO_2 (dry/control) and GWP-CH_4 (wet/control) increased by 464 and 145%, respectively, and**
3. **Quotients of GWP-CH_4 (dry/control) decreased by 66%,**
   \>>> CO_2 emission from the drained is thought to be enhanced by *soil and ecosystem respiration* and *CH_4 uptake* compared to the wet section,
   \>>> CH_4 emission from wet is thought to be stimulated by *increased methanogenatiic activity* under an anoxic environmental by saturated standing water.

CONCLUSIONS

1) **Different production processes of CO_2 and CH_4 from manipulated Arctic coastal tundra,**
2) **CO_2 emission in drained section from ecosystem respiration,**
3) **CH_4 production in the inundated section from metanogenesis,**
4) **Expansion of tundra lakes, implying enhanced CH_4 release, a**
5) **Disappearance of lakes, connected to stimulated CO_2 emission in the Arctic.**

ACKNOWLEDGEMENTS

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