Linking CO-flux with Tundra Vegetation

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Introduction

The Arctic climate is rapidly changing and perhaps the most impactful ecosystem change is the shifting balance between photosynthesis and respiration towards respiration. This imbalance between photosynthesis and respiration can cause impactful and global repercussions and the switch from the tundra acting as a carbon sink to a carbon source is already being seen in some areas of the Arctic (Euskirchen et al. 2017) . Not only is there a change in the CO2-flux being seen in the Arctic, but there are also changes in the vegetation (Hollister et al. 2015). Here we correlated CO2-flux data generated from experimentally warmed and control plots established by the International Tundra Experiment (ITEX) at the dry heath tundra in Utqiaġvik, AK with several abiotic and vegetation measurements conducted on the same plots. The belief is that changing vegetation may impact carbon dynamics in addition to climate itself. Linking the change of CO2-flux to the changes in tundra vegetation will provide a deeper understanding of the impacts of climate change on the Arctic and allow for more accurate predictions of future carbon dynamics.

Methods

The research was established in Utqiaġvik, Alaska in 1994 and is located within the dry heath tundra (Fig 1A). The dry site consists of 24 control plots and 24 experimental plots which are experimentally warmed using open top chambers (OTCs); each plot is ~$1 m^2$. These OTCs are made of fiberglass and raise the temperature of the plot from 1°C - 3°C on average for the summer (Fig1B). The CO2-flux data (Fig 2) was collected using the LiCor6400 which was attached to diurnal chambers that were placed in ten of the plots at the dry site in Utqiaġvik and quantifies gross primary productivity, ecosystem respiration, and net ecosystem exchange. Cover data (Fig 4) was collected and grouped into functional groups using the non-destructive pointframe method. For each plot, growth measures (Fig 5) and flower counts (Fig 6) are done weekly every season on the species (Fig 1C). Growth measures measure the height of the inflorescence for marked individuals and the largest reproductive plant for the graminoid species in each plot. Flower counts were measured by counting the flowers of each species in every plot. The correlations between the carbon data and the growth measures and flower counts were made with data taken from similar dates.

C

Graminoids (GRAM)
- *Alopecurus alpinus* (AALP)
- *Arctagrostis latifolia* (ALAT)
- *Carex stans* (CSTA)
- *Dupontia fisheri* (DFIS)
- *Juncus biglumis* (JBIG)
- *Luzula arctica* (LARC)
- *Luzula confusa* (LCON)
- *Poa arctic* (PARC)

Forbs (FORB)
- *Potentilla hyparctica* (PHYP)
- *Stellaria laeta* (SLAE)
- *Saxifraga punctata* (SPUN)

Evergreen Shrub (ESHR)
- *Cassiope tetregona* (CTET)

Deciduous Shrub (DSHR)
- *Salix rotundifolia* (SROT)

Bryophytes (BRYO)
Lichens (LICH)
Litter (LITT)

Figure 1A: Location of study site in Utqiaġvik, Alaska. B: Working at Utqiaġvik dry site at an OTC plot. C: Utqiaġvik dry site species that were used in this analysis and the abbreviations used in later figures

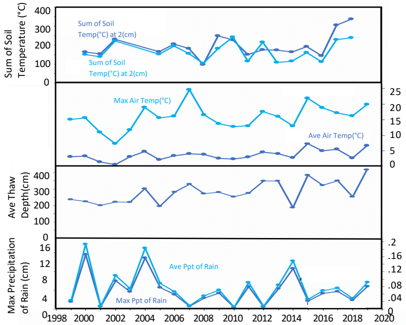

Figure 3. Abiotic measurements collected over time.

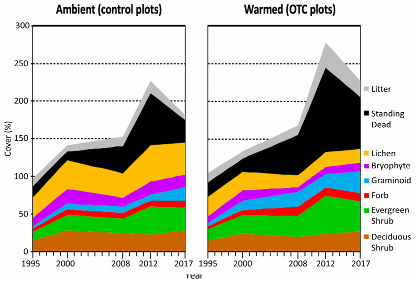

Figure 4. Change in cover, by functional groups, in control and warmed plots over time. Years of sampling provided in the x-axis.

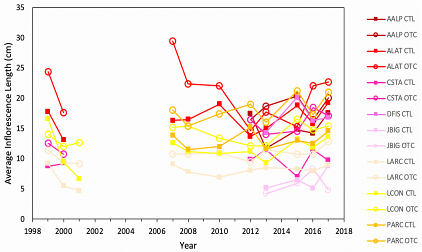

Figure 5. Average Inflorescence length (cm) for graminoid species in late July in each year.

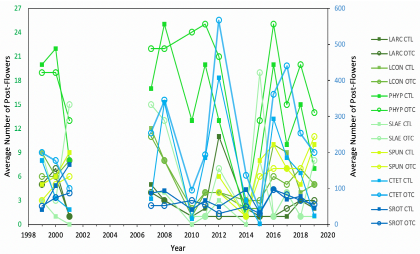

Figure 6. Post-flower counts for the prominent flowering species in late July each year.

Flux Values	Abiotic Factors						
	Avg Thaw Depth (cm)	Max Ppt of Rain (cm)	Max Air Temp(°C)	Avg Ppt of Rain (cm)	Avg Air Temp(°C)	Soil Temp(°C) at 2 (cm)	Soil Temp(°C) at 10 (cm)
Avg NEE	-0.095	0.041	-0.134	0.041	-0.286	***-0.379***	***-0.463***
Avg ER	-0.162	0.048	-0.079	0.048	***-0.441***	***-0.524***	***-0.469***
Avg GPP	0.168	-0.053	0.021	-0.053	0.280	***0.362***	0.240

Figure 7. Spearman correlation results for CO2-flux and abiotic factors. Rho-values are bolded and italicized if they are significant ($p < 0.05$).

Flux Values	Functional Groups						
	BRYO	DSHR	ESHR	FORB	GRAM	LICH	LITT
Avg NEE	-0.079	-0.418	-0.539	-0.588	***-0.806***	-0.006	-0.515
Avg ER	0.030	-0.176	-0.539	-0.261	-0.588	0.091	-0.297
Avg GPP	0.030	0.152	0.321	-0.139	0.285	-0.030	0.018

Figure 8. Spearman correlation results for CO2-flux and cover data. Rho-values are bolded and italicized if they are significant ($p < 0.05$).

Flux Values	Plant Species							
	AALP	ALAT	CSTA	DFIS	JBIG	LARC	LCON	PARC
Avg NEE	***-0.673***	***-0.549***	-0.559	0.419	-0.429	-0.356	-0.435	-0.435
Avg ER	-0.515	-0.295	-0.392	0.634	-0.238	0.017	-0.074	-0.403
Avg GPP	-0.224	-0.177	-0.147	-0.304	-0.452	-0.417	-0.409	0.029

Figure 9. Spearman correlation results for CO2-flux and inflorescence length. Rho-values are bolded and italicized if they are significant ($p < 0.05$).

Flux Values	Species						
	CTET	LARC	LCON	PHYP	SLAE	SPUN	SROT
Avg NEE	***-0.482***	-0.008	-0.136	***-0.529***	***-0.445***	0.093	0.382
Avg ER	-0.267	0.169	0.276	-0.133	-0.130	0.184	***0.794***
Avg GPP	-0.057	-0.385	***-0.565***	-0.245	-0.232	-0.095	-0.527

Figure 10. Spearman correlation results for CO2-flux and post-flowering counts. Rho-values are bolded and italicized if they are significant ($p < 0.05$).

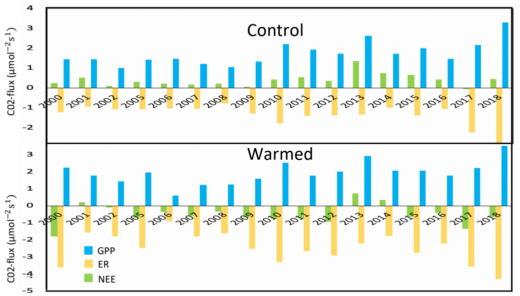

Figure 2. CO2-flux measurements collected over time. GPP= Gross Primary Productivity ER= Ecosystem Respiration NEE= Net Ecosystem Exchange

Results and Discussion

The results showed that the change in carbon dynamics is correlated to the change in tundra vegetation. The lack of significance between the flux and cover data is most likely because there were only five cover samples and therefore limited sample sizes. However, the correlation still showed that as percent cover of graminoids increases, the NEE decreases (Fig 8). The correlation between the abiotic data (Fig 3) and CO2-flux supported the hypothesis that the change in carbon dynamics was due to increasing temperature (Fig 7). The correlation between inflorescence length and carbon showed that as the plants were growing larger, (due to increasing temperature) (Hudson et al. 2011), carbon was being lost (also due to increasing temperature) (McGuire et al. 2009) (Fig 9). The correlations between flower counts (measured here as plants that have already flowered) and carbon dynamics also support the hypothesis that carbon dynamics and vegetation change are correlated due to climate change (Fig 10). These data show that the relationships between carbon dynamics and vegetation measurements is often stronger than the relationship with abiotic measurements. In conclusion, climate change is driving a change in the carbon dynamics of the Arctic as well as a change in the tundra vegetation (Pearson et al. 2013). Future studies should consider correlating CO2-flux with other plant measurements such as biomass and plant functional traits such as leaf area and density.

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References:

Euskirchen, E.S., Bret-Harte, M.S., Shaver, G.R. *et al.* (2017). Long-Term Release of Carbon Dioxide from Arctic Tundra Ecosystems in Alaska. *Ecosystems* 20, 960–974.

Hollister, R. D., May, J. L., Kremers, K. S., Tweedie, C. E., Oberbauer, S. F., Liebig, J. A., Botting, T. F., Barrett, R. T., & Gregory, J. L. (2015). Warming experiments elucidate the drivers of observed directional changes in tundra vegetation. *Ecology and evolution*, *5*(9), 1881–1895.

Hudson, J. M. G., Henry, G. H. R., & Cornwell, W. K. (2011). Taller and larger: shifts in Arctic tundra leaf traits after 16 years of experimental warming. *Global Change Biology*, *17*(2), 1013–1021.

McGuire, A.D., Anderson, L.G., Christensen, T.R., Dallimore, S., Guo, L., Hayes, D.J., Heimann, M., Lorenson, T.D., Macdonald, R.W. and Roulet, N. (2009), Sensitivity of the carbon cycle in the Arctic to climate change. *Ecological Monographs*, 79: 523-555.

Pearson, R. G., Phillips, S. J., Loranty, M. M., Beck, P. S. A., Damoulas, T., Knight, S. J., & Goetz, S. J. (2013). Shifts in Arctic vegetation and associated feedbacks under climate change. *Nature Climate Change*, *3*(7), 673–677.