CO_2 exchange rates from lichen, moss, and tussock, Council, Alaska

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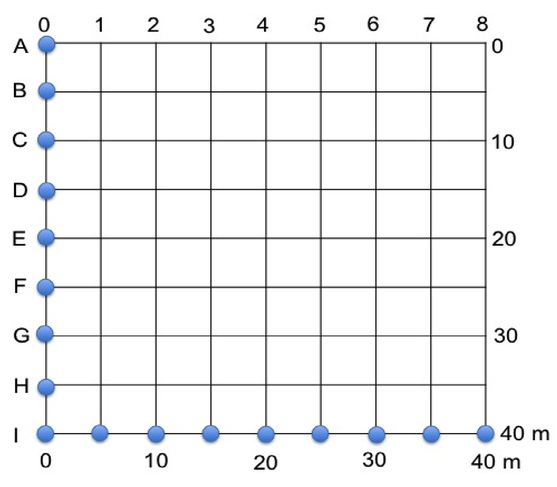
ABSTRACT

CO_2 flux-measurement in dominant tundra vegetation on the Seward Peninsula of Alaska was examined for spatial representativeness, using a manual chamber system. In order to assess the representativeness of CO_2 flux, a 40 m × 40 m (5-m interval; 81 total points) plot was used in June, August, and September of 2011. Average CO_2 fluxes in lichen, moss, and tussock tundra were 3.4 ± 2.7, 4.5 ± 2.9, and 7.2 ± 5.7 $mgCO_2/m^2/m$ during growing season, respectively, suggesting that tussock tundra is a significant CO_2 source, especially considering the wide distribution of tussock tundra in the circumpolar region. Further, soil temperature, rather than soil moisture, held the key role in regulating CO_2 flux at the study site: CO_2 flux from tussock increased linearly as soil temperature increased, while the flux from lichen and moss followed soil temperature nearly exponentially, reflecting differences in surface area covered by the chamber system. Regarding sample size, the 81 total sampling points over June, August, and September satisfy an experimental average that falls within ±10% of full sample average, with a 95% confidence level. However, the number of sampling points for each variety of vegetation during each month must provide at least ±20%, with an 80% confidence level. In order to overcome the logistical constraints, we were required to identify the site's characteristics with a manual chamber system over a 40 m × 40 m plot and to subsequently employ an automated chamber for spatiotemporal representativeness.

Methodology



1. Council: 64°51'38.3" N; 163°42'39.7" W; 45 m.a.s.l.,
2. Plant: lichen, tussock tundra, sphagnum and feather moss,
3. Portable CO_2 efflux-measurement system (NDIR analyzer, pump, laptop) within 81 point (40X40 m; 5-m interval),
4. Measurement of soil temperature, thaw depth, soil moisture

Results and Discussion

1. Meteorological Data

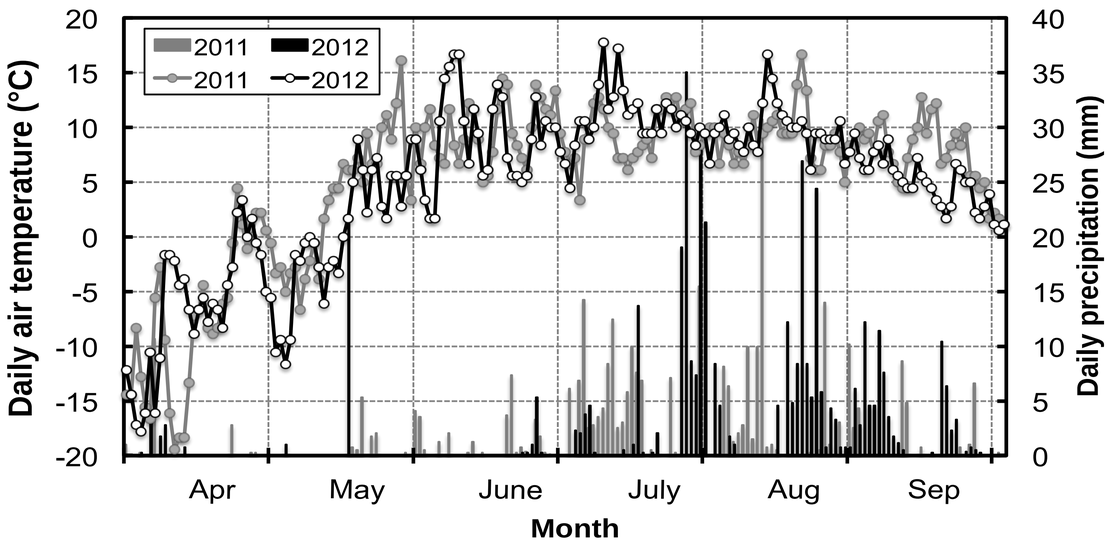


Fig. 1. Daily precipitation and average daily ambient temperature in Council, Seward Peninsula, Alaska during growing seasons of 2011 and 2012 (Western Regional Climate Center). Greyed and open circles denote daily mean air temperature in 2011 and 2012. Greyed and solid bars indicate daily precipitation in 2011 and 2012.

2. Thaw Depth

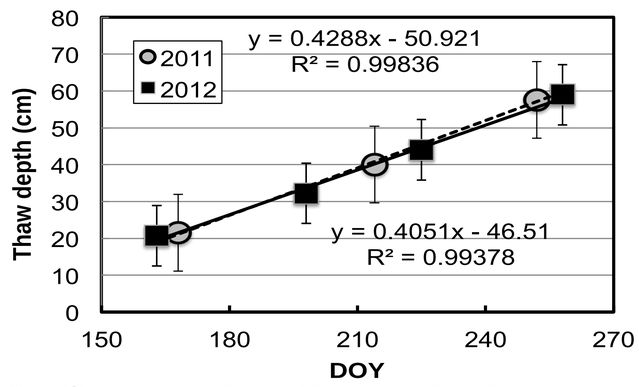


Fig. 2. Temporal variations of thaw depth in 2011 (circle) and 2012 (square) during the growing season, indicating that the thawing rate are 0.43 and 0.41 cm/day, respectively. Dash and solid lines denote 2011 and 2012.

3. Snow depth and cluster

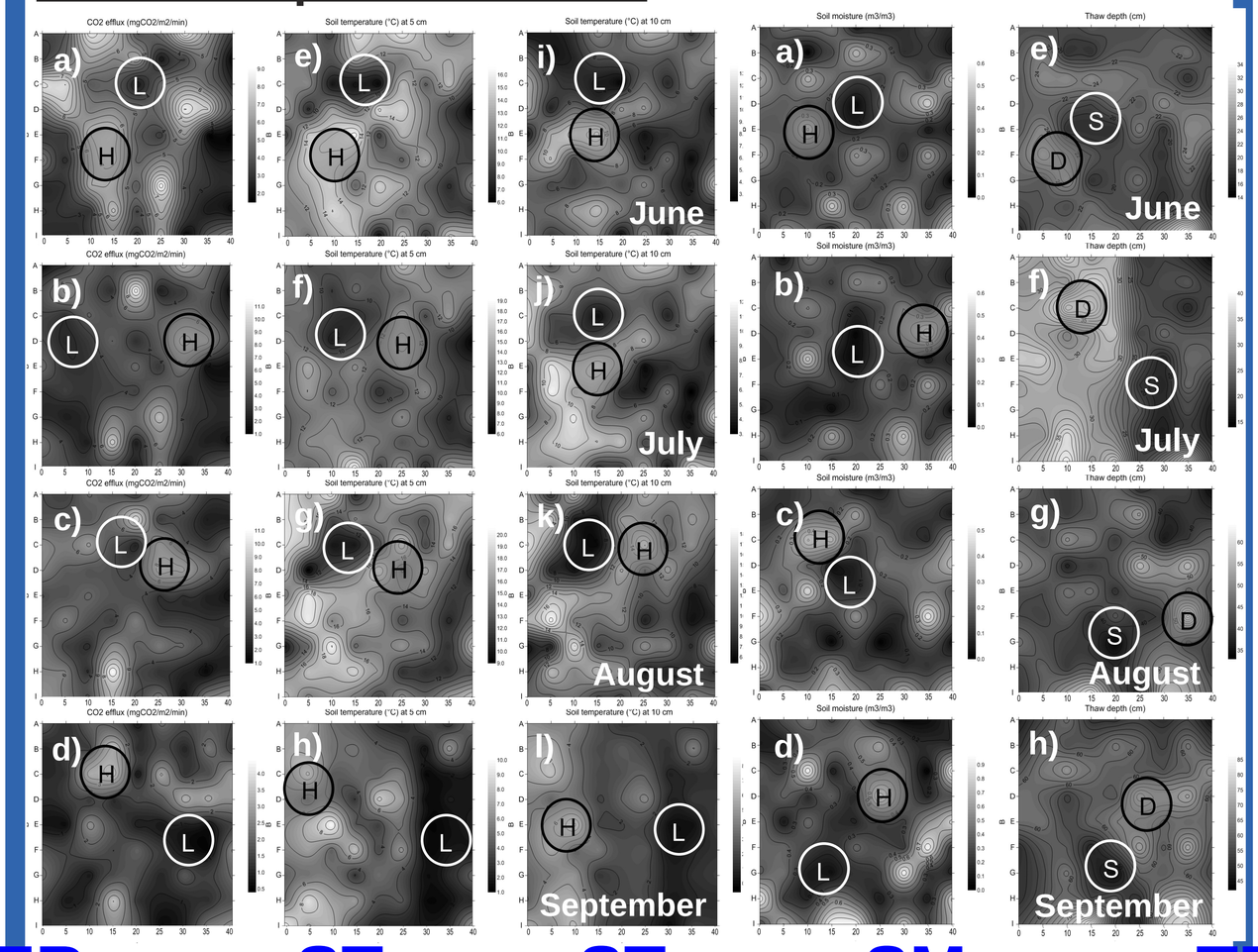


Fig. 3. Spatiotemporal variations of ecosystem respiration(1st column), soil temperature at 5 cm (2nd), and 10 cm (3rd), soil moisture (4th), and thaw depth (5th) within 40 m X 40 m plot (5-m interval; 81 points), Council, Seward Peninsula, Alaska on June (1st row), July (2nd), August (3rd), and September (4th) of 2012. White and black areas denote higher and lower ecosystem respiration, and soil temperature at 5 and 10 cm depth, soil moisture, and deeper and shallower thaw depth.

4. Ecosystem Respiration vs Soil Temperature

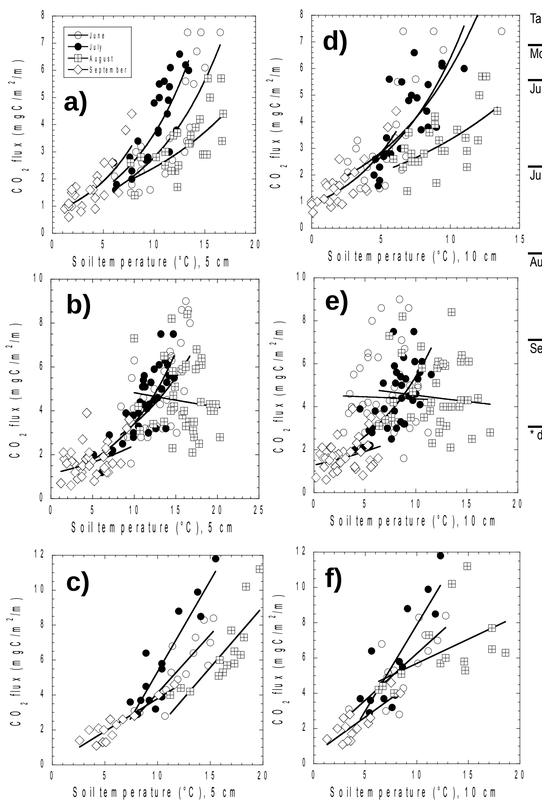


Table 1. Average ± standard deviation (coefficient of variation, %) of CO_2 flux, soil temperature at 5 and 10 cm below the surface, soil moisture and thaw depth in lichen, moss, tussock, and grass, Council, Seward Peninsula, Alaska on June, July, August, and September 2012

Month, 2012	Vegetation	n	CO_2 flux ($mgCO_2/m^2/m$)	Soil temperature (°C) 5 cm	Soil temperature (°C) 10 cm	Soil moisture (m3/m3)	Thaw depth (cm)
June	Lichen	25	3.7±2.0 (53)	11.1±3.0 (27)	5.9±2.6 (44)	0.213±0.113 (53)	22±3 (12)
	Moss	38	4.7±1.8 (39)	12.7±2.4 (19)	7.1±2.3 (32)	0.189±0.097 (51)	21±3 (16)
	Tussock	14	5.6±1.9 (33)	12.2±2.4 (19)	8.8±2.5 (29)	0.339±0.136 (40)	21±2 (11)
	Grass	4	5.2±2.1 (40)	10.4±3.0 (28)	6.4±2.1 (33)	0.304±0.149 (49)	21±2 (8)
	Average	81*	4.6±2.0 (42)	11.5±2.6 (23)	6.6±2.5 (38)	0.224±0.125 (56)	21±3 (14)
July	Lichen	25	4.0±1.5 (38)	10.1±2.1 (21)	6.9±1.8 (26)	0.165±0.088 (53)	33±3 (9)
	Moss	38	4.3±1.5 (35)	11.2±2.4 (22)	7.9±1.9 (25)	0.243±0.086 (60)	31±4 (13)
	Tussock	14	5.9±2.8 (48)	10.5±2.5 (23)	7.9±2.5 (31)	0.268±0.140 (52)	31±2 (8)
	Grass	4	5.6±1.9 (34)	9.9±1.1 (11)	6.6±1.0 (15)	0.208±0.088 (42)	36±6 (16)
	Average	81*	4.2±2.0 (47)	11.3±2.2 (19)	7.2±2.4 (33)	0.191±0.118 (62)	27±6 (23)
August	Lichen	25	3.3±1.1 (33)	13.0±2.6 (20)	9.3±2.2 (23)	0.201±0.117 (58)	45±4 (10)
	Moss	38	4.7±1.6 (35)	16.0±2.5 (15)	11.9±2.7 (22)	0.258±0.115 (73)	44±7 (15)
	Tussock	14	6.4±2.1 (33)	16.2±2.5 (15)	12.6±4.0 (32)	0.288±0.120 (42)	43±3 (7)
	Grass	4	5.5±2.4 (43)	13.2±0.8 (6)	9.3±1.2 (13)	0.199±0.069 (35)	47±11 (22)
	Average	81*	4.6±1.9 (45)	15.0±2.9 (19)	11.0±3.2 (29)	0.198±0.126 (63)	44±6 (13)
September	Lichen	25	1.6±0.9 (54)	3.5±1.9 (55)	2.1±1.6 (75)	0.465±0.260 (56)	59±7 (11)
	Moss	38	1.8±0.8 (44)	4.9±2.3 (47)	3.1±1.8 (59)	0.340±0.264 (78)	60±9 (16)
	Tussock	14	2.3±1.0 (44)	5.9±2.5 (42)	4.1±2.0 (48)	0.427±0.121 (28)	57±4 (7)
	Grass	4	2.2±0.9 (40)	2.9±2.5 (26)	2.0±1.6 (82)	0.456±0.378 (82)	64±9 (14)
	Average	81*	1.6±0.8 (50)	4.4±2.2 (50)	2.7±1.8 (65)	0.399±0.262 (66)	59±8 (13)

* denotes total measured points.

Table 2. Q_{10} values and correlation coefficient between CO_2 flux and soil temperature at 5 and 10 cm below the soil surface in lichen, moss, tussock, and grass during the growing season based on a one-way ANOVA with a 95% confidence level

Vegetation	Month	5 cm Q_{10}	5 cm R^2	5 cm p	10 cm Q_{10}	10 cm R^2	10 cm p
Lichen	June	4.03	0.66	<0.001	1.40	0.24	<0.001
	July	5.04	0.69	<0.001	0.57	0.65	<0.001
	August	2.41	0.46	<0.001	2.50	0.35	<0.001
	September	6.17	0.57	<0.001	9.55	0.59	<0.001
	Total	2.86	0.65	<0.001	1.09	0.19	<0.001
Moss	June	2.62	0.37	<0.001	0.95	0.01	<0.001
	July	3.82	0.66	<0.001	3.51	0.51	<0.001
	August	1.15	0.01	<0.001	1.14	0.01	<0.001
	September	2.10	0.16	<0.001	2.18	0.11	<0.001
	Total	2.44	0.54	<0.001	2.35	0.33	<0.001
Tussock	June	5.06	0.77	<0.001	4.59	0.68	<0.001
	July	3.78	0.73	<0.001	2.78	0.50	<0.001
	August	2.98	0.77	<0.001	1.59	0.37	<0.001
	September	4.12	0.72	<0.001	5.01	0.59	<0.001
	Total	3.11	0.76	<0.001	3.00	0.62	<0.001
Grass	Total	2.28	0.41	<0.001	3.11	0.38	<0.001

Fig. 4. Responses of monthly ecosystem respired CO_2 fluxes to soil temperature at 5 (left panels) and 10 cm (right panels) depths in lichen (a and d), moss (b and e), and tussock (c and f) on June, July, August, and September of 2012.

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