Soil respiration rates of seasonally frozen soils in Ny-Ålesund

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Introduction

Polar soil is critically subject to global warming much more than soils at mid-latitudes or tropics and its transformation resulting from global warming is one of critical issues. To make clear the transformation and mechanisms behind it, we took soil samples in soil depths within 50 cm at two tundra places different in period after deglaciation, namely Rabben (5%<SOC<9.5%) and Site 3 (1.4%<SOC<2.4%) at Ny-Ålesund. Then, we investigated soil respiration under incubated conditions at -7°C, -2°C, 5°C and 15°C as a parameter of soil carbon decomposition to simulate actual range of soil temperature.

Materials and Methods

Soil was taken at site3 and at Rabben Japanese lodging site in Ny-Alesund. The vegetation of the two sites are similarly vegetated with moss and vascular plants such as *Salix polaris* partly covered with lichens. Soils at site3 were taken every 10 cm of soil depth, 0-10cm, 10-20cm, 20-30cm, and 40-50cm from three places which are a few meter apart from the quarter plot of site3. The three samples from the three places except 0-10cm where duplicated total 6 samples were used to measure soil CO_2 emission. Soils at Rabben site were taken until the depth of 15cm at three places from vegetated site and non-vegetated site. The soils from vegetated site were divided to organic soil of root part and mineral soils under the organic soil. The three samples from the three places at Rabben site were used to measure soil CO_2 emission. The sampled soils were stocked under cold temperatures as low as possible and were sent by air to Japan and were stocked refrigerator at 1°C for 6 months.

Taking out from the refrigerator that was cooled at 1°C, soil was incubated in vials for 7 days at 5°C. Then, the vials were divided to 4 temperature conditions at -7°C, -2°C, 5°C, and 15°C. Soil CO_2 emissions were measured for half year. To avoid large accumulation of CO_2 in vials, the vials were opened when the concentration exceeded 2% of CO_2.
Soil CO_2 emissions were measured by closed-chamber method (Yonemura et al., 2017). CO_2 concentrations were measured by NDIR using as comparison (Takachiho Chemicals). The calculation is based on mass balance equation (Yonemura et al., 2017). The soil respiration rates were calculated as unit of emission/soil g. Temperature dependence was estimated by Q10 and EA values for negative (-5°C and -2°C) and positive temperature (5°C and 15°C).

Results and Discussion

Soil respiration was evolved from all the soils at all the temperatures except those from site3 at -7°C and periodically at -2°C. The CO_2 emissions of all the samples from site3 at -7°C showed negative values about until 70 days; the soil respiration rates at -2°C under 20-30cm from site3. A little CO_2 uptake was observed at site3 until 10 days at the initial stage of incubation time. Excluding the uptake,the CO_2 emissions can be attributable to soil respiration and hereafter we use soil respiration to show soil CO_2 emission.

We averaged soil respirateion rates until the measurement finished because the soil respiration rates did not change with incubation time at both sites (Table 1). Furthermore, periods of CO_2 uptake were not incorporated into the averages. Soil respiration rates at Rabben sites were larger than those at site3. Soil respiration rates of organic soil was several times higher

[illegible] residence times calculated through division of soil organic carbon by one-year-integrated soil respiration (Table 1) were not constant even at the same temperatures. Residence time at Rabben is shorter than those at site3. For examples, residence times at Rabben at positive degrees were lee than 100 years, whereas those at Site3 were some- to several-hundreds years. Considering soil temperatures at Ny-Alesund, residence times of Rabben and Site3 were estimated about 100 years and several to 1000 years, respectively.

Since soil respiration rates were more with higher temperature (Table 2), Q10 and EA were calculated from soil respiration rates (Table 2). The Q10 values (5°C -15°C) of Rabben and Site3 were relatively constant (2.7-3.1) with an exception of 4.1 from 40-50cm. Q10 and EA (5°C-15°C) values of site3 were significantly higher than those of Rabben.

Cross temperatures, where Ahhrenis equations for soil respiration rates at negative and positive temperatures intersected each other were within the range of ±1.5°C. The cross temperatures were higher for samples with higher carbon contents or influenced by vegetation .

Table 1 CO_2 emissions and its temperature dependence of the soils.

Site	CO_2 emission								Residence time** of soil organic carbon			
	-7°C		-2°C		5°C		15°C		-7°C	-2°C	5°C	15°C
	ave ±	std	ave ±	std	ave ±	std	ave ±	std	(year)	(year)	(year)	(year)
	(nmol g^{-1} d^{-1})		(nmol g^{-1} d^{-1})		(nmol g^{-1} d^{-1})		(nmol g^{-1} d^{-1})					
Rabben												
veg.u.	22.8 ±	20.7	190.9 ±	38.3	1127.0 ±	767.3	3133.7 ±	1691.9	943	113	19.1	6.9
veg.l.	4.3 ±	2.2	38.4 ±	27.4	173.9 ±	89.3	530.5 ±	220.0	3813	424	93.7	30.7
bare	2.3 ±	0.9	34.3 ±	13.1	158.2 ±	72.1	467.3 ±	209.4	5110	348	75.4	25.5
Site3												
0-10cm	1.0 ±	0.4	8.3 ±	3.5	32.6 ±	14.7	93.4 ±	51.8	5575	653	165.7	57.8
10-20cm	0.4 ±	0.5	3.0 ±	0.6	8.7 ±	3.5	26.8 ±	13.2	14047	1799	627.7	203.9
20-30cm	(n.a*)		2.0 ±	0.8	5.4 ±	2.0	15.9 ±	6.9	(n.a*)	1929	713.1	243.4
40-50cm	(n.a*)		1.3 ±	0.3	4.4 ±	1.0	17.9 ±	11.4	(n.a*)	2462	745.0	181.6

Footnote:

* soil respiration and then residence time of soil carbon was not estimated because of low CO2 emission.

** Residence time of soil organic carbon was obtained by dividing the amount of soil organic matters by soil respiration rate.

Table 2 Temperature dependence and cross temperature

Site	Temperature dependence				Cross temperature
	(-7°C:-5°C)		(5°C:15°C)		
	Q10	E_A (kJ)	Q10	E_A (kJ)	(°C)
Rabben					
veg.u.	70.2	255.0	2.78	68.1	1.4
veg.l.	80.7	263.5	3.05	74.3	0.2
bare	215.9	322.5	2.95	72.2	-0.2
Site3					
0-10cm	73.0	257.4	2.87	70.2	-0.1
10-20cm	61.0	246.6	3.08	74.9	-1.2
20-30cm	*(n.a.)		2.93	71.6	*(n.a.)
40-50cm	*(n.a.)		4.10	94.1	*(n.a.)

* Temperature dependence and cross temperature were not calculated because soil CO2 emission was not able to be measured at -7°C

References

Yonemura S., Ono K., Ikawa H., Kim W., Mano M. & Miyata A., Comparison of fallow season CO_2 efflux from paddy soil estimated using laboratory incubation with eddy covariance-based flux, Journal of Agricultural Meteorology 73(3), 140–145, 2017.