Tôhoku Geophys. Journ. (Sci. Rep. Tôhoku Univ., Ser. 5), Vol. 36, No. 4, pp. 544-549, 2003

Distribution of Soil Respiration Rate Along a Latitudinal Alaskan Transect (Extended Abstract)

YONGWON KIM[1], KEIJI KUSHIDA[2] and NORIYUKI TANAKA[1]

[1]Frontier Observational Research System for Global Change, International Arctic Research Center, University of Alaska Fairbanks, 930 Koyukuk Dr., Fairbanks, AK 99775-7335, USA
[2]Institute of Low Temperature Science, Hokkaido University, W8 N19, Kita-Ku, Sapporo, 060-0819, Japan

(Received December 2, 2002)

Abstract: Dynamic chamber flux measurements were observed at representative sites of tundra and boreal forest along a latitudinal Alaskan transect (148°W) during the summers of 2000 and 2001. Average regional soil respiration rates in tundra and boreal forest stands were 0.027 ± 0.011 GtC/season and 0.056 ± 0.014 GtC/season for light and dark chambers during the growing period, respectively. Average regional net respiration rate by aboveground surface vegetation along Alaskan transect was 0.007 ± 0.005 GtC/season in tundra and 0.023 ± 0.015 GtC/season in boreal forests. These findings suggest that soil respiration and net respiration are one of the significant sources of atmospheric CO_2 in Alaska for the regional carbon budget. Soil respiration and net respiration showed remarkable soil-temperature dependence in the tundra and boreal forest soils during summer. Q_{10} values (1.00 to 2.96) derived from the temperature at three soil depths (10, 20 and 30 cm) indicated considerable differences, suggesting that this results in the difference of soil physical characteristics.

1. Introduction

The terrestrial ecosystems including tundra and boreal regions cover a little less than 18% of the earth's land surface, but they contain more than 40% of all carbon present in the terrestrial biome (Kasischke, 2000). Higher-latitude ecosystems are particularly vulnerable to climate change due to the large carbon pools in northern latitude soils. Soil carbon pool estimates for the combined arctic tundra-boreal forest range from 21% (Raich and Schlesinger, 1992) to 30% (Post *et al.*, 1982) of the total global carbon pool. Northern boreal forests represent approximately 35% of the world's forest; however, they contain roughly 66% of the world's forest soil carbon pools with soil organic matter as well as permafrost (Van Cleve and Dryness, 1983; Kasischke and Stocks, 2000). The carbon balance of the arctic varies over time and space, resulting in a significant variance in soil respiration rate over seasonal scales and spatial scales (Oechel *et al.*, 1998). Therefore, the objectives of this study are to estimate the soil respiration rate and the net respiration rate by aboveground vegetation using the static chamber measurements, to understand the soil temperature sensitivity of soil respiration and net respiration rates at different soil depths, and to make a better spatial distribution of the contents of biomass, carbon, and nitrogen from the aboveground vegetation and soils at representative ecosystem sites. These sites are along a latitudinal Alaskan transect (148°W) and flux measurements are taken during the summer seasons of 2000 and 2001.

2. Materials and Methods

2-1. Sampling Site and Methods

The Alaskan ecosystems (a transect of the state at 148°W latitude) consist of tundra and boreal forest that significantly affect the global carbon budget. The tundra ecosystem ranges from the northern side of Brooks Range to Prudhoe Bay, and the boreal forests are widely spread over the southern side. Figure 1 shows the sampling locations of the coastal arctic tundra (CT), sub-arctic upland tundra (UT), sub-alpine tundra (SaT), forest-tundra ecotone (TZ), boreal forest sites near Cooldfoot (BC-1) and near Fairbanks (BC-2). Site BC-2 was reported by Kim and Tanaka (2002). Two-type chambers were used for the estimation of net respiration rate by soil surface vegetation, which means the difference of CO_2 flux between light chambers (e.g. sum of soil respiration and photosynthesis by the aboveground vegetation) and dark (e.g. sum of soil respiration and vegetation respiration). Flux measurements in this study were used when the correlation coefficient (R^2) was above 0.98. The two type chambers were light and dark chambers for the estimation of net respiration rate by soil surface vegetation. Measurement of soil temperature conducted at 5, 10 and 20 cm under the soil surface with

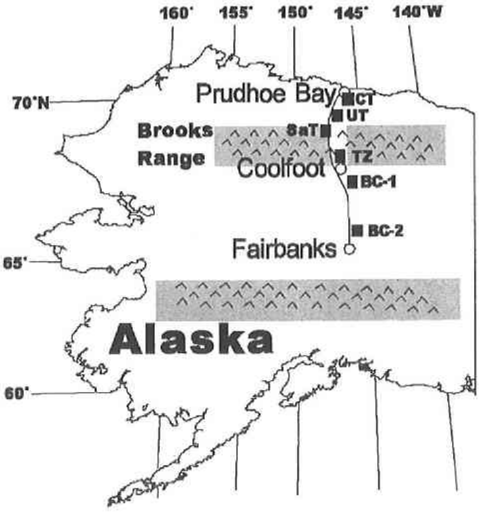

Fig. 1 Location of sampling sites. CT is coastal tundra, UT is upland tundra, SaT is sub-alpine tundra in northward slope of Brooks Range, TZ is ecotone zone between tundra and boreal forests, BC-1 and 2 are typical boreal forests in Coldfoot and Fairbanks of south side of the Range, respectively.

portable thermometer.

3. Results and Discussion

3.1. Soil Respiration Rate

The temporal and spatial variation of soil respiration rate (CO_2 emission) at each site was shown in Fig. 2(a). The soil respiration at site CT was below 0 value measured with light chamber, which means faster the photosynthesis rate of aboveground vegetation than the decomposition rate of soil organic matter.

Soil respiration rate was different between 2000 and 2001 owing to the difference of air temperature. Through the low air temperature during 2000, the respiration rates with dark chamber were much higher than those during 2001. There was no significance between the values obtained with dark chamber during 2000 and 2001 except for site CT under 95% of confidence level. In term of soil carbon, accumulated soil respiration was

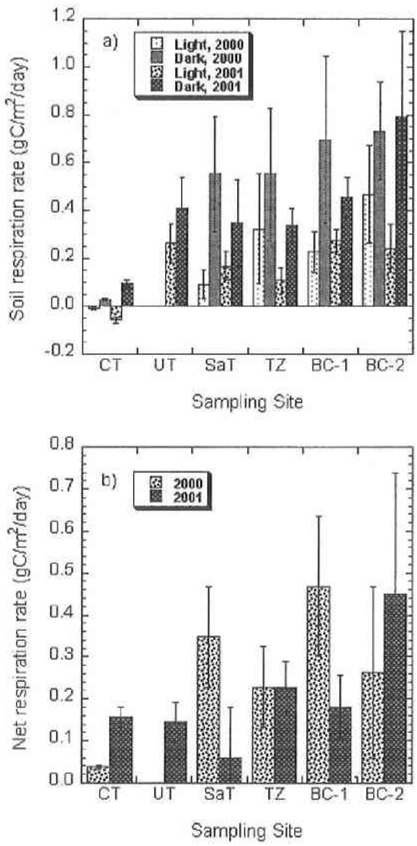

Fig. 2. Temporal and spatial variation of a) soil respiration and b) net respiration rate along a latitudinal Alaskan transect during summer season of 2000 and 2001.

equivalent to 16 ± 12 gC/m^2 for the light chamber and 35 ± 24 gC/m^2 for the dark chamber in tundra soils, and 57 ± 47 gC/m^2 for the light chamber and 102 ± 38 gC/m^2 for the dark chamber in boreal forest soils during the summer of 2000. During 2001, the rate was 18 ± 15 gC/m^2 for the light chamber and 42 ± 18 gC/m^2 for the dark chamber in tundra, and 43 ± 22 gC/m^2 for the light chamber and 107 ± 55 gC/m^2 for the dark chamber in boreal forest. Gilblin *et al.*, (1991) observed the soil respiration rate ranged from 5.9 to 20 gC/m^2 in arctic Alaska soils during the growing season, which is similar to the values obtained in tundra using the light chamber in this study. The average respiration rates in arctic tussock and wet sedge varied between 4.4 and 44 gC/m^2 (Oechel *et al.*,1997), which corresponds to 20% and 40% of the total soil respiration rate in tundra soils. Raich and Shlesinger (1992) described the annual soil respiration in tundra and boreal forest soils to be 60 ± 6 gC/m^2/yr and 322 ± 31 gC/m^2/yr, respectively. If the growing season is 136 days in tundra and 167 days in boreal forests (Oechel *et al.*, 1997), average soil respiration was 22 ± 2.2 gC/m^2 and147 ± 14 gC/m^2 in tundra and boreal, respectively, which was slightly higher than our data. Our data was lower than those published elsewhere ; this may be due to the lower temperature and the latitudinal difference of site BC-1, which is located in 300 km north from BC-2 (see Fig. 1). This may reflect the lower microbial activity at site BC-1 under the low soil temperature.

3.2. Net Respiration Rate by the soil surface vegetation

Spatial and temporal variations of the net respiration rate at each site are shown in Fig. 2(b). Based on the *t*-test, there was no significant difference for the spatial variations of net respiration between tundra (0.14 ± 0.12 gC/m^2/day) and boreal forest (0.27 ± 0.21 gC/m^2/day) during the summer season of 2000 ($P < 0.05$). On the other hand, there was a significant difference for net respiration between tundra (0.18 ± 0.11 gC/m^2/day) and boreal forest (0.38 ± 0.30 gC/m^2/day) during 2001 with space ($P < 0.05$). There was no significant difference for temporal variation of the net respiration between during the summer seasons of 2000 and 2001. Accumulated net respiration rates were 19 ± 16 gC/m^2 and 45 ± 35 gC/m^2 in tundra and boreal forest soils during the summer of 2000, and 24 ± 15 gC/m^2 and 64 ± 50 gC/m^2 in tundra and boreal soils during the growing season of 2001, respectively. Mean respiration rate corresponds to 54% of the total respiration rate throughout the entire data during two summers, suggesting that the net respiration rate plays an important role on the regional carbon cycling in tundra and boreal forest ecosystems along a north-south Alaskan transect. Despite the fact that vegetation was diverse along the Alaskan transect, this value is similar to the average value (54%) obtained at typical boreal forest ecosystem site (BC-2), interior Alaska during three-summer season (Kim and Tanaka, 2002).

3.3. Effect of Soil Temperature

Soil temperature became well known as one of major factors determining soil respiration rate in terrestrial ecosystems. Relationship between soil respiration and temperature was plotted and then Q_{10} values were estimated at each site along north-

Table 1. Q_{10} and correlation coefficients (R) for the relationship between soil respiration and soil temperature at 5, 10, and 20 cm during summer seasons of 2000 and 2001

Site	Q_{10} (s.e)#			R			Chamber
	5 cm	10 cm	20 cm	5 cm	10 cm	20 cm	
CT	1.13 (0.09)	1.92 (0.11)	–*	0.10	0.27	–	Light
	–	–	1.74 (0.17)	–	–	0.51	Dark
UT	1.49 (0.31)	–	–	0.56	–	–	Light
	1.31 (0.24)	1.00 (0.08)	–	0.54	0.02	–	Dark
SaT	1.12 (0.02)	–	–	0.96	–	–	Light
	1.09 (0.10)	1.01 (0.14)	1.52 (0.67)	0.69	0.06	0.14	Dark
TZ	1.09 (0.12)	1.05 (0.01)	1.35 (0.67)	0.33	0.13	0.27	Light
	1.07 (0.09)	1.10 (0.10)	1.32 (0.72)	0.41	0.29	0.25	Dark
BC**	1.47 (0.03)	1.61 (0.55)	2.79 (0.28)	0.84	0.58	0.78	Light
	1.17 (0.10)	1.20 (0.16)	2.96 (0.19)	0.60	0.42	0.84	Dark

#s.e. is standard error for Q_{10}.
*- is not determined.
**Data averaged from at boreal forest sites BC-1 and BC-2.

south Alaskan transect (Table 1). Q_{10} values have no significance between light and dark chambers at same site under 95% of confidence level. The Q_{10} values varied from 1.00 to 2.96 through the entire data, which are close to previous data for soil respiration rate (1.3 to 3.3 ; Raich and Schlesinger, 1992 ; Lloyd and Tayor, 1994). At site BC-2, Q_{10} ranged from 1.00 to 3.49 under wet and dry weather condition, which nearly correspond the values obtained at site BC-1. This indicates that two sites have identical vegetation that was black spruce forest. Raich and Schlesinger (1992) argued that Q_{10} value of soil respiration was higher at low than at high temperatures, indicating that temperature increases in northern latitudes would have greater impacts on soil respiration rates than would similar changes in warmer climates.

References

Gilblin, A.E., K.J. Nadelhoffer, G.R. Shaver, J.A. Laundre, and A.J. MaKerrow, 1991 : Biogeochemical diversity along a riverside toposequence in arctic Alaska, *Ecological Monographs* **61**, 415-435.

Kasishcke, E.S., 2000 : Boreal Ecosystems in the Global Carbon Cycle. In : *Fire, Climate Change, and Carbon Cycling in the Boreal Forest* (ed. Kasishcke, E.S. and B.J. Stocks). Springer, New York, 19-30.

Kasishcke, E.S. and B.J. Stocks (eds.), 2000 : *Fire, Climate Change, and Carbon Cycling in the Boreal Forest.* Springer, New York, 461.

Kim, Y.-W. and N. Tanaka, 2002 : Effect of Forest Fire on the Fluxes of CO_2, CH_4, and N_2O in Boreal Forest Soils, Interior Alaska. *Journal of Geophysical Research* (In Press).

Lloyd, J., and J.A. Taylor, 1994 : On the temperature dependence of soil respiration. *Functional Ecology*., 8, 315-323.

Oechel, W.C., G.L. Vourlitis , and S.J. Hastings, 1997 : Cold season CO_2 emission from arctic soils. *Global Biogeochemical Cycles*, **11**, 163-172.

Oechel, W.C., G.L. Vourlitis, S. Brooks, T.L. Crawford, and E. Dumas, 1998 : Intercomparison among chamber, tower, and aircraft net CO_2 and energy fluxes measured during the Arctic System Science Land-Atmosphere-Ice Interactions (ARCSS-LAII) Flux Study. *Journal of Geophysical Research*, **103**, 28993-29003.

Post, W.M., W.R. Emanuel, P.J. Zinke, and A.G. Stangenberger, 1982 : Soil carbon pools and world life zone, *Nature*., **298**, 156-159.

Raich, J.W., and W.H. Schlesinger, 1992 : The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. *Tellus*, **44**, 81-99.

Van Cleve, K., and C.T. Dyrness, 1983 : Introduction and overview a multidisciplinary research project : the structure and function of a black spruce (*Picea mariana*) forest in relation to other fire-affected taiga ecosystems. *Canadian Journal of Forest Research*, **13**, 695-702.