EVALUATION OF INTER-ANNUAL CARBON BUDGET FOR A SUB-ARCTIC BLACK SPRUCE FOREST BASED ON CONTINUOUS FLUX OBSERVATION

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ABSTRACT
Measurements of CO_2 flux were made by the eddy correlation method over a sub-arctic black spruce forest in interior Alaska. Observed CO_2 budget were sinks of -531~-247 and -219~0 g CO_2 m^{-2} $year^{-1}$ during 2003 and 2004, respectively. The broad range is caused by uncertainty regarding assessment of the nocturnal fluxes. The sequestration of CO_2 during 2004 was limited by high temperature, drought or low light intensity conditions. The net CO_2 flux is in a delicate balance between two large terms, which would shift from sink to source due to global warming.

INTRODUCTION

Recent reports showed obvious warming at high latitudes, which accelerated greenhouse gas emissions in relation to a large carbon content. Boreal forests, which cover approximately 9.2% of the earth surface and carry out 2.6% of global net primary production [*Chapin et al.*, 2002], are important on global C budget. However, there is a little information about inter-annual C budget of boreal forests, especially in the sub-arctic. We conducted continuous flux observation at a sub-arctic forest over two years. In this paper, we present the delicate C balance between photosynthesis and respiration and its sensitivity to the climate.

SITE AND OBSERVATION

The research site was located at a boreal forest in central Alaska (64^o 52'N, 147^o 51'W), which stands on discontinuous permafrost. Black spruce is the dominant tree species, which consist of an open canopy with a height of 6 m. The forest floor is composed of vascular plants and short shrubs, which almost are completely covered by moss and lichens. Fluxes of CO_2, H_2O, and energy were measured by the eddy correlation method since November 2002.

RESULTS AND DISCUSSION

Half hourly net ecosystem exchange (NEE) was determined the sum of CO_2 flux by the eddy correlation and air-column storage. To evaluate the nighttime NEE and daytime respiration, simple exponential relationship between ecosystem respiration and air temperature was used (Fig.1). There was considerable scatter in the relationship, which could be caused by the difference of sensitivity between heterotrophic and autotrophic respiration of various components. This relationship changed among the season. The shift in the Q_{10}, the temperature sensitivity, could mainly reflect the changing canopy physiology and physics [*Yuste et al.*, 2004] or other environmental conditions. They suggested that the Q_{10} fitted to the entire yearly data sets reflected not only temperature sensitivity but also plant phonological patterns, and the use of a constant Q_{10} in models might cause significant errors. The Q_{10} value of growing season, 1.5 ~ 2.1, was higher than that of snow covered period, 1.5, which was lower than other black spruce forest. Thus, there was low temperature sensitivity of this black spruce forest.

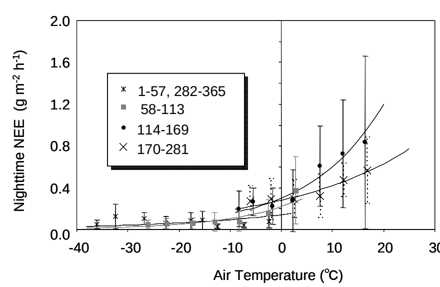

Fig.1 Relationship between ecosystem respiration and air temperature for each period.

The half-hourly NEE readings for the whole two years are shown in Fig.2a. Gray area in Fig.2 represents a missing observation due to system failure, which filled using tundra CO_2 budget model (TCBM), which divides NEE into photosynthesis and respiration and calculates canopy conductance and other parameters using meteorology as a big-leaf approach [*Yoshimoto et al.*, 1997]. Obvious uptake of CO_2 was measured after around day of year (DOY) 58, each year, when the forest floor was completely covered with snow, suggesting that the photosynthesis of black spruce could occur during the daytime. The daytime uptake was rapidly increased after DOY 120, and the maximum level was in DOY 170 during 2003.

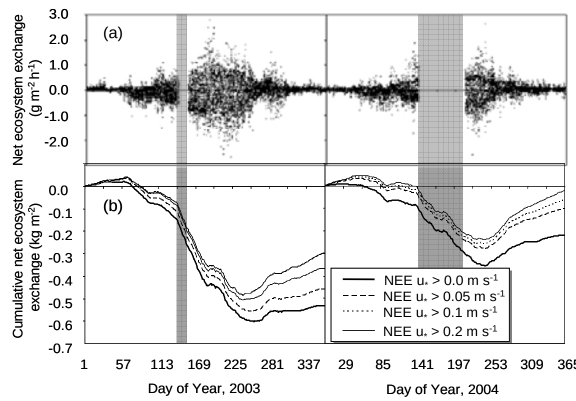

Fig.2 Half-hourly net CO_2 exchange above the black spruce stands (a) and cumulative net CO_2 exchange for applying the different threshold of u_*(b) .

The cumulative NEE during the whole two years is shown in Fig.2b. The accumulated NEE was -531.2 and -219.2 g CO_2 m^{-2} $year^{-1}$ during 2003 and 2004, respectively. Applying the friction velocity (u_*) threshold, however, observed NEE was decreased 56~86% and 9~46% of that not applying the threshold, which could be caused by uncertainty regarding assessment of the nocturnal fluxes. Assuming the uncertainty, annual budget of the CO_2 sink was -531~ -247 and -219~0 g CO_2 m^{-2} $year^{-1}$ during 2003 and 2004, respectively.

The fixed CO_2 during 2004 was less than half of that during 2003, which could be caused by the difference in the meteorology. The mean temperature between May and August during 2004 was higher by 2.7^{o}C than that during 2003, and the precipitation during 2004 was 38% of that during 2003. To clarify the components of CO_2 budget, we applied TCBM (Fig.3). According to TCBM, while the high temperature until DOY 180 enhanced the respiration, the drought after that period limited the respiration in 2004. The high temperature also limited the photosynthesis in whole growing season of 2004. During mid-summer of 2004, in addition, cloud cover caused by forest fire often occurred, which could also reduce the photosynthesis. In consequence, high temperature, drought and low light intensity mainly limited the carbon sequestration in 2004. The net CO_2 flux was in a delicate balance between two large terms, photosynthesis and respiration (Fig.3). A small shift in one of them could change the carbon balance.

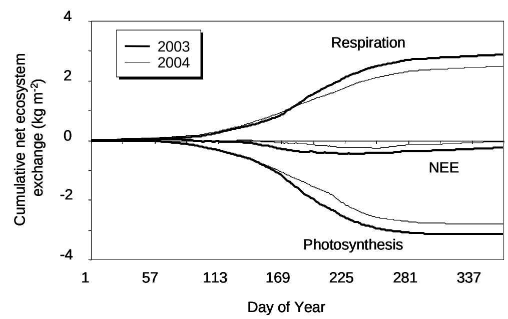

Fig.3 The CO_2 budget calculated using TCBM.

CONCLUSION

The annual budget of CO_2 measured using the eddy correlation was sink of -531~-247 and -219~0 g CO_2 m^{-2} $year^{-1}$ during 2003 and 2004, respectively. High temperature, low precipitation or low light intensity during growing season could limit the carbon sequestration. The net CO_2 flux is in a delicate balance between two large terms, which would shift from sink to source due to global warming.

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