Estimate of the CO_2 uptake on the scale from the forest to subcontinent by boundary layer observation

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Total Budget for FY2001-FY2003 86,031,000Yen (**FY2003**; 26,589,000Yen)

Key Words CO_2, Forest uptake, Planetary Boundary layer, Atmospheric transport, Observation method

1. Introduction

To estimate a carbon flux on the subcontinent scale by using an inverse method for atmospheric transport model, atmospheric CO_2 records observed 1) in many sites 2) in high frequency 3) not only at the surface but also in the free troposphere are required.

The continuous CO_2 measurements on the ground station provide CO_2 data in high frequency and is easy to extend the observation sites. But the ground based measurements hardly get the information in the CO_2 variation at the free troposphere.

The CO_2 measurements onboard the aircraft is only way to obtain a vertical distribution in high quality. But it is hard to carry out in many sites in high frequency because of its skillful operation and higher cost.

In this study, both continuous measurements and intense aircraft measurements are conducted in the forest area. In comparing both results, we investigate optimizing combination of ground and aircraft observation to estimate a CO_2 flux on the subcontinent scale. We also establish an analytical method to quantify the CO_2 flux using a one dimensional model.

2. Methods

To understand the CO_2 exchange between planetary boundary layer (PBL) and free troposphere (FT), frequent measurements of atmospheric CO_2 are conducted using a small aircraft and a tower at the forest area in West Siberia. Continuous CO_2 measurement system was installed in Berezorechka village, West Siberia (56°10'N, 84°20'E) in October 2001. We put air intakes and meteorological sensors at the following altitudes of the Berezorechka tower.

80m: CO_2, Temperature, Humidity
40m: CO_2, Rn[1], O_3, Wind, Temperature, Humidity
20m: CO_2
5m : CO_2, Rn, O_3, Temperature, Humidity

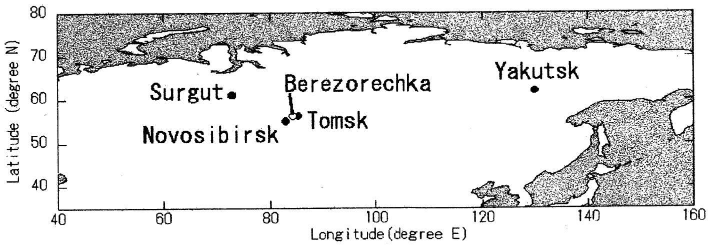

Figure 1. Map of observation site

The aircraft observation has carried out using An-2 between 3km and 0.15km over Berezorechka at two or three times per month. CO_2 mixing ratios were measured continuously using small CO_2 observation system based on LI-COR, LI-800.

3. Results and discussion

The CO_2 mixing ratios observed on the tower show both diurnal and seasonal variations (Figure 2). The amplitudes in diurnal variation are less than 15ppm in winter. In summer, the amplitudes are up to 60ppm at 80m and 120ppm at 5m. Since diurnal variations are clearly found in winter, substantial amount of CO_2 flux from the ecosystem exist even in extremely low temperature.

The daytime CO_2 values are high in winter and low in summer with a peak-to-peak amplitude of 30ppm, which is apparently larger than that observed in the forest near Yakutsk, east Siberia[2].

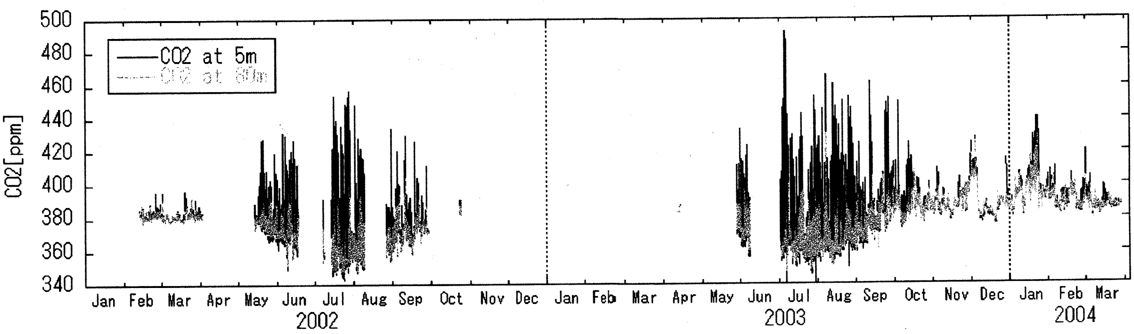

Figure 2. Temporal variations in CO_2 mixing ratio observed in Berezorechka.

Vertical CO_2 profiles over Berezorechka observed by aircraft are shown in Figure 3. In winter, the CO_2 profiles are almost constant over 0.5km. When inversion layer is observed near the ground, CO_2 mixing ratios show extremely high values (02 Feb. 2002 and 14 Nov. 2002). In summer, vertical gradients are larger than winter, with lower values in lower altitudes, and also scatters of mixing ratio are larger.

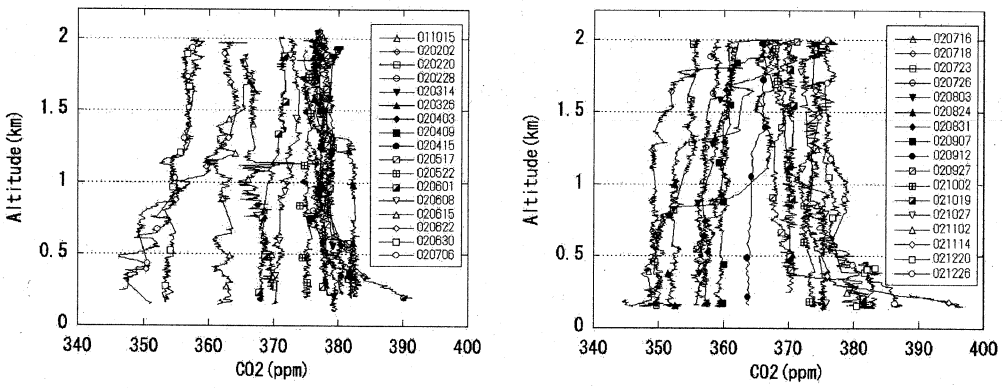

Figure 3. Vertical CO_2 profiles over Berezorechka

The peak-to-peak amplitude in seasonal CO_2 variation at 0.5km over Novosibirsk is 26ppm[3]. On the other hand, peak-to-peak amplitude at 0.5-1km over Berezorechka is calculated to 29ppm, which is 3ppm larger than that at 0.5km over Novosibirsk, even though higher altitude data are used in Berezorechka. To compare the CO_2 variation between in PBL and FT, CO_2 mixing ratios were separated using vertical profiles of Temperature, Potential Temperature and Humidity. Figure 4 indicates temporal variations of CO_2 in PBL and FT over Berezorechka. CO_2 mixing ratios in PBL were 10 ppm lower than FT in summer and 3-4 ppm higher in winter. Peak-to-peak amplitude is 34.4 ppm in PBL and 16.4 ppm in FT. Annual mean values in PBL are 2 ppm higher than those in FT, indicating existence of rectifier effect.

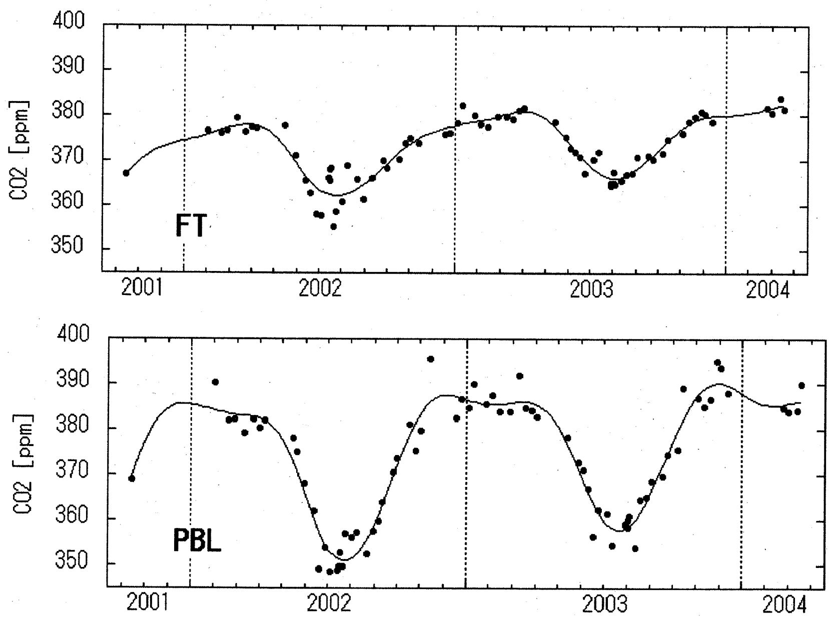

Figure 4. Temporal variations of CO_2 mixing ratio in the PBL and FT over Berezorechka. Solid circles represent observed data, solid line best fit curces.

The PBL data observed by aircraft are compared with tower data obtained in the afternoon (Figure 5). Both data agree well in winter. In summer, aircraft values are similar to lower data in the scatter of tower measurements.

Both daytime tower values and aircraft PBL values are agreed within 2 ppm under the conditions without inversion layer in winter or small temporal variation in summer. This fact indicates that tower data can represent CO_2 mixing ratios in PBL under the appropriate conditions.

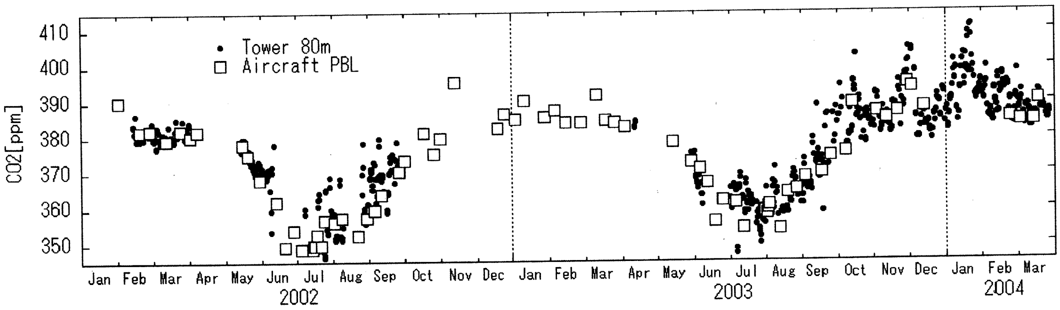

Figure 5. Comparison of CO_2 temporal variation in aircraft PBL data with those of tower data observed in the afternoon.

The CO_2 mixing ratios simulated by 3-D carbon cycle model[4] are compared with observed data in Figure 6. The phase in seasonal variation is well simulated by model but the seasonal amplitudes are under estimated. In addition, CO_2 values in early winter are too low compared to late winter, which is similar to CO_2 variation in FT. These results suggest that vertical transport between PBL and FT is too efficient in the model.

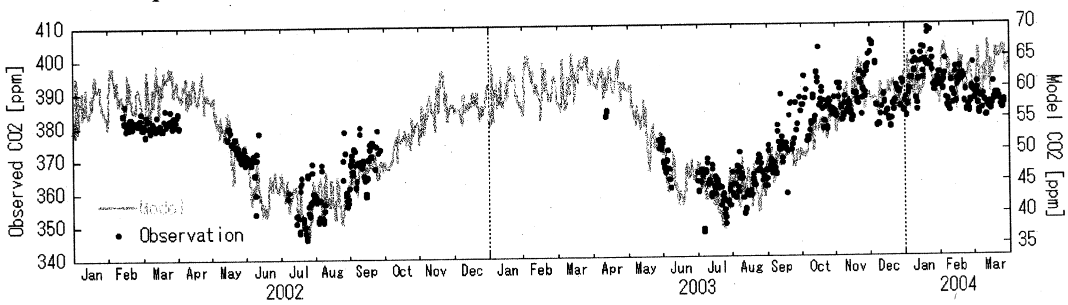

Figure 6. Comparison of CO_2 variation simulated by 3-D carbon cycle model with those of tower data observed in the afternoon.

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