B-4.5 Altitude Distribution of CO_2 over Forest and Sink Source Evaluation

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Abstract

The flux of carbon dioxide has been compared between the micro-meteorological eddy covariance method and the change of column concentration trapped in the temperature inversion at nighttime at Tomakomai, Hokkaido in August 2000. The accumulation of carbon dioxide in a temperature inversion by the respiration of forest ecosystem has been measured by a tethered balloon equipped with a sampling tube obtaining the altitude distribution up to 120 m. The distribution up to 2100 m has been obtained on board of a model aircraft equipped by an NDIR carbon dioxide sensor. The latter has been operated from early morning and the uptake of carbon dioxide in the temperature inversion by forest ecosystem has been evaluated. The nighttime respiration value thus obtained was more than twice of the value from micro-meteorological method, and the early morning photosynthesis was equivalent each other.

The flux of CO_2 has been observed at Takayama site since 1998 with eddy covariance method. The Takayama site is located over a hill in the complex terrain, however, many kinds of disturbance induced by the complex terrain may influence the obtained data. The relations between local wind system and CO_2 flux, local wind system and CO_2 concentration, and turbulent fluxes and wind direction were investigated. The amount of nighttime CO_2 flux measured at 27-m tower highly depends on the stability of the boundary layer. Observed momentum flux and latent heat flux depend on the wind direction. When the wind direction is westerly, latent heat flux should be underestimated, because relatively dry air, which is brought up along a steep cliff at the west side of the tower, intrudes into the surface layer. The CO_2 concentration attains the daily maximum value at mid night due to the advection of local down slope wind.

Key Words: CO_2 flux, NEP, complex terrain, CO_2 concentration change, mesoscale model

1. Introduction

The estimation of the flux of carbon dioxide over forest ecosystem is one of the major

objectives of carbon cycle research. The eddy-covariance method is an excellent method to obtain the flux in time series, but there remain several problems to be solved. Therefore, adding some other observation methods such as accumulated CO_2 within and above the canopy, and the analysis of local and mesoscale transportation, etc., are still required.

The altitude distribution measurement of CO_2 over the flux monitoring site is expected to offer useful information about the above process especially at nighttime and early morning, when the eddy-correlation method may cause an error over a complex landscape and even over a very simple landscape.

Takayama site is the first point where CO_2 flux is continuously observed in Japan (Yamamoto et al., 1999), however, the site is located in the complex terrain. The effects of complex terrain were investigated from three points; (a) the effect of local down slope wind on the nighttime CO_2 flux measured at the top of the 27-m tower, (b) the effects of topography just around the tower on the measured turbulent fluxes, and (c) the effects of local wind on the daily variation of CO_2 concentration.

2. Altitude Distribution Measurement for the Analysis of Column Concentration of CO_2

2-1. Research Objective

The column concentration change of CO_2 over Tomakomai Flux Monitoring Site should be equivalent to the micro-meteorological eddy covariance flux if the horizontal transportation can be neglected. The comparison at nighttime and early morning are of interests.

2-2. Research Method

The nighttime accumulation of CO_2 has been obtained by lifting the air-sampling tube by a tethered balloon up to 120 m. The early morning uptake of CO_2 and the start of convection transportation have been observed by use of a model aircraft equipped by a light weight CO_2 sensor.

2-3. Results

The nighttime accumulation of CO_2 in the temperature inversion on Aug. 24-25, 2000, has been observed by the tethered a balloon method. The increasing rate of column concentration between 0 and 120 m was 0.4 $mgCO_2/m^2/sec$. The altitude distribution change up to 2100 m has been observed on Aug. 27, 2000, by a model aircraft. The temperature inversion height was found to be 600 m, and the column concentration for the altitude below 600 m at 5 a.m. was 14 gCO_2/m^2. It decreased to zero at 11 a.m. and the rate was found to be –0.6 $mgCO_2/m^2/sec$.

2-4. Conclusion

(1) The nighttime respiration evaluated from the column concentration change was 0.4-1.0 $mgCO_2/m^2/sec$, which is more than twice of that obtained by eddy-covariance method.

(2) The early morning carbon-uptake rate was evaluated to be 0.6 $mgCO_2/m^2/sec$ from the column concentration change, which is equivalent to that obtained by eddy-covariance

method. But the time dependence of this rate was different each other.

(3) The effect of horizontal transportation should be analyzed both by additional experiments and model evaluation.

3. Analysis of Landscape Effect at Takayama Flux Monitoring Site

3-1. Research Objective

Many towers where energy or CO_2 flux is measured are often mounted in the complex terrain, however, the effects of those complex terrain are not always clear. It is necessary to clarify what is the effect induced by the complex terrain in the flux and concentration measurement of CO_2.

3-2. Research Method

A 3-m small tower was mounted 40 m west of the 27-m tower to measure another CO_2 flux and micro meteorology in a small valley, and the flux is compared with that obtained at 27-m tower. The characteristics of covariance to calculate the fluxes were examined with so-called four-quadrant analysis. The relation between daily variation of CO_2 concentration and local wind was analyzed with a mesoscale numerical model.

3-3. Results

When the stability is stable in the canopy at night, down slope wind is generated and CO_2 flux measured at 27-m tower is much less than that in near neutral stability. The momentum flux and latent heat flux measured at 27-m tower in the westerly wind has different characteristics from the fluxes in other wind directions. Particularly, latent heat flux was transported to downward in the westerly wind, which may be one of the reasons of energy flux imbalance at Takayama. This downward flux is transported by upward motion of dry air, which is brought up along the cliff at the west of the tower. The wind at the tower often turns the direction to down-slope direction at mid night. Then air mass with relatively low CO_2 concentration is carried from high mountainous region where activity of the forest ecosystem is not high. This causes to reduce the CO_2 concentration after mid night at Takayama (Kondo et al., 2001).

4. Conclusions

(a) The change of the column concentration of CO_2 has been calculated from the altitude distribution of CO_2 by a tethered balloon system, and the nighttime respiration of 0.4 mg CO_2/m2/sec was obtained.

(b) The similar calculation from the altitude distribution by a model aircraft system shows the uptake rate of CO_2 at early morning to be 0.6 mgCO_2/m2/sec.

(c) The amount of CO_2 flux measured at 27-m tower at night highly depends on the stability of the boundary layer. When the stability is stable, the flux measured at the 27-m tower is much less than that in the neutral stability.

(d) The turbulent transfer measured at 27-m tower has a peculiar pattern when the wind direction is westerly. Particularly, latent heat flux may be underestimated in the westerly wind direction.

(e) The maximum CO_2 concentration is often attained at mid night when the local wind is generated around Takayama site. The down slope wind at night causes to reduce the concentration, because the wind has blown down over the area with low ecosystem activity such as low respiration before reaching at Takayama.

References

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