B-4.3.4 Study on International cooperative observation study of flux evaluation in large scale at reference field in Japan (Micrometeorological Measurements of Mass and Energy Exchange between a Rice Paddy and the Atmosphere)

Contact Person Yoshinobu HARAZONO
Head of Micrometeorology Lab.
National Institute of Agro-Environmental Sciences,
MAFF/Japan
Kannondai, Tsukuba, 305 Japan
Phone +81-298-38-8207 Fax +81-298-38-8211
e-mail yoshi4@niaes.affrc.go.jp

Total Budget for FY1996 1,976, 000 Yen

Abstracts Field measurements of carbon dioxide (CO2), water vapor (H2O, latent heat lE), methane (CH4) and heat fluxes (sensible H) were conducted at Hachihama Field, Okayama University in 1996 summer. Over the flooded rice field, CO2, H2O and heat fluxes were measured by an eddy correlation method and CH4 flux was determined by modified gradient method.

In order to get accurate flux numbers, the spectrum distribution of flux were examined on eddy correlation measurement and the line averaging effects of the fluctuations of concentrations and vertical wind speed was corrected. For methane flux, the level was examined comparing with the flux obtained by the Inverse Lagrangian method originally proposed by CSIRO, Australia group. From these examination, flux levels include the spectrum correction were considered to be accurate compare to those exclude the corrections. The modified gradient method was also confirmed as more accurate method to determine the trace gas flux.

The flux levels of CO2 and H2O were almost same as those obtained at similar vegetation previously. The measurement site was special field with weekly drainage. During the flooded period, water table suppressed transfer of CO2 from soil layer, thus the CO2 flux in flooded periods was smaller than that in drainage period.

Key Words Carbon dioxide, flux, flooded rice field, micrometeorology,

1. Introduction

Recently, we have initiated a collaborative research to measure and analyze fluxes and concentration profiles of trace gases such as methane and carbon dioxide in a rice paddy. The eddy correlation technique was employed to measure these fluxes along with a suite of other micrometeorological, plant and soil measurements. Here we present some preliminary results on energy partitioning, CO2 exchange, and turbulence statistics measured in a rice paddy in the summer of 1996.

2. Materials and Methods

2.1 Study Site

The study was conducted at a rice paddy located in the agricultural station of the Okayama University (34.5 N, 134 E) in Okayama, Japan. The study site was approximately 300m x 300m wide, surrounded by similar rice paddies. Micrometeorological instruments and masts were deployed on 2 August 1996 and the measurements were made from 6 August through 16 August. The experiment was interrupted from the afternoon of 13 August to the morning of 15 August by a typhoon. During the measurement period the canopy height (hc) was on average 0.72m and the row spacing was about 0.27m. Leaf area index (LAI) was about 3.1. Because of the high salinity, the site was irrigated on a weekly basis (inundated during weekdays and then drained during weekend).

2.2 Micrometeorological Measurements

The eddy correlation instruments were located at the northwestern edge of the site so that the fetch was at least 200m for the winds from east to southwest. To measure the fluctuations in the horizontal and the vertical wind speeds and in the concentrations of carbon dioxide and water vapor, we used a three-dimensional sonic anemometer (Solent, Model-1012R with 0.15m path length) and an infrared CO2 & H2O fluctuation meter (Advanet, Model-E009A with 0.2m path length), respectively. These sensors were installed 1.5m above the canopy (i.e., 2.2m above the ground) and the separation between the two was approximately 0.17m. To measure the turbulence within the canopy, we also used the two miniature three-dimensional sonic anemometers (Kaijo-Denki, model-DATW295, 50mm path length). The measurement levels of these miniature sensors were varied throughout the study period to cover the whole canopy height (Figure 1). Also, we measured the surface soil CO2 flux and the leaf area index using a portable infrared gas analyzer (Licor, LI-6400) and a canopy analyzer (Licor, LI-2000), respectively.

All the signals from the sensors were recorded with a sampling rate of 10 Hz in binary codes and were monitored with a virtual oscilloscope for quality control. Eddy fluxes and other statistics were computed for 30 minute averaging period. The fluxes of CO2 and water vapor were corrected for the variation in air density due to the transfer of heat and water vapor following the method of Webb et al. (1980). The sign convention used here is that flux toward the surface is negative.

3. Preliminary Results

3.1 Energy partition

In Fig. 2A, the detail variation of energy partitioning (averaged for the study period) is shown in terms of the Bowen ratio, b (=H/lE, where H and lE are the sensible heat and latent heat fluxes, respectively). During the day b ranged from 0.01 to 0.23. It reached the peak around 10:00 hrs (when H was the maximum) and then gradually decreased, indicating that more energy was partitioned into latent heat flux as the day progressed. There was small but consistent evaporation from the soil at night, resulting in small negative values of b.

3.2 CO_2 exchange

With the onset of photosynthetic activity after sunrise, CO_2 uptake by the rice canopy increased rapidly and its magnitude ranged from 1 to 1.3 mg m-2 s-1 during midday (Fig. 2B). At night it released CO_2 at a rate of 0.18 - 0.4 mg m-2 s-1(about 20-30% of the midday magnitude). The soil surface CO_2 flux showed a large spatial variation with a daytime average of about 0.43 (+- 0.3) mg m-2 s-1 when the soil was not flooded. After irrigation, however, the surface soil CO_2 flux became almost zero. The persistent standing water probably impaired the respiratory CO_2 release from the soil surface. In fact, we found at some locations significantly positive flux values (< 0.01 mg m-2 s-1), indicating that CO_2 was taken up by the water surface. Interestingly, the partial pressure of CO_2 in the paddy water at our site was increasing during the day (Ohtaki, personal communication, Watanabe et al., 1997).

3.3 Turbulent statistics

To understand properly the transport within the rice canopy we need knowledge of the turbulence statistics. Some of these were obtained from the measurements of u* and sw in the air layer above the canopy and measurements of sw and su within the canopy made with 3-dimensional sonic anemometers. Because the most important scale within the canopy is of order hc, leaf area profile and statistics of the wind moments as functions of z/hc in Fig. 3 and Fig.4. The mean stream wise wind component U is normalized with value at the reference height (1.5 m above the canopy), U (z=3.1 hc) in Fig. 3B. The mean wind profile is strongly sheared near z=hc, attenuating within the canopy depending on the LAI profile. The upper layer within the canopy exerted most of the drag on the wind above the rice crop. The profiles of turbulence statistics, su and sw (normalized for u*), are shown in Fig.4. The ratios su/u* approached typical surface-layer values (e.g., Raupach, 1988; Kaimal & Finnigan, 1994) of 2.5 and 1.25, respectively. Both ratios seem to fall with decreasing z above the canopy with values at z=hc of approximately 2.1 and 1.1, respectively. The turbulence was strongly height-dependent and su/u* and sw/u* decreased more rapidly as z decreases within the canopy.

4. Concluding remarks

We have measured and analyzed fluxes of carbon dioxide and water vapor in a rice paddy. Energy partitioning and the CO_2 exchange in a rice canopy showed generally similar characteristics to those of plant canopies with similar structure (e.g., Verma et al., 1995 for a review). Turbulent statistics (normalized by hc) of rice canopy seem to fall within the range of those reported from previous studies. Detailed analyses on these micrometeorological data including concentration profiles of CO_2, H_2O and CH_4 are currently in process.

References

Kaimal, J. C. and J.J. Finnigan, 1994: Atmospheric boundary layer flows: Their structure and measurement, Oxford University Press, 289 pp.

Raupach, M.R., 1988 : Canopy transport processes, In : W.L. Steffen and O.T. Denmead (Editors), Flow and Transport in the Natural Environment: Advances and Applications. Spring-Verlag, 95-127.

Verma, S.B>, J. Kim, R.J. Clement, N.J. Shurpali, and D.P. Billesbach, 1995 : Trace gas and energy fluxes: Micrometeorological perspectives, In : R. Lal, J. Kimble, E. Levine and B.A. Stewart (Editors), Soil and Global Change, Advances in Soil Science, Lewis Publishers, 361-376.

Webb, E.K., G.I. Pearman, and R. Leuning, 1980 : Correction of flux transfer. Quart. J. Roy. Met. Soc., 106, 85-100.

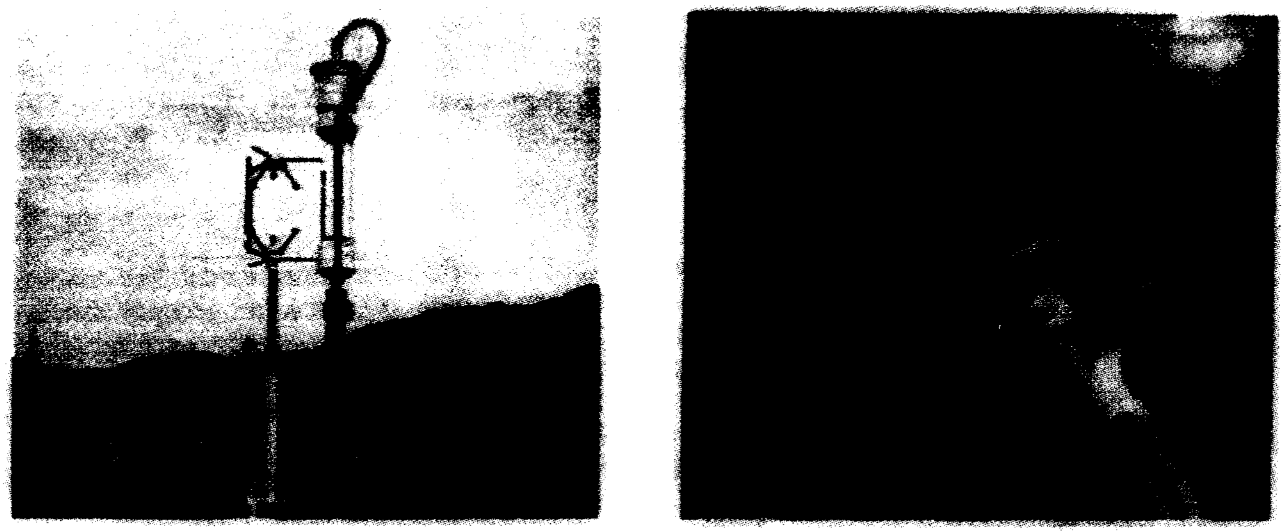

Fig. 1. Eddy correlation system installed (A) above and (B) within the rice canopy during Okayama study in Japan (August 1996).

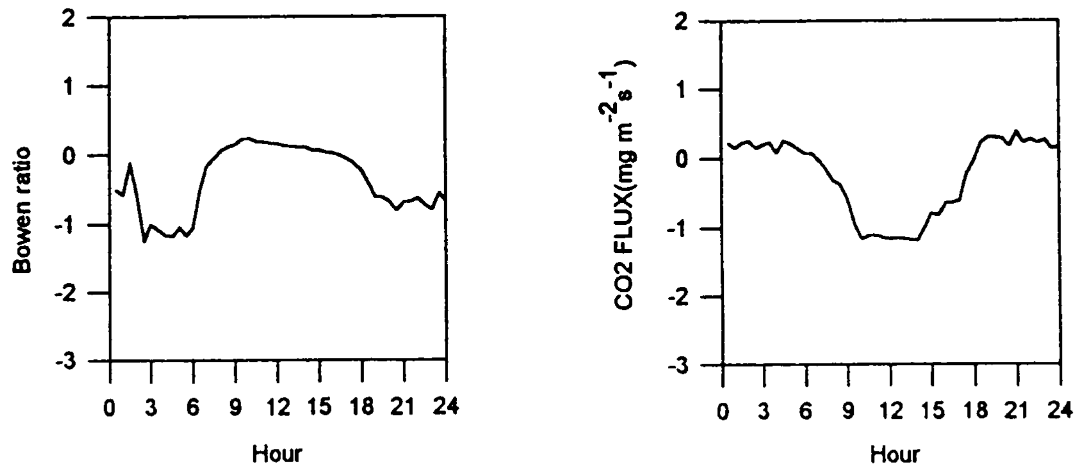

Fig. 2. Averaged daily variations of (A) b and (B) CO2 flux.

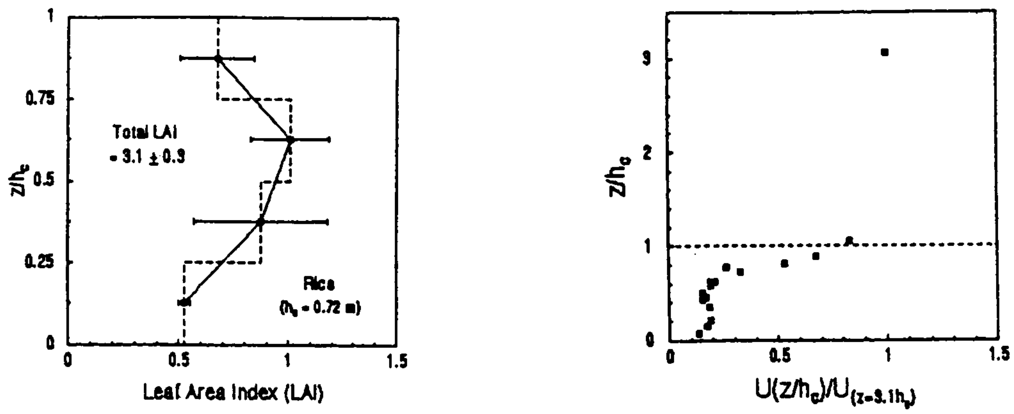

Fig. 3. Profiles of (A) LAI and (B) U for rice canopy.

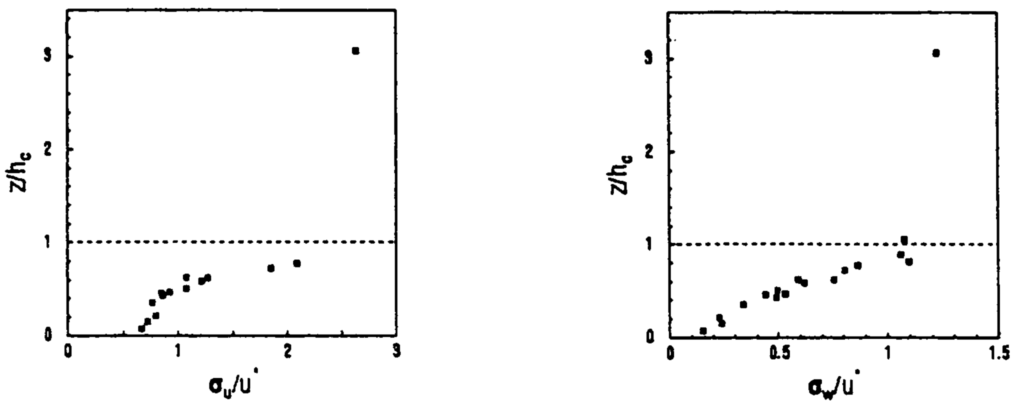

Fig. 4. Profiles with height of (A) su and (B) sw.