Characteristics of Flux Data Measured in the Forest Area of National Arbortum at Kwangneung, Korea (Session 3: In-site Flux Observation studies)

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CHARACTERISTICS OF FLUX DATA MEASURED IN THE FOREST AREA OF NATIONAL ARBORTUM AT KWANGNEUNG, KOREA

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1. Introduction

The Korea Monsoon Experiment (KORMEX) had been planned in 1996 and performed the intensive field observation during two years, 1998 and 1999. As a part of KORMEX, the flux measurement carried out to archive the basic data necessary for understanding the processes of the energy and water exchange over the Korean peninsula. Micrometeorological and flux measurements in KORMEX have been made over a temperate forest in the central part of the Korean peninsula continuously from October 1998. The measurement site, National Arboretum at Kwangneung (37^{o} 45' 25.370"N, 127^{o} 9' 11.620"E, 331m asl) is located in the representative mountainous forest area in Korea, about 40km away from the northern margin of Seoul. The reason that the mountainous forest was chosen as the flux measurement site in KORMEX is that about 70% of land-use in the Korean Peninsula is mountainous areas. The canopy height was approximately 15 m above the surface so that the 30m height of micrometeorological tower was constructed for the adaption of the eddy covariance technique to measure fluxes of latent and sensible heat. The upwind fetch of forest may extend several kilometers in all directions.

The objectives of this study are to briefly introduce the flux measurement system in KORMEX and its data quality control processing, and to preliminarily survey the energy budget measured in the forest area of the central Korean peninsula.

2. Measurement system

The instruments designed to measure fluxes of latent and sensible heat were placed on a scaffold tower 30 m above the surface and about 15 m above the canopy. Wind speeds and virtual temperature fluctuations have been measured with a three-dimensional sonic anemometer (model CSAT, Campbell Scientific, Inc.). Fluctuation in water vapor has been measured with an open path, ultraviolet krypton hygrometer (model KH20, Campbell and Tanner, 1985) which is similar in principle to the Lyman-alpha hygrometer (Buck, 1976), except that the source tube contains krypton gas. CSAT3 and KH20 are calibrated yearly at Campbell Scientific, Inc. KH20 mounted next to the CSAT3 with a separation of 10 cm. A fine wire thermocouple (model FW05) was mounted to the side of CSAT3 block to measure the temperature fluctuations. This eddy covariance system directly measured the latent and sensible heat fluxes and is proper at the tall plant area such as mountainous geography (NCAR, 1989). And the net radiation above the canopy has been measured with Q-7.1 net radiometer and CNR1 net radiometer. Net radiometer pointed to south and mounted far enough from other instruments so that it be never shaded. Soil heat flux has been measured with two heat flux plates (model HFT-3, Radiance Energy balance Systems) completely inserted into 8cm under ground surface completely. And multi-layer (31m, 24m, 16m, and 9m) temperatures, vapor pressures, and wind speed observations were also carried out with HMP45C Temperature and Relative Humidity Probe mounted inside of the RM Young 43408 Aspirated Radiation Shield, and RM Young 03001 Wind Sentry set, respectively.

3. Data processing

Two types of net radiometer, Q-7.1 and CNR1, used to measure net radiation. The Q-7.1 is a high-output thermopile sensor that measures only the algebraic sum of incoming and outgoing all-wave radiation. Incoming radiation consists of direct and diffuse solar radiation plus long-wave irradiance from the sky. Outgoing radiation consists of reflected solar radiation plus the terrestrial long-wave component. In comparison with Q-7.1, the CNR1 can be used in two modes, the net radiation mode and the four separate components mode. In the net radiation mode of CNR1 all radiation signals are combined to form one signal only, representing the net radiation. In the four separate components mode the upward and downward components of solar and terrestrial radiations are separately measured, and this mode has been adapted KORMEX radiation measurement since July 1999. In this case there are some errors in solar radiation measurements, especially, at lower solar elevation than 10 degrees, and these yield unreliable results. This is due to deviation in the directional response of upward-facing pyranometer. Therefore, before of net radiation calculation, these erroneous data should be checked and then corrected. If downward solar radiation is negative at solar elevation above the horizon, the downward solar radiation is treated as zero. And at solar radiation below the horizon, net solar radiation will always be zero.

Also there are many erroneous larger and smaller data, outliers, at raw data set of flux measurement. These data due to anomalous turbulent statistics and sensor malfunction introduced periods with missing data. Most of the missing data occurred when precipitation or dew obscured sensor optics which are periods when flux were expected to be small (Wilson and Baldocchi, 2000). To remove automatically these data from the KORMEX flux measurement dataset, we first calculated hourly means and standard deviations of each flux components for each month, i.e. fluxes of sensible, latent and soil heat, and net radiation. If a value of data is larger than mean plus two standard deviations or smaller than mean minus two standard deviation, that data is removed from dataset. The mean and standard deviation were recalculated and removed a value according to above criterion. We repeated three times these processings to remove outlier. Fig. 1 shows the average and range, which are determined after the outlier removal process, of 30 minute mean values at a certain time. However, outliers are still included in dataset. Because distributions of fluxes are positively skewed, the criterion for smaller values, mean minus two standard deviation, is too large to remove erroneously small values. So these erroneous smaller values can not removed from above outlier removal process. We finally removed the value of less than -150 Wm^{-2}

for the sensible heat flux and -200 Wm^{-2} for net radiation. This outlier removal process removes 3 to 10 per cent of data logged at data logger.

We corrected the surface slope under eddy covariance system because KORMEX flux measurement site is not flat. Wesely's coordinate conversion equation (1970) was adapted for coordinate rotation. Fine wire thermocouple (FW05) junction, which is need to measure the temperature fluctuation for estimation of sensible heat flux in eddy covariance system, is extremely fragile. It easily breaks if struck by airborne debris, insects, or rain and snow. We replaced with sonically measured virtual temperature fluctuation with CSAT3.

4. Energy balance closure tests

The performance of the eddy covariance measurement system is often evaluated examining energy balance closure. For each half-hour period, total net radiation (Rn) should approximately balance the sum of energy distributed between latent (LE) and sensible (H) heat fluxes, soil heat flux (G) and heat storage within the canopy (Cs) (i.e. $Rn = LE + H + G + Cs$). The canopy heat storage term is occasionally an important sink or source of energy. Because the term usually changed signs between daytime and nighttime hours, the average daily magnitude rarely exceeded 2-3 W m^{-2} (Wilson and Baldocchi, 2000). Therefore, energy balance closure of the KORMEX flux measurement data did not consider the heat storage term and was evaluated by examining the energy closure term defined as the ratio, η, of the sum of latent, sensible and soil heat flux to net radiation (Denmead and Bradley, 1985). As expected, on monthly time scales η is approximately unity, while for each half-hour period η is 0.57 (0.63 at daytime and 0.51 at nighttime) (refer Fig.2). Therefore canopy heat storage on monthly time scales is negligible.

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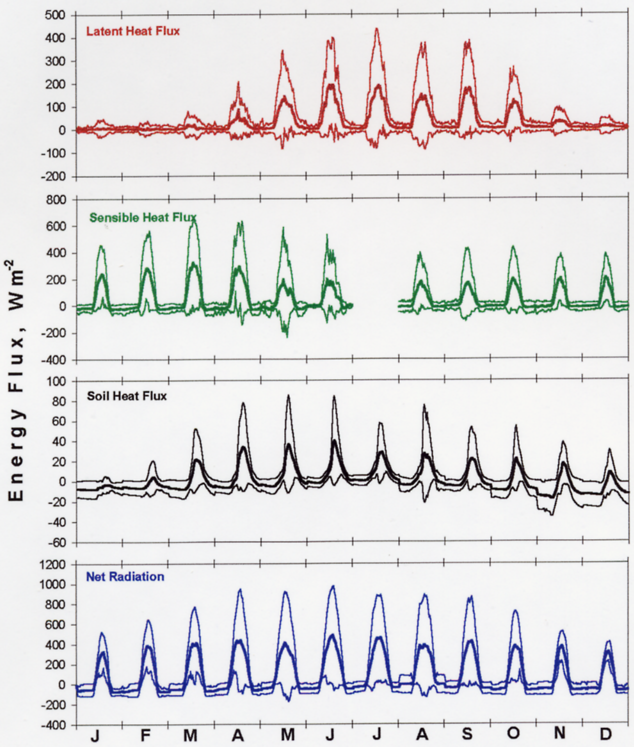

Fig. 1. Diurnal distributions of monthly mean and range of fluxes at a certain time, based on data from 20 October 1998 to 24 October 2000.

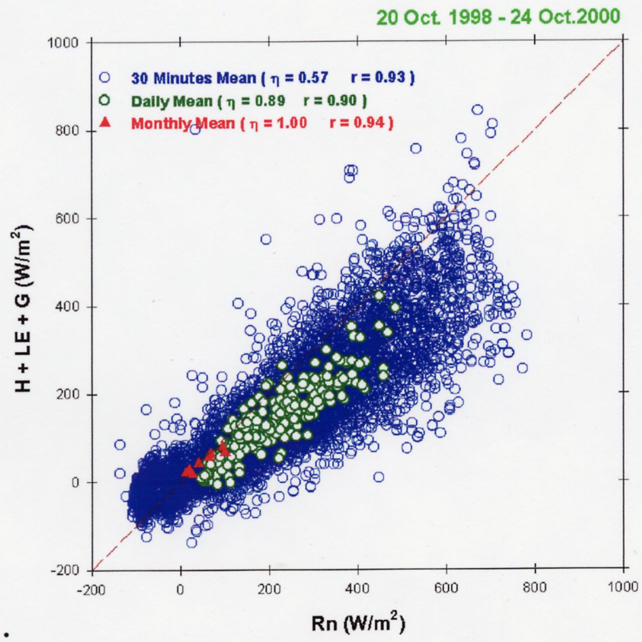

Fig. 2. Energy budget closure of fluxes measured in the forest area of National Arboretum at Kwangneung, Korea.