P1.4 ESTIMATING EVAPOTRANSPIRATION OVER A RICE PADDY USING SATELLITE THERMAL-INFRARED TEMPERATURES COMBINED WITH A HEAT BUDGET MODEL

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1. INTRODUCTION

Radiometric information of earth's surface detected by satellites is often interrupted by clouds, and diurnal course of satellite data set could not be completed even with data of a geo-stational satellite. This study aims evaluating regional distribution, and diurnal and day to day variations of surface heat budget over a rice paddy, using limited number of satellite thermal-infrared images (NOAA-AVHRR), meteorological data, combined with a two source, prognostic heat budget model for a vegetation surface.

2. ESTIMATION METHOD

The outline of the estimation method is that parameters, which are aerodynamic conductance and evaporation efficiency of a vegetation surface, are calibrated by satellite thermal-infrared temperatures.

Diurnal courses and day to day variations of surface heat budget are calculated by a linear heat budget model, which was originally developed by Matsushima and Kondo (1995). The model was originally for a bare soil surface only, but in the present study, it is expanded for a vegetation surface with shallow water storage. Therefore, the model is suitable for a rice paddy. The simple frame of the linear prognostic model is following gives as

$$\frac{d}{dt}\begin{bmatrix} T_c \\ T_g \end{bmatrix} = A(t)\begin{bmatrix} T_c \\ T_g \end{bmatrix} + B(t)\begin{bmatrix} S \\ L \\ T_a \\ q_a \\ U_a \end{bmatrix} \qquad (1)$$

where T_c and T_g are the surface temperature of the canopy and ground (water) surface, which are the prognoitic variables, S and L are the downward solar and longwave radiation, T_a, q_a, and U_a are the air temperature, specific humidity, and the wind speed at the same reference height. A(t) and B(t) are time (t)-variant parameter matrices including the aerodynamic conductance, evaporation efficiency, surface albedo, emissivity, wind speed, and etc. S, L, T_a, q_a, and U_a are known variables as input, which was given by meteorological data, and driving the system. Thermal-infrared temperature T_r as the output of the model is calculated by a combination of T_c and T_g considering leaf are index (LAI), satellite viewing angle, and emissivity. Parameters to be optimized were aerodynamic conductance g_a and evaporation efficiency b of both canopy and ground surface. Albedo, emissivity, and thermal properties of subsurface were given. The aerodynamic conductance was formulated as

$$g_a = a + b(U_a - U_M) \qquad (2)$$

where U_M is daily mean of wind speed, a and b are parameters to be optimized. This formulation was adopted because of considering the effect of daytime free convection. To obtain optimal parameters of the model without having diurnal course of satellite data, spatial distribution of thermal-infrared temperature was used in this study. If satellite data over an objective region has sufficient scatter, a variational method or least squares method could be used. In this study, a simple variational method was adopted using distribution of sensible heat flux at the satellite snapshots over the objective region as well as thermal-infrared temperature, assuming standard errors of them. The sensible heat was estimated by another method developed by Matsushima and Kondo (1997).

3. DATA

The objective period of this study is June, 1994. This period was in a growing season of rice, and the range of LAI was between 0.1 and 2. Satellite data were obtained from a database (JAIDAS) of NOAA-AVHRR images (Ch.4), which is archived in Tohoku Univ. Available satellite data were taken three times in the month, which are shown in Table 1. Thermal-infrared temperatures were adjusted on absorption gases by LOWTRAN 7 with radio-sounding data.

Table 1. Time of satellite overpass and LAI

No.	Satellite overpass	LAI
1	2 June, 1994, 0751h JST	0.14
2	16 June, 1994, 1616h J ST	0.68
3	23 June, 1994, 0657h JST	1.01

Input variables were obtained by surface meteorological

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data acquisition system (AMeDAS) in Japan, and grid data of them were made by an objective interpolation. Heat flux data for verification of the calculation, and LAI were measured at a flux site (Kitaura, where is denoted in Fig. 2) by Ishida et al. (1997) and Matsushima and Kondo (1997).

4. RESULTS

Optimal surface parameters were firstly optimized for the three satellite overpass. The optimal parameters were shown in Table 2.

Table 2. Optimal parameters. b_g=1 was always hold, because the rice paddy stored water.

No.	a_g	b_g	a_c	b_c	b_c
1	0.0024	0.00135	0.0007	0.00045	0.90
2	0.0018	0.00090	0.0040	0.0020	0.35
3	0.0015	0.00065	0.0057	0.0020	0.50

Of the results of optimal parameters, aerodynamic conductances of both canopy and ground correspond well with increasing LAI, but evaporation efficiency of canopy does not seem to correspond with LAI. This seems partly because times of satellite overpass of No.1 and 3 were early morning, and leaf surface of the canopy was fairly dewed.

Model calculation of day to day variation over whole period of June 1994 was performed using the optimal parameters. Values of parameters were interpolated in logarithumic manner on daily basis. Figure 1 illustrates day to day variations of heat budget components at the flux site. The calculations agree fairly well with observations.

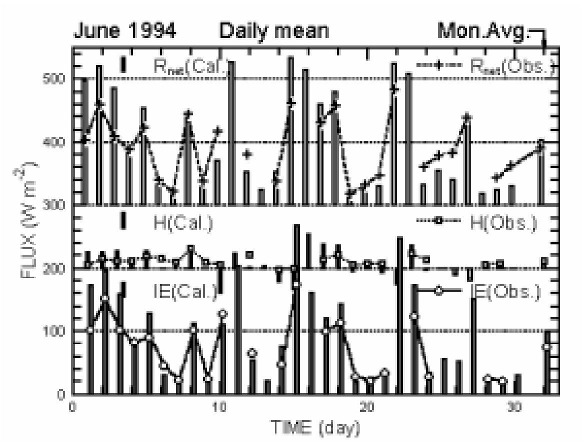

Fig. 1 : Comparison of day to day variation of heat budget components of calculation and observation. Zero base of net radiation and sensible heat are offset.

Estimation of day to day variation in evaporation efficiency of canopy b_c was affected by dew conditions, which was not always appropriate for daytime conditions. Then, a sensitivity test, in which the value of b_c was constant, was performed. Results of the two runs were not different from each other (not shown).

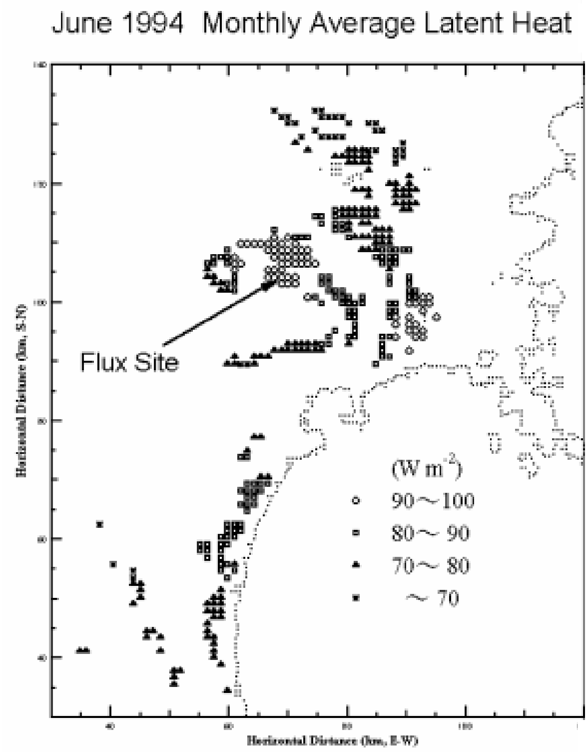

Fig. 2 : Spatial distribution of calculated latent heat flux averaged over June 1994.

Calculations in this study use only thermal-infrared as remote sensing data, and not include near-infrared and visible data, which may provide LAI and other surface parameters and variables. These parameters and variables were given from surface and meteorological measurements. Future issues are including those remote sensing data into the estimation method, and seasonal estimation over various types of land cover.

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