Surface energy components and land characteristics of a rice paddy

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Abstract

Many meteorological and air quality models require land characteristics as inputs. A field experiment was conducted to study the surface energy budget of a rice paddy in Taiwan. During the day, the energy balance ratio measured by an Eddy Covariance (EC) system was found to be 95% after considering the photosynthetic and local advected heat fluxes (Figure 1 and Table 1). The observations by the EC system suggest that the Bowen Ratio was about 0.18 during the daytime. The EC system also measured the daytime absorbed CO_2 flux. The equivalent photosynthetic energy flux was about 1% of net solar radiation. Table 2 describing the land characteristics of rice paddies for use in meteorological and air quality models is listed, which shows the albedo and the Bowen Ratio measured over rice paddies were lower than those listed in many state-of-the-art models. This study proposes simulating latent heat flux by assigning proper values for canopy resistance rather than by assigning constant values for Bowen Ratio or surface moisture availability. The diurnal pattern of the canopy resistance of the rice paddy was found to be U shaped. Daytime canopy resistance was observed to be 87 s m^{-1}, and a high canopy resistance (~ 900 s m^{-1}) should be assigned during nighttime periods.

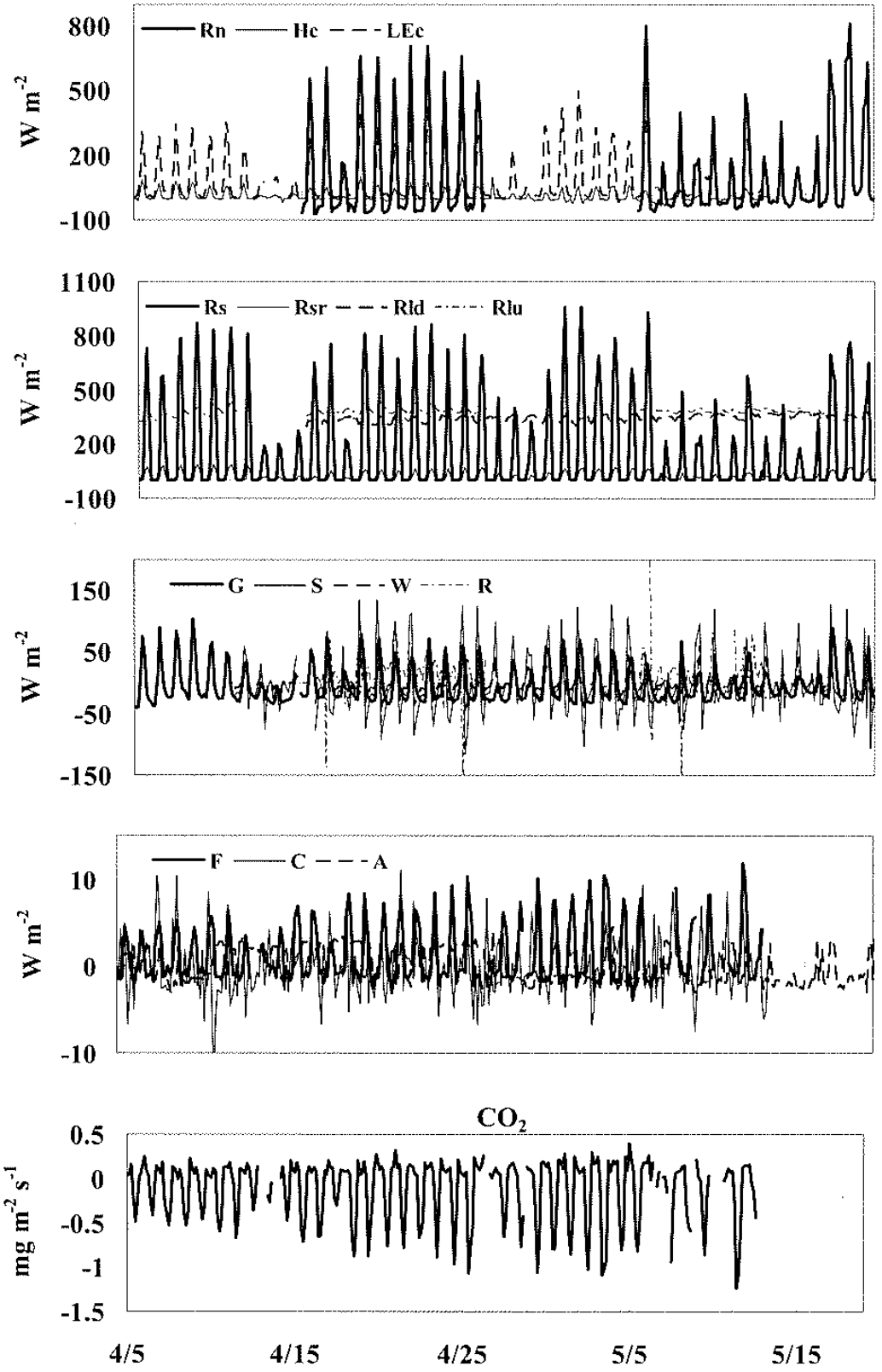

Figure 1. Net radiation (R_n), sensible heat flux at the canopy height (H_c), latent heat flux at the canopy height (LE_c), incoming solar radiation (R_s); reflected solar radiation (R_{sr}); atmospheric longwave radiation (R_{ld}); terrestrial longwave radiation (R_{lu}); ground heat flux (G), soil heat storage (S), liquid water heat storage (W), photosynthesis heat flux (F), canopy heat storage (C), advected heat flux (A), Residual (R) and CO_2 flux measured at a rice paddy site in Taiwan from 5 April to 19 May 2005.

Table 1. Summary of energy components and Bowen Ratios measured in a rice paddy in Taiwan from 16 - 25 April 2005, where daytime: 8am-6pm, nighttime: 7pm-6am, sunrise/sunset: 6-8am and 6-7pm, and $V=R_n-G-S-W-F$. The units of energy components are W m^{-2} (%V).

subtotal	daytime	nighttime	sunrise/sunset	full day
R_s	446 (179%)	0 (0%)	52 (100%)	192 (161%)
R_{sr}	38 (15%)	0 (0%)	6 (12%)	17 (14%)
R_{ld}	345 (138%)	328 (1571%)	331 (638%)	335 (281%)
R_{lu}	410 (164%)	373 (1787%)	379 (729%)	389 (326%)
R_n	342 (137%)	-45 (-217%)	-1.1 (-2%)	121 (102%)
C	1.1 (0.4%)	-0.8 (-4%)	-0.2 (-0.4%)	0.1 (0.1%)
G	30 (12%)	-25 (-119%)	-18 (-35%)	-1.2 (-1.0%)
S	40 (16%)	-28 (-134%)	-24 (-46%)	1.1 (0.9%)
W	18 (7%)	-12 (-58%)	-10 (-20%)	0.5 (0.4%)
A	1.9 (1%)	1.1 (5%)	1.6 (3%)	1.5 (1.2%)
F	5 (2%)	-1.2 (-6%)	-0.4 (-1%)	1.3 (1.1%)
H_c	34 (14%)	-2 (-11%)	0.1 (0.3%)	13 (11%)
LE_c	200 (80%)	7 (34%)	23 (44%)	90 (75%)
$B_c=H_c/LE_c$	0.17	-0.33	0.01	0.15
H	36 (14%)	-2 (-10%)	1.3 (3%)	14 (12%)
LE	202 (81%)	7 (35%)	23 (44%)	90 (76%)
B=H/ LE	0.18	-0.30	0.06	0.16
H+LE	238 (95%)	5 (24%)	24 (47%)	104 (87%)
G	88 (35%)	-65 (-311%)	-53 (-101%)	0.1 (0%)
V	249 (100%)	21 (100%)	52 (100%)	119 (100%)
R	12 (5%)	16 (76%)	28 (53%)	15 (13%)

Table 2. Characteristics of rice paddies reported in the literature.

Variable	This study	Gao et al. (2003)	Harazono et al. (1998)	Yoshimoto et al. (2005)	AERMOD (USEPA, 2004)[1]	MM5 & WRF (Dudhia et al., 2005)[2]
Location	Taichung, Taiwan (24°01'N, 120°41'E, 50 m above sea level)	Anhui, China (32°30'N, 119°07'E)	Okayama, Japan (34°50'N, 134°E)	Iwate, Japan (39°40'N, 141°00'E, 200 m above sea level)		
Albedo	0.09 (0.07-0.19) or Eq. (19)	0.08 -0.17	-	-	0.14 (spring)	0.18 (summer)
Bowen Ratio	0.18 (daytime) -0.30 (nighttime)	0.23 (noon) 0.06 (full day)	0.08 (drained condition) 0.04 (flooded conditions) (daytime)		0.30 (spring, daytime, wet condition)	
Canopy resistance (r_c)	82 s m^{-1} (daytime) 885 s m^{-1} (nighttime)		91 s m^{-1} (daytime)	50 - 200 s m^{-1} (daytime)		
Moisture Avail.	0.43 (daytime)		0.33 (daytime)			0.50 (summer)
Surface emissivity	0.86	0.96 (assume)				0.92 (summer)
Area heat capacity	2.8×10^5 J m^{-2} K^{-1}					2.5×10^5 J m^{-2} K^{-1}

1: Cultivated Land; 2: USGS Irrigated Crop Pasture Land type