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Estimation of Surface Fluxes of Radiation and Heat at Ile-Ife During 5-8 March 2007

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Abstract: In this study, an attempt has been made to measure the surface fluxes, net radiation, sensible heat, latent heat and the ground heat over an agricultural farmland at a humid tropical station Ile-Ife (7.55° N, 4.56°E, 294.0 m), for the dry convective period 5-8 March 2007. The Turbulenzknecht software (TK version 2) was used to calculate the sensible and the latent heat fluxes from the data obtained from the eddy covariance set-up while the net radiation and the soil heat flux were measured directly. The sensible heat and the ground heat fluxes accounted for about 58.9 and 29.4% of the net radiant energy respectively. The latent heat flux for the period was generally of low magnitude due to the dry condition that prevailed during the period thus accounting for only about 10.23% of the total net radiation. The period average for the net radiation, sensible, latent and ground heat fluxes are 91.85 Wm^{-2}, 100.56 Wm^{-2}, 10.53 Wm^{-2} and 7.80 Wm^{-2} ,respectively.

Key words: Measure the surface fluxes, net radiation, sensible heat

INTRODUCTION

The interaction between the earth's surface and overlying atmosphere takes place through the exchange of surface fluxes of momentum, moisture and heat into the atmosphere and vice versa. The surface fluxes generally determine to a great extent the state of the Planetary Boundary Layer (PBL) and are treated as primary surface conditions for weather prediction and climate studies (Nagar *et al*., 2002). However, there is little information about this in the humid forest zone of tropical West Africa. And also data for the surface energy fluxes by direct measurement in the humid forest zone of the tropical West Africa are scarce. This study attempts to make some contributions in this area.

A few attempts have been made to estimate the surface fluxes in the humid tropical region. The majority of the attempts made use of Bowen ratio (Bowen, 1926) and modified Bowen ratio energy balance method (Liu and Foken, 2001) to estimate the fluxes of momentum and heat.

In Nigeria, field experiments such as SEBFEX-99 (Surface Energy Balance Field Experiment); NIMEX-1-3 (Nigeria Mesoscale Experiment) were conducted to investigate the characteristics of the land surface-atmosphere energy exchange processes in the surface layer (Jegede and Lofstrom, 1997; Balogun *et al*., 2002; Mauder *et al*., 2007 and Jegede *et al*., 2001).

In the present study, an attempt is made to estimate the various fluxes such as net radiation, sensible heat flux, ground heat flux and the latent heat flux at a tropical humid site at Ile-Ife during 5-8 March 2007 using the Eddy Correlation method.

Experimental site and description of data: SEFEX-07 (Surface Energy Flux Experiment) was conducted during the period February 2007 to April 2007 at Ile-Ife (7.55° N, 4.56°E, 294.0 m) in the southwestern part of Nigeria. The experiment aims to collect surface and subsurface atmospheric data to study the land surface processes as well as investigate the surface energy balance during the period. The site is an agricultural land located in the Obafemi Awolowo University campus, Ile-Ife that has Fine sandy clay loam as the topsoil. The thermal conductivity of the soil 1.21 $Wm^{-1}K^{-1}$; thermal diffusivity 0.44× x 10^{-6} m^2s^{-1}; thermal admittance 1.34 $Jm^{-2}S^{-1/2}K^{-1}$ and the Heat capacity 1.45×10^{6} $Jm^{-3}K^{-1}$ (Oladosu and Jegede, 2005). At this site a 15m tower and a 2.5 m mast were installed. Different sensors to measure air temperature, wind speed and direction, are installed at 0.5,1, 3, 5, 9, 14 heights on the 15m tower. Radiation instruments were fitted at 1m heights. The soil heat flux plates (HP3/CN3) and the soil temperatures probes were buried at depth 5, 10, 30 cm, respectively. A Metek (Germany) sonic anemometer and a Campbell scientific KH20 Krypton Hygrometer were mounted at level 2.35m on the 2.5m mast. The sonic anemometer is a sophisticated, fast-response turbulence instrumentation, which measures the fluctuations in the temperature and in all the three components of wind.

The data were recorded automatically using a CR10X datalogger powered by a battery, which is charged from the mains and a stand by generator in case of power failure. The data-logging was done every second for all the channels and averaged for 10 min on the datalogger which was later downloaded

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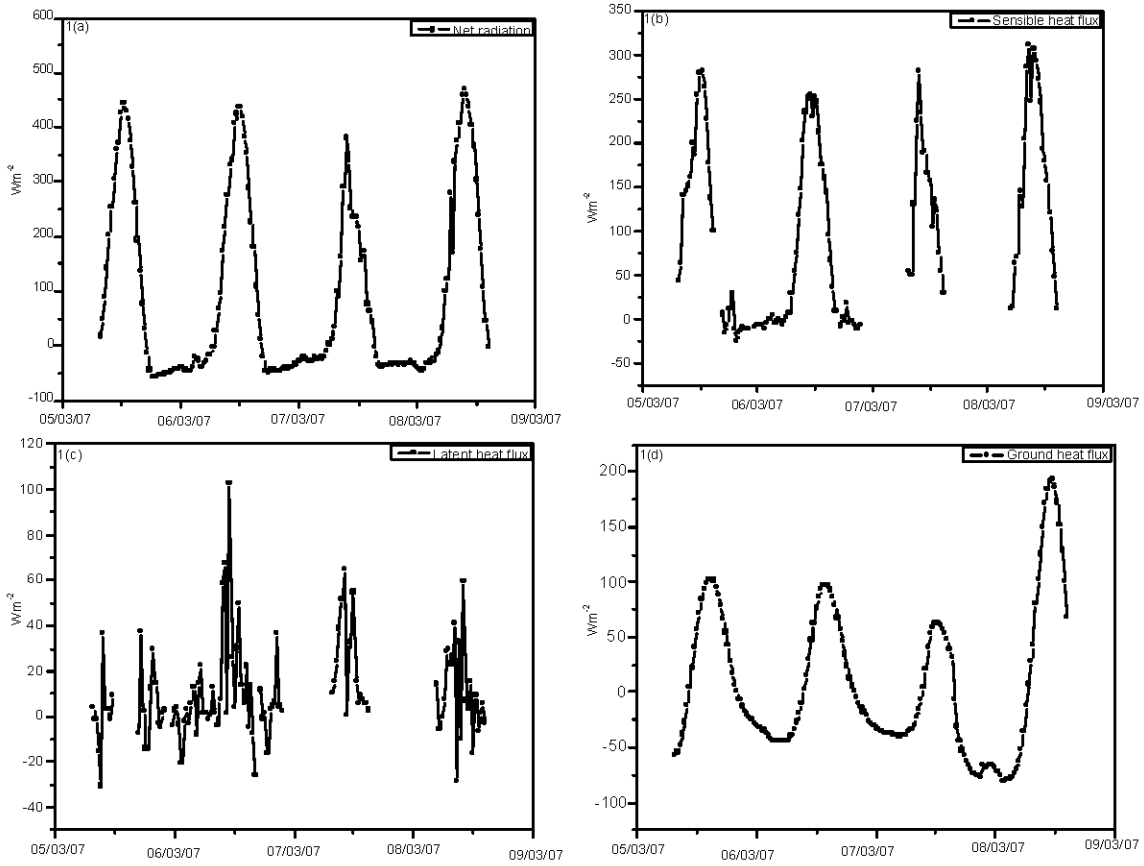

Fig. 1a-d: Plot showing net radiation, sensible, latent and the ground heat fluxes during 5-8 March 2007

on to a dedicated laptop computer and store permanently. In ten-minutes averaging mode, the datalogger storage module could store up to 2 days' continuous data. Continuous tower data at ten-minute interval during intensive observational periods (IOPS) for four days from 5-8 March 2007 were collected at the site. In all 3 IOPs were conducted from February to April 2007. The sonic anemometer and the krypton hygrometer data are collected only during the IOPs.

The month of March have been selected for the present study, as it is the transition month between the dry and wet season characterized with shift from clear sky condition to a cloudy sky condition (Hastenrath, 1991).

For the present study, the ten-minute averaged data from the tower are further averaged for 30 min interval at 0030, 0100, 0130...0730, 0800, 0830...1730, 1800...2330. The temperature and wind data from sonic anemometer as well as the humidity data from krypton hygrometer are sampled at 16 Hertz and collected at 30 min interval. It is observed that the heat flux becomes positive in the morning around 1000 and it again changes sign and become negative at around 2100. The software developed by the Department of Micrometeorology of the University of Bayreuth, TK2 (Mauder and Foken, 2004) was used to handle the data quality assessment and control and subsequently to calculate the turbulent fluxes.

RESULTS

During the period 5-8 March 2007 the air temperature varied from 22.13-39.46°C, giving a diurnal range of 17.33°C. The subsurface temperature at 5 cm depth varied from 23.41 to 37.64°C. The incoming short wave radiation exceeded 800 Wm^{-2} at noon and the wind speed was less than 4 ms^{-1}. Consequently the surface was highly unstable during the daytime. But no significant weather activity was noticed and no precipitation occurred during the entire study period.

Figures 1a-d show the day to day fluxes of radiation, that is, net radiation, sensible heat, latent heat and the ground heat fluxes for 5-8 March 2007. The net radiation showed a diurnal pattern with peak values at the afternoon period around 1400 h for all the days. The maximum net radiation value of 473.25 Wm^{-2} was recorded on the 8 of March while the minimum of 381.42 Wm^{-2} occurred on the 6 of March (Fig. 1a).

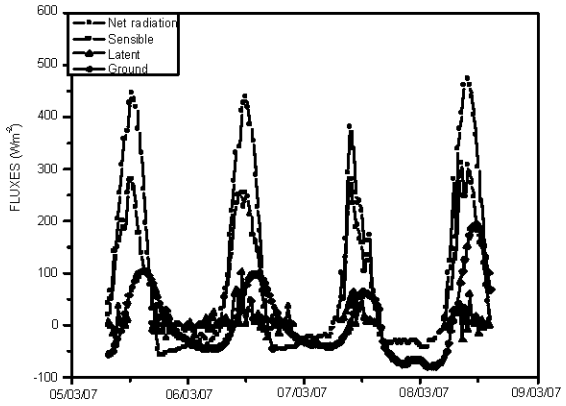

Fig. 2: Surface fluxes of radiation for 5-8 March 2007

The period statistical analysis shows that the minimum, maximum and mean values of –57.69 Wm^{-2}, 470.23 Wm^{-2} and 91.85 Wm^{-2} respectively. The diurnal pattern of the radiation plot as shown in the plot indicated a fairly smooth pattern, this is because of the cloudless condition that prevailed during the IOP.

In Fig. 1b is shown the plot for the sensible heat flux. It can be observed that in response to the solar heating and with the fact that no precipitation occurred during this period, the values of the sensible heat flux was fairly high. For example, a peak value of 310.25 Wm^{-2} was recorded on the 8 of March in response to the peak value of 473.25 Wm^{-2} for the net radiation. The mean value for the IOP is 100.57 Wm^{-2} while the period minimum and maximum are –25.70 Wm^{-2} and 310.98 Wm^{-2}, respectively.

Also in Fig. 1c is shown the plots of latent heat flux. From the figure it is clear that the period was clearly a dry period as indicated in the low range of values obtained. The period statistics shows a maximum value of 102.41 Wm^{-2} as compared to 310.98 Wm^{-2} recorded for the sensible heat flux. The period mean was 10.53 Wm^{-2}.

However, the ground heat flux was fairly higher in magnitude than the latent heat flux, this is not unexpected because of the dry surface condition during the period of observation. The period maximum value was 193.57 Wm^{-2} while the minimum value was –81.23 Wm^{-2}. The period mean was 7.80 Wm^{-2}. In Fig. 2 is shown the plots for all surface fluxes for the IOP and this clearly shows diurnal variation of each of the fluxes.

CONCLUSION

The surface fluxes of radiation have been estimated using a robust eddy correlation method over a humid tropical station, in the southwestern part of Nigeria. The period maximum for the net radiation, sensible, latent and ground heat fluxes, are respectively 470.23 Wm^{-2}; 310.25 Wm^{-2}; 102.41 Wm^{-2} and 193.57 Wm^{-2}.

The result shows that the surface fluxes, sensible, latent and ground heat are strongly dependent on the incoming solar radiation and the prevailing weather condition.

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