Diurnal and Seasonal variations of Sensible and Latent Heat Fluxes at an Agricultural site in Ile-Ife, Southwest Nigeria

Adewale Ajao, Omodara Obisesan, Muritala Ayoola and Oluwagbemiga Jegede

Department of Physics and Engineering Physics, Obafemi Awolowo University, Ile-Ife, Nigeria

(ORCID # for A. I. Ajao: 0000-0001-8546-5242)

Introduction

Warming of the earth's surface during daytime is primarily due to the absorption of incoming solar radiation resulting into a positive net radiation, which cools off at nighttimes as heat is released (negative net radiation). In the tropical areas, occurrences of rain showers or soil tillage during daytime bring about lowering of the surface temperature. Accordingly, a significant drop in the value of *Bo* is recorded due to the increase of *LE* . Attendant to wetting of soil is decrease of surface albedo and correspondingly, increase in available energy. Such scenarios bring about significant reduction in the value of *H*. Accuracy of estimated *Bo* increases when magnitudes of *H* and *LE* are greater than 10 W m^{-2}, which is commonly found in daytime conditions. In the nighttime ($|R_n| < 10$ W m^{-2}), measurement errors are comparably of the same magnitudes as the fluxes, hence estimates of *Bo* can be inaccurate.

Methodology

The experimental site is situated at the Teaching and Research Farm of Obafemi Awolowo University, Ile-Ife, Nigeria (7.52 ^{o}N, 4.52 ^{o}E). The farm area is approximately 5 ha. It is surrounded by low hills to the eastern and southern flanks, and some distance away from the farming area. The climate of the area is monsoonal thereby experiencing two alternating seasons; dry and wet in accordance with movement of the ITD line. The surface flow for Ile-Ife is weak (mean wind speed < 1.5 m s^{-1}). Annual precipitation ranges between 1000 and 1500 mm. The instrumentation comprises an eddy covariance system (a CSAT3 ultrasonic anemometer and a LiCOR LI 7500 infrared gas analyser) mounted at 1.8 m on a 2.0 m mast. Additionally, two other masts of heights 2.5 m and 6.0 m, were installed for measurements of the following atmospheric parameters: air temperature, relative humidity, atmospheric pressure, soil temperature, soil moisture, PAR, global and net radiation fluxes. All turbulent parameters were sampled at 10 Hz and averaged at 30-mins interval. The raw data was subjected to quality assurance and quality control (QA/AC) protocol. Stationarity test was performed following the procedure by Foken and Wichura (1996).

Fig. 1a: Aerial view of experimental site (OAU Met-station) T & R Farm, Ile-Ife, Nigeria.

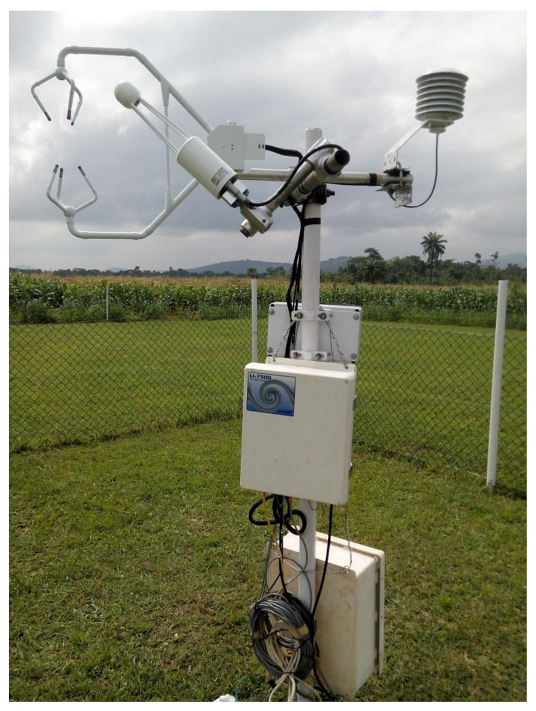

Fig. 1b: Eddy covariance instrumentation at OAU Met-station, Ile-Ife, Nigeria

Results

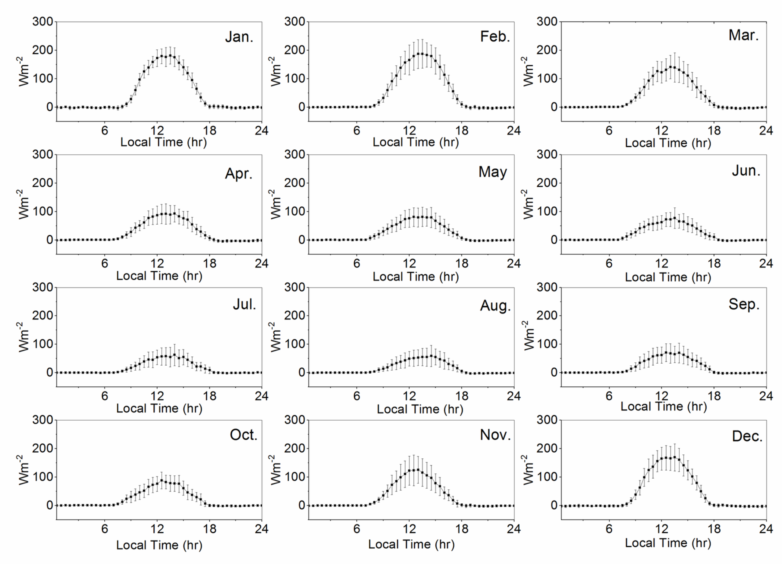

Fig. 2: Diurnal variation of sensible heat flux at OAU Met-station, Ile-Ife, Nigeria from Jan. 2017 to Dec. 2018.

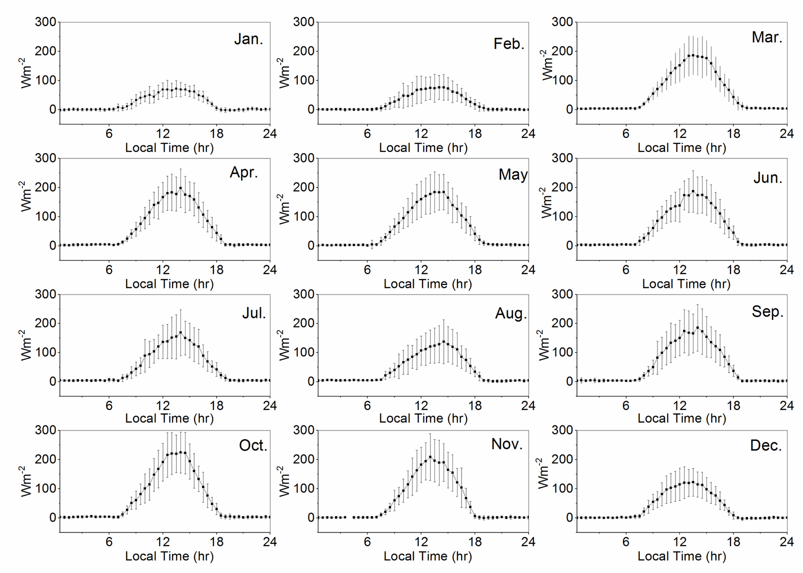

Fig. 3: Diurnal variation of latent heat flux at OAU Met-station, Ile-Ife, Nigeria from Jan. 2017 to Dec. 2018.

Results Cont'd

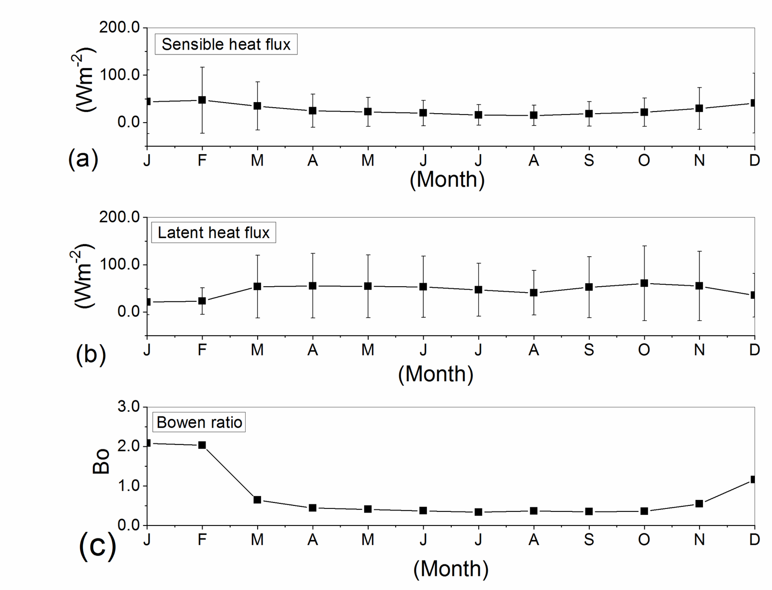

Fig. 4: Monthly Trends of (a) sensible heat flux (b) latent heat flux and (c) Bowen ratio as observed at OAU Met-station, Ile-Ife, Nigeria from Jan. 2017 to Dec. 2018.

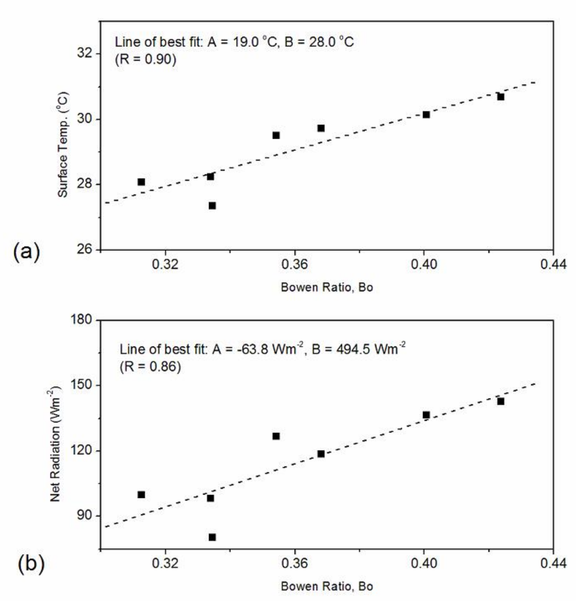

Fig. 5: Scatter plots relating Bowen ratio and (a) surface temperature (b) net radiation as observed at OAU Met-station, Ile-Ife, Nigeria from Jan. 2017 to Dec. 2018.

Period	Sensible Heat Flux (W m^{-2})				Latent Heat Flux (W m^{-2})				Bowen ratio
	Min.	Max.	Range	Mean	Min.	Max.	Range	Mean	
Wet	-2.2	73.1	75.3	19.7± 27.2	3.2	180.1	177.0	52.1±63.5	0.37
Transitional	-2.8	133.2	136.0	32.3±47.3	2.0	196.5	194.5	53.9±69.4	0.60
Dry	-2.6	179.4	182.0	44.0±66.4	-0.6	89.3	89.9	26.6±33.7	1.65
Annual	-2.2	108.4	110.5	27.9±40.3	2.2	157.7	155.5	46.0±57.0	0.61

Table 1: Seasonal variation of sensible and latent heat fluxes at OAU Met-station, Ile-Ife, Nigeria from Jan. 2017 to Dec. 2018.

Discussion

In Fig. 2, sensible heat flux (*H*) peaks at about 1:00 PM local time which coincides with the solar noon at Ile-Ife. For consecutive dry months at the study location, the value of H_{max} increased from 166.3±45.7 W m^{-2} in December to 179.0 ± 26.0 W m^{-2} in January and 187.2 ± 50.5 W m^{-2} in February. H_{max} in March, 140.6±41.3 W m^{-2} (which is a transition from dry to wet season) was significantly lower than for the dry season. Consequently, net radiation is a maximum value at the time. In Fig. 3, half-hourly averaged data for latent heat (*LE*) in December, January and February indicated a peak value at about 13:00 hr (LT) giving the values of 126.3±48.6 W m^{-2}, 69.3±31.5 W m^{-2} and 76.3±40.8 W m^{-2} respectively. January is the peak of dry season and as such, LE_{max} value was a minimum. As the season transited to wet in March, LE_{max} increased substantially to 186.1±66.9 W m^{-2}. This suggested that evaporation at the surface increased significantly due to rainfall occurrence. In the wet season, April – October, the diurnal range for *H* was 75.3 W m^{-2}, while it was 177.0 W m^{-2} for *LE*. Conversely, for the dry season (December – February), diurnal range for both fluxes were 182.0 W m^{-2} and 89.9 W m^{-2} respectively. During the transition, from wet-to-dry (November) or dry-to-wet (March) season, the diurnal range was 136.0 Wm^{-2} and 194.5 W m^{-2} for *H* and *LE* respectively. There was a lag of about 1 hr between *H* (peak value is ahead at 13:00 hr LT) and *LE* at the surface due to a phase change (water to vapour).

Conclusions

From sunrise to sunset, hourly values of *H* and *LE* showed considerable fluctuations depending on the season. A lag of about 1 hr was observed between *H* (peak value is ahead at 13:00 hr LT) and *LE* at the surface due to phase change. *Bo* values for wet, transition and dry seasons were 0.4, 0.6 and 1.7 respectively. Larger percentage of the available energy is used for latent heat, typical for tropical latitudes. Removal of heat from the surface is faster in the dry season than in the wet season. There is seasonal reversal between *H* and *LE* such that *H* > *LE* in the dry season and *H* < *LE* in the wet season.

Acknowledgements

The authors appreciate supports received from International Institute of Physical Sciences (IPPS) Uppsala University, Sweden, University of Bayreuth, Germany, and members of atmospheric physics research group (APRG), Obafemi Awolowo University, Ile-Ife, Nigeria.

References

Akuoko, O., Koo,l D., Sauer, T. J. and Horton, R. 2018. Surface energy balance partitioning in tilled bare soils. Agricultural and Environmental Letter, 4pp. doi:10.2134/ael2018.07.0039.

Foken, T. and Wichura, B. 1996. Tools for quality assessment of surface-based flux measurements. Agric. and For. Meteorology, **78** (1–2), 83-105.

Foken, T. 2008. Micrometeorology: Springer-Verlag, Berlin, 308 pp.

Mamadou, O., Cohard, J. M., Galle, S., Awanou, C. N., Diedhiou, A., Kounouhewa, B. and Peugeot, C. 2014. Energy fluxes and surface characteristics over a cultivated area in Benin: daily and seasonal dynamics. Hydrol. Earth Syst. Sci., **18**, 893–914. doi: 10.5194/hess-18-893.

Perez, P. J., Castellvi, F., Ibañez, M. and Rosell, J. I. 1999. Assessment of reliability of Bowen ratio method for partitioning fluxes. Agric. And For. Met., **97**, 141 – 150.