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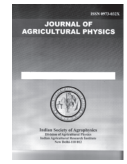

Research Article

Dynamics of Sensible Heat Flux in irrigated Wheat Crop using Large Aperture Scintillometer in Semi -Arid region

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ABSTRACT

Sensible heat flux (H) plays a crucial role in the energy balance of crop surfaces to estimate crop evapotranspiration and can be estimated based on atmospheric turbulence theory. Large aperture scintillometer (LAS) is an efficient method to record sensible heat fluxes over a larger foot print area which works on the Monin-Obukhov similarity principle. A LAS equipment was installed over the irrigated cropland in IARI farm with a path length of 990 m to record the dynamics of H during the rabi season of 2015-16 and 2016-17 dominant with wheat crop. The diurnal variation results showed positive H values during daytime when the surface get heated and negative during nighttime with lowering of surface temperature. Peak H values were recorded in April month (229.45 W m^{-2} for 2015-16 and 211.79 W m^{-2} for 2016-17). A negative correlation (R^2= -0.57) was observed between soil moisture and sensible heat flux (H) during the wheat growing season indicating that incident radiation is getting partitioned more into latent heat flux than sensible heat flux. The study found LAS to be an effective instrument to offer path averaged estimates of sensible heat flux (H) on lager scale and to study its relation with land surface parameters.

Key words: Energy flux, Sensible heat, Energy balance, Scintillometer, Wheat

Introduction

The surface energy balance assessment over a crop surface is important to understand the partitioning of the available energy into different components, depending on the properties of the crop canopy and the underlying soil surface. Among the three components of latent heat flux (LE), sensible heat flux (H) and ground heat flux (G), measurements of the H are important to calculate the LE (i.e. evapotranspiration) using measurements of other energy balance components. Besides, the H is a key parameter for dynamics of the lower atmosphere and atmospheric stability as it represents an essential means of heat transfer between surface and the air in the vicinity of the ground surface. So, it is the transfer of heat from the surface to the atmosphere without any phase change and is dependent on the (a) temperature difference between the surface and the overlying air, (b) on turbulence and (c) on convection (Myhre *et al*., 2017). Mukherjee *et al*. (2012) used the Bowen ratio to determine the ratio of sensible and latent heat fluxes. At the surface, energy partitioning is a complicated result of relationships

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between atmospheric boundary layer development and crop physiology. The reliable micro-meteorological technique to measure H is by employing the instruments based on eddy covariance technique but its footprint is generally small depending on the height of sensors above surface.

Now a days scintillometry is increasingly being applied as a method to estimate H after extensive studies and improvements to the theory of the scintillation method (Tatarskii, 1961; Hill and Clifford, 1978; Andreas, 1990; De Bruin, 2002). It works by monitoring changes in light intensity generated by the refractive scattering of turbulent eddies across a specified route of emitted electromagnetic waves from a transmitter. These fluctuations represent a measure of the structure parameters of the refractive index (C_n^2), temperature (C_T^2), and humidity (C_Q^2), which can be related to each other using the relationships developed by Wesely (1976) and Hill *et al*. (1980). These relationships along with the Monin–Obukhov similarity theory (MOST) can be utilized to estimate H and LE as described by Wyngaard *et al*. (1971) and Andreas (1988). The scintillometry approach has the potential to bridge the current gap between field scale observations (usually hundreds of meters using micrometeorological or eddy covariance sites) and local scale data (i.e., ten kilometers at least with airborne atmospheric measurements). Turbulence measurements with a scintillometer are utilized in hydrological, micrometeorological, agricultural, and water resource investigations. The capacity to offer path-averaged and area-averaged estimates of sensible (H) and latent (LE) heat fluxes over wide geographical scales increases their relevance and efficacy. Depending on the type of instrument, these estimates could cover several kilometers (Meijninger *et al*., 2002 a, b; Chehbouni *et al*., 1999) as compared to Bowen ratio or eddy covariance systems, which essentially provide local-scale measurements on the order of hundreds of meters. They can be applied for ground measurements in order to verify and calibrate hydrological, remote sensing algorithms, and local atmospheric models which helps in providing spatial estimation of surface energy fluxes. This study analyzed the diurnal and monthly pattern in area averaged H over irrigated cropland dominated with wheat crop.

Material methods

The experiment was conducted at the research farm of ICAR- Indian Agricultural Research Institute, New Delhi, India located at 28.08°N, 77.12°E with the altitude of 228.6 m above sea level. The climate of the study site is subtropical and semiarid type. The mean daily temperature during the summer and winter ranges from 22.2 to 33.5°C and from 12.5 to 20.9°C, respectively. The rainfall in the study area usually mostly occurs during June to September with small rainfall also received during winter months due to western disturbances.

The research farm was equipped with a Large Aperture Scintillometer (LAS) (Kipp and Zonen, MKII) which uses 840 nm wavelength radiation to measure scintillations. The transmitter and receiver of the LAS system were installed at the opposite edges of the field covering a path length of 990 meters from transmitter to receiver and at a height of 4.5 m above ground. The site during rabi season of experimental years of 2015-16 and 2016-17 was mainly dominated by wheat crop. The data of LAS was recorded at 5 minutes interval and H was computed using EVATION software (Kipp & Zonan). The 5 minute flux data recorded by LAS was further averaged at hourly scale to analyze their diurnal patterns over different months for analyzing the dynamics of H over the wheat growing area during both the experimental years. Besides, the measurements on crop phenology and soil moisture on volumetric basis using TDR probe were taken at regular interval in the wheat crop over the LAS path length. Average soil moisture from the wheat growing season was computed by averaging it over path length.

Results and Discussion

Sensible heat flux (H)

The diurnal pattern of H for different months of *rabi* season for the experimental years of 2015-16 and 2016-17 are shown in Fig. 1 and Fig. 2, respectively. During the *rabi* season, it was observed that for all the months on clear days, the H increased as the surface heated in the morning (generally remained positive between 7:00 AM to 17:00 PM with peak occurring at noon coinciding with peak of

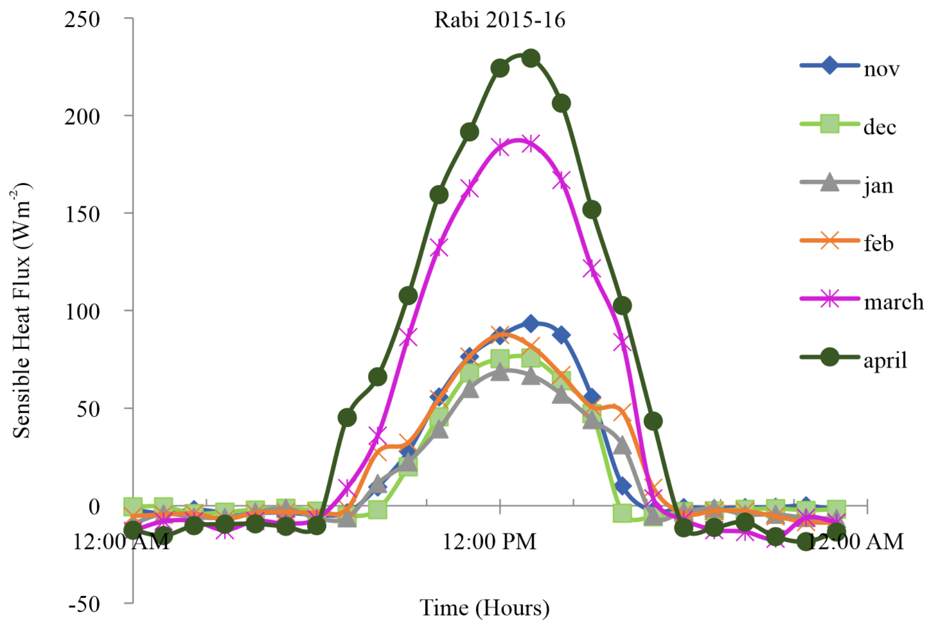

Fig. 1. Diurnal pattern of sensible heat flux (H) for wheat field during rabi season 2015-16

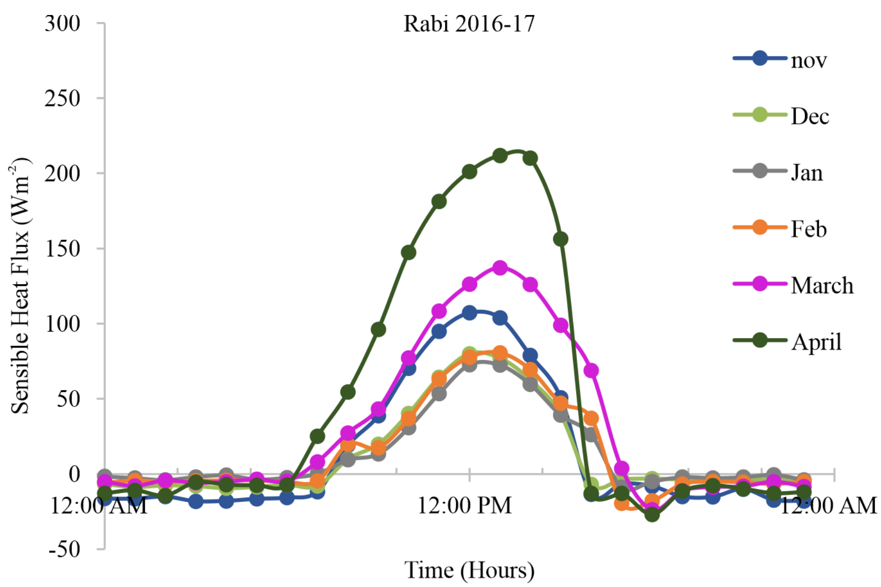

Fig. 2. Diurnal pattern of sensible heat flux (H) for wheat field during rabi season 2016-17

global solar radiation and decreases as surface cooled in the evening remaining either zero or negative during night hours. The peak H value attained in the month of April in both the experimental years (229.45 Wm^{-2} for 2015-16 and 211.79 Wm^{-2} for 2016-17) at noon. The lowest diurnal peak was observed in the month of January in both the years (68.83 Wm^{-2} for 2015-16 and 72.66 Wm^{-2} for 2016-17) at noon. Higher value of H in the month of April was attributed to no crop cover due to harvesting of the wheat crop and higher net radiation due to clear weather. Whereas lowest value in the month of January may be due to lower net radiation as a result of foggy weather conditions. Arya *et al.* (2019) reported in his study that wheat H/Rn ratio increased from dough to maturity stage (9% and 19%,

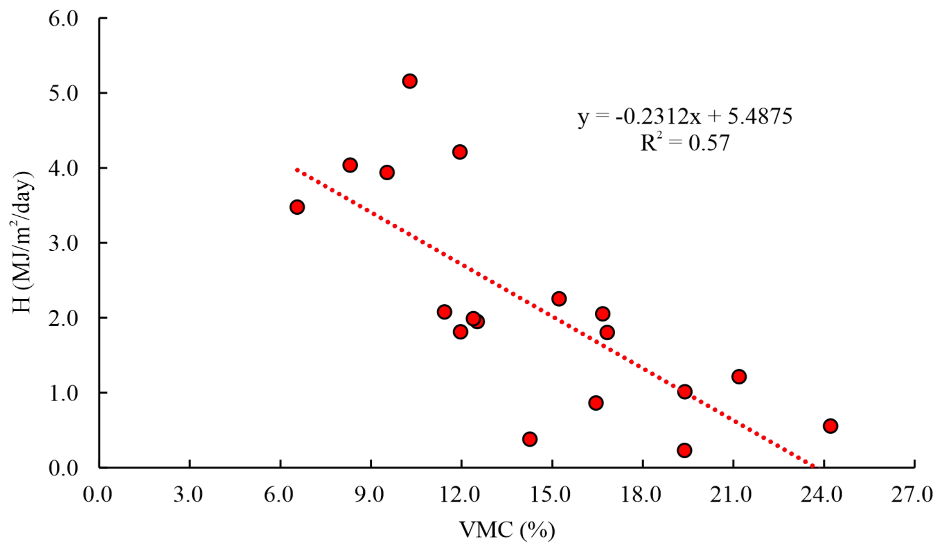

Fig. 3. Relation between sensible heat flux (H) and volumetric soil moisture during wheat growing season for the years 2015-16 and 2016-17

respectively). The tillering stage had the largest partitioning of Rn to H (21.04%), followed by physiological maturity (19%). This indicates that when the crop canopy is not adequately formed or has suffered severe senescence, Rn conversion to sensible heat flux is at its peak.

Relationship of sensible heat flux (H) and soil moisture content (VMC%)

The relationship between average soil moisture with sensible heat flux (*H)* during wheat growing season is shown in Fig. 3. Soil moisture content of field showed a significant negative relation with *H* (R^2 = 0.57). The cumulative (2015-16 and 2016-17) soil moisture values varied from 6.56% to 24.22% with a maximum value on 8th December 2015. Whereas, sensible heat flux varied from 0.23 MJ m^{-2} d^{-1} to 5.125 MJ m^{-2} d^{-1}. It has been observed that during high soil moisture values period sensible heat flux was low and vice versa. When the soil moisture was high, more partitioning of net radiation towards latent heat flux, thereby decreasing the sensible heat flux. The relation between soil moisture and H was influenced by crop growth stage. During sowing to early crop stage when the crop cover was negligible, H was influenced mainly by soil evaporation. However, with the progress of crop growth, H was influenced by both soil moisture as well as transpiration from crop plant. After the harvesting of the crop in the month of April there was low soil moisture leading to very low ET which may have resulted in higher H. It was observed that when the soil moisture dropped below the critical level it reduced the available soil water which coupled with available energy limits the evaporation rate and thereby increasing the sensible heat flux.

Conclusions

In our study, we studied the diurnal changes in sensible heat flux over the irrigated wheat crop grown in semi-arid condition using the LAS. It was observed that sensible heat flux remained positive from morning to evening and decreased during nighttime (becoming negative) as the surface cooled down. Higher values of sensible heat flux were observed in April month during both the experimental after the harvesting of wheat crop. There exists a negative correlation between soil moisture and sensible heat flux throughout *rabi* season. The results indicate that the LAS is an effective instrument to offer path averaged estimates of H covering larger spatial scales.

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References

Andreas, E.L. 1988. Atmospheric stability from scintillation measurements. *Appl. Opt.* **27**: 2241–2246.

Andreas, E.L, Ed. 1990. Selected Papers on Turbulence in a Refractive Medium. SPIE Milestone Series, Vol. 25, SPIE, 693 pp.

Arya, S., Mukherjee, J., Sharma, A., Sehgal, V.K., Krishnan, P., Burman, M. and Das, D.K. 2019. Seasonal energy flux pattern over irrigated maize and wheat under subtropical semi-arid condition using BREB method. *Journal of Agricultural Physics* **19**(2): 185-913.

Chehbouni, A. and Coauthors. 1999. Estimation of area-average sensible heat flux using a large-aperture scintillometer during the Semi-Arid Land-Surface-Atmosphere (SALSA) experiment. *Water Resource Research* **35**: 2505–2511.

De Bruin, H.A.R. 2002. Introduction: Renaissance of scintillometry. *Bound.-Layer Meteor.* **105**: 1–4.

Hill, R.J. and Clifford, S.F. 1978. Modified spectrum of atmospheric temperature fluctuations and its application to optical propagation. *JOSA* **68**(7), 892-899.

Hill, R.J., Clifford, S.F. and Lawrence, R.S. 1980. Refractive-index and absorption fluctuations in the infrared caused by temperature, humidity and pressure fluctuations. *J. Opt. Soc. Amer.* **70**: 1192–1205.

Mukherjee, J., Kumar, S. and Mandal, S. 2015. Surface energy flux and radiation interception in mustard. *Journal of Agricultural Physics* **15**(1): 103-107.

Myhre, G., Samset, B.H., Hodnebrog, O., Andrews, T., Boucher, O., Faluvegi, G., Flaschner, D., Forster, P.M., Kasoar, M., Kharin, V., Kirkevag, A., Lamrque, J.F., Olivie, D. and Richardson, T.B., Shawki, D., Shindell, D., Shine, K.P., Stjern, C.W., Takemura, T. and Voulgarakis, A. 2018. Sensible heat has significantly affected the global hydrological cycle over the historical period. *Nature Communications* **9**(1): 1-9.

Meijninger, W.M.L., Hartogensis, O.K., Kohsiek W., Hoedjes, J.C.B., Zuurbier, R.M. and De Bruin, H.A.R. 2002a. Determination of area-averaged sensible heat fluxes with a large aperture scintillometer over a heterogeneous surface—Flevoland field experiment. *Bound. -Layer Meteor.* **105**: 37–62.

Tatarskii, V. I. 1961. Wave Propagation in a Turbulent Medium. McGraw-Hill, 285.

Wesely, M.L. 1976. The combined effect of temperature and humidity fluctuations on refractive index. *J. Appl. Meteor.* **15**: 43–49.

Wyngaard, J.C., Izumi Y. and Collins S.A. Jr. 1971. Behavior of the refractive index structure parameter near the ground. *J. Opt. Soc. Amer.* **15**: 1177–1188.

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