Journal of Atmospheric and Solar-Terrestrial Physics 122 (2015) 138–144

Contents lists available at ScienceDirect

Journal of Atmospheric and Solar-Terrestrial Physics

journal homepage: www.elsevier.com/locate/jastp

Delineation of surface energy exchanges variations during thunderstorm and non-thunderstorm days during pre-monsoon season

Bhishma Tyagi [a], A.N.V. Satyanarayana [b,*]

[a] CNR, National Research Council, Napples, Italy
[b] Centre for Oceans, Rivers, Atmosphere and Land Sciences, Indian Institute of Technology, Kharagpur 721302, West Bengal, India

ARTICLE INFO

Article history:
Received 11 August 2012
Received in revised form
6 November 2014
Accepted 25 November 2014
Available online 27 November 2014

Keywords:
Net radiation flux
Sensible heat flux
Latent heat flux
Thunderstorms

ABSTRACT

Turbulent surface energy exchanges from land–air interface play an important role in generation and enhancing the convection. During pre-monsoon months (April–May) thunderstorms generate over Chota Nagpur plateau area of NE India and move over the study area Ranchi (23°25′N, 85°26′E). Even though convective conditions prevail over Ranchi during these months, thunderstorm occurs on some days only. To address this important aspect, present study focuses on understanding of surface energy budget (SEB): partitioning of net solar radiation flux (Q_N) into sensible (Q_H), latent heat (Q_E) and soil heat fluxes during different epochs of thunderstorm activity over study site at Ranchi. For this purpose, micro-meteorological data sets which comprise of fast response turbulent measurements and slow response data during 2008, 2009 and 2010 over Ranchi are used. A total of 25 thunderstorm cases are selected for the present study. The study reveals that prior to the occurrence of thunderstorm the Q_H and Q_E fluxes reach the same order followed by soil heat flux (Q_G). No significant variation of soil heat (Q_G) flux is noticed between thunderstorm days and non-thunderstorm days. The variations in the partitioning of Q_N flux into Q_H, Q_E and Q_G fluxes are distinguishable between the days of thunderstorm (TD) and non-thunderstorm (NTD). This variation can be used as precursor signal for the occurrence of thunderstorm activity. The results emanated from the present work are important in validating the performance of the meso-scale models in simulating these storms.

1. Introduction

Surface energy balance (SEB), which is partitioning of net available radiation energy into dissipative turbulent fluxes of sensible, latent and soil heat at a particular site depends upon the surface morphology (Middel et al., 2012). It also depends on the land surface temperature and the soil moisture content at any site (Bateni and Entekhabi, 2012).

Various researchers have explored energy partitioning at different sites to understand the dynamics of convection (e.g. Raman et al., 1998; Venalainen et al., 1998; Beringer and Tapper, 2002; Rouse et al., 2003; Schuttemeyer et al., 2006; Jun et al., 2007; Bhat and Arunchandra, 2008; Xufeng and Mingguo, 2009). SEB studies are helpful in understanding the link between the land surface and atmosphere, which have great influence on regional climate and water cycle as well as for the global climate (Moncrieff and Green, 1972; Keenan et al., 1989; Beringer et al., 2001; Arya, 2001).

Thunderstorms initiation is associated with the supply of these energy fluxes from the surface. Byers and Braham (1949) proposed three ingredients for the favorable thunderstorm conditions: sufficient low level moisture, conditional instability and lifting mechanism. Investigation of surface fluxes is crucial to examine the convective lifecycle of thunderstorms and starting of initial convection is dependent on the sensible heating which helps in early onset of convection (Keenan et al., 1994, 2000; Satyanarayana et al., 2014). But such studies are very few over eastern and north-eastern India due to paucity of the data, where the pre-monsoon (March–May) severe thunderstorms are quite common every year, locally known as "*Kalbaishakhi*" or *Nor'westers* (STORM Science Plan, 2005). The main objective of this study is to understand the variations in surface energy fluxes and their contributions to the total budget during the days of thunderstorm and non-thunderstorm activity over Ranchi and to differentiate these variations of SEB between thunderstorm days (TD) and non-thunderstorm days (NTD).

* Corresponding author. Fax: +91 3222 255303.
E-mail addresses: bhishmatyagi@gmail.com (B. Tyagi), anvsatya@coral.iitkgp.ernet.in, achanta.satya@gmail.com (A.N.V. Satyanarayana).

http://dx.doi.org/10.1016/j.jastp.2014.11.010
1364-6826/

2. Site description

Ranchi (23°25′N, 85°26′E) which lies in humid subtropical monsoon area of India has been chosen as study area. In general, this place experiences hot wet summers and cold winters. Maximum rainfall takes place during South West monsoon period from July to September which accounts for more than 90% of total rainfall. The site consists of sandy loam soil, which is a mixture of sand (60%), silt (8.7%), and clay (31.3%) (Gupta and Gajbhiye, 2002). A 32 m tower is established at main campus of Birla Institute of Technology, Ranchi, with six levels of instrumentation (1, 2, 4, 8, 16 and 32 m respectively) as part of the Department of Science and Technology, New Delhi, sponsored project *"Observational study of land surface atmosphere interaction in the monsoon trough along its active eastern end"*. Details of employed sensors can be obtained from Tyagi et al. (2012).

The site is having scanty dry patchy grass near the instrumentation area. Observational site is having clear fetch (∼1200 m) towards North North West (NNW) to South (S) directions and single storey buildings exist after ∼1200 m distance. A boundary of trees exists in South East (SE) to South West (SW) direction to the site at around 400 m away. The tree plantation range is having river 'Subarnarekha' in its back end. To the North of tower, there is a small residential area (of one storey buildings) at a distance of around 1 km. The location of Ranchi site on a topographical map depiction of India and by further zooming in the site details (Using Google Earth imageries) is depicted in Fig. 1.

3. Delineation of thunderstorm day and non-thunderstorm day

In general, the classification of a TD is based on occurrence of thunderstorm event at any time of that particular day (Rodriguez et al., 2010). The log-book information during the observations, tower observations and Doppler Weather Radar (DWR) information collected from Cyclone detection centre, India Meteorological department, Kolkata are used in finalizing the time of occurrence and duration of the thunderstorm event at the field site. When during the whole day no weather activity is noticed, the day is henceforth referred as NTD.

4. Data sets and quality control

The slow response data consist of 1 min averages for air temperature, relative humidity, wind speed, wind direction, soil temperature, and one hourly average for the surface pressure and albedo. The fast response data (10 Hz) (i.e. 10 values for each second) of wind (u, v, w components) and temperature are also used in the study. Data sets used in the present study are collected during pre-monsoon months (April–May) of 2008, 2009, and 2010. Based on the occurrence of thunderstorms during the study period, twenty five (25) thunderstorm days (TD) and thirty one (31) non-thunderstorm days (NTD) are selected. The chosen TD cases are listed in Table 1 along with timing of thunderstorm event, associated rainfall with event, and total rainfall in that day.

The selected NTD cases are as follows:

In year 2008: April 7, 8, 11, 21, 25, 28, and May 1, 14, 15, 16, 17, 27.
In year 2009: April 1, 2, 13, 14, 15, 18, 27 and May 8, 10, 19.
In year 2010: April 3, 4, 5, 11, 12, 19, 25 and May 11, 12.

The fast data (10 values for each second) have been subjected to quality check before going into analysis. Steps of quality checks employed in present study have been discussed in this section.

4.1. Spike removal

Spikes are characterized as short duration and large amplitude fluctuations. The method of Vickers and Mahrt (1997) has been followed for the spike removal. It computes the mean and standard deviation for a series of moving window, which moves one point at a time through the series. Any individual value falling within ±3 standard deviation from the mean is retained and the rest are replaced by mean ±3 standard deviations (Viswanadham et al., 1997). The point is replaced using linear interpolation between data points, but four or more consecutive points are not considered as spikes.

4.2. Tilt angle correction and mean wind rotation

The tilt error can lead to wrong depiction of momentum flux values (Kaimal and Haugen, 1969). The influence of sloping terrain leads to an artificial wind direction dependence of the vertical velocity as measured by the anemometer, which severely affect the flux values. Double rotation (DR) scheme and tilt angle corrections are incorporated in data (Wilcjak et al., 2001).

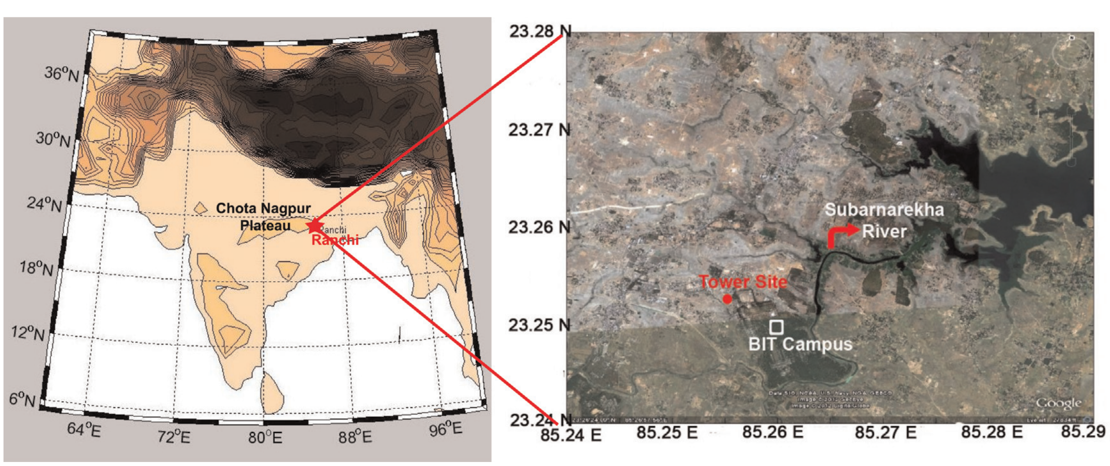

Fig. 1. Location of Ranchi has been shown with respect to Chota Nagpur plateau on the map of India in the left hand side panel, and by zooming into site in the right hand side panel (obtained from google maps).