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Prevailing weather conditions during the monsoon period of 1990 over Jodhpur region

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सार – गांगेय क्षेत्र के मैदानों में 1990 के दौरान मानसून द्रोणी के प्रदेशों में वायुमंडलीय परिसीमा स्तर पर जाँच पड़ताल करने के लिए मानसून द्रोणी परिसीमा स्तर प्रयोग (मौंट बलैक्स) एक बहुसंस्थानीय प्रयास था। इस प्रयोग को करने के लिए उत्तरी भारत में द्रोणी अक्ष की सामान्य स्थिति के साथ साथ चार विभिन्न स्थानों पर चार सूक्ष्म मौसम वैज्ञानिक स्तंभ लगाए गए। जोधपुर (26.3°उ., 73°पू.), राजस्थान स्थित केंद्रीय शुष्क क्षेत्र अनुसंधान संस्थान के परिसर में 30 मी. की उँचाई वाला एक इसी प्रकार का स्तंभ लगाया गया है। इस स्तंभ के 1 मी., 2 मी., 4 मी., 8 मी., 15 मी. और 30 मी. की उँचाई वाले उपस्करों के छः स्तर हैं जिन्हें यहाँ क्रमशः पहला, दूसरा, तीसरा, चौथा, पाँचवा और छठा स्तर कहा गया है। इन स्तंभों (रूद्र कुमार और प्रभू 1991) के विभिन्न स्तरों पर तेज़ और धीमे दोनों प्रकार की प्रतिक्रिया संवेदी का उपयोग किया गया है। हमने इस अध्ययन में तेज़ और धीमें प्रतिक्रिया आँकड़ों, कप पवनवेगमापी और पवन दिक् सूचक के 6 स्तरों, धीमी प्रतिक्रिया तापमान संवेदी के 4 स्तरों और तीव्र प्रतिक्रिया तापमान संवेदी के 2 स्तरों से प्राप्त परिणामों को प्रस्तुत किया है।

इस शोध–कार्य का उद्देश्य जोधपुर क्षेत्र में बहुस्तरीय अनुमान की सहायता से युक्तियुक्त उष्मा अभिवाह का मूल्यांकन करने के लिए उपयुक्त स्तर का पता लगााना है।

ABSTRACT. The Monsoon Trough Boundary Layer Experiment (MONTBLEX) was an intense multi-institutional effort to probe the atmospheric boundary layer (ABL) over the monsoon trough region of the Gangetic Plains in 1990. For this experiment, four micrometeorological towers were set up at four different locations along the normal position of the trough axis over Northern India. One such tower of 30 m height was located at Jodhpur (26.3° N, 73° E), Rajasthan in the campus of Central Arid Zone Research Institute. This tower had six levels of instrumentation at 1m, 2m, 4m, 8m, 15m and 30m heights, which are termed here as Ist, 2nd, 3rd, 4th, 5th and 6th level respectively. Both fast as well as slow response sensors at various levels of the tower (Rudrakumar and Prabhu, 1991) were utilized. In the present study, we have presented the results evaluated both from fast and slow response data, 6 levels of cup anemometers and wind vanes, 4 levels of slow response temperature sensors and 2 levels of fast response temperature sensors are presented.

The purpose of the present work is to find out the suitable layer for evaluating sensible heat flux for the Jodhpur region with the help of multilayer hypothesis.

Key words − MONTBLEX, Boundary layers, Jodhpur.

1. Introduction

Atmospheric Boundary Layer (ABL) is a very interesting part of study for the researchers, as it is directly influenced by the earth's surface, and responds to surface forcings with a time scale of about an hour or less (Stull, 1994). Thus, it plays an important role to control the weather system. ABL Experiments started during the late sixties. The pioneering work in this field in India was the Monsoon Experiment (MONEX-79) where, a 10m high mast was installed at a coastal station close to the Bay of Bengal to probe the boundary layer (Mohanty *et al.*, 1995). After a long development, in the summer monsoon season (June-September) of 1990, the Monsoon Trough Boundary Layer Experiment, acronym as MONTBLEX, was designed to carry out exclusive surface boundary layer observations over land surfaces along the monsoon trough. During this experiment, a micrometeorological tower of 30m height with slow and fast response sensors fixed at six nearly logarithmic levels were installed at four locations along the normal position of trough over northern India. These locations represent the dry convective to moist convective nature of the atmosphere along the normal axis of the monsoon trough.

As a part of this experiment, one such tower is placed at the Central Arid Zone Research Institute (CAZRI), Jodhpur, Rajasthan, which represents the dry convective end of the monsoon trough.

Here, the tower had six levels of instrumentation. Booms were placed at 1m, 2m, 4m, 8m, 15m and 30m heights and mentioned here as 1st, 2nd, 3rd, 4th, 5th and 6th levels respectively. In these 6 levels data for wind velocity, wind direction and temperature of both slow response as well as fast response type were collected. The details about instrumentation are available in the literature (Rudra Kumar *et al*., 1995). The Lyman-Alpha instrument, which measures the absolute humidity, was placed at one level and three Humicups were placed at three different levels measures relative humidity. The validation of the available data was carried out at Indian Institute of Science, Bangalore (Rudra Kumar and Prabhu, 1991).

As the tower of 30m falls within the lower part of ABL, *i.e*., surface layer, so studies has been undertaken, with this tower data to evolve this surface layer. The study of the surface layer is based on Monin-Obukhov similarity theory (Stull, 1994), which describes that the layer is constant flux layer, *i.e*., the gradients of the vertical flux of mass and momentum can be neglected. But the actual observations show that, there is a non-negligible amount of fluxes in the layer. To make a bridge between the theory and actual phenomenon Kramm gives an idea of multilayer hypothesis (Kramm, 1989). Although choosing of the layer efficiently, is a challenging task. Pradhan *et al*. (1994) have chosen the layer using a special technique which was already established for Kharagpur region. But this technique is not tested over Jodhpur region. Chattopadhyay and De (2000) have used a different layered hypothesis for their study over Jodhpur region. Here two methods are used namely Approach A and Approach B. In the present work, an attempt has been made to compare between two different types of layered hypothesis over Jodhpur region.

The main objective is to develop a suitable methodology for evaluation of the sensible heat flux over Jodhpur region, such that each isolated layer may be taken to have a definite stability parameter where the concept of constant heat flux should be supported.

2. Methodology and procedure

Since, the tower placed at 30m height lies within the surface layer of ABL, so all the parameters derived in the course of the present work are the surface layer parameters. Incidentally, as the potential temperature gradient has both signs successively even within a 30 m height in both fast and slow response data, one needs to introduce the concept of a number of isolated layers even within the surface layer so that each distinct layer can have a particular stability parameter and the concept of constant heat flux should preserve.

The slow response temperature and wind data are available at all six levels, which is generally continuous as one-minute averaging (Rudra Kumar *et al*., 1995). These one minute averaging data are further averaged for 30-minute period, as it has been observed that for 30 minute averaged, shows best diurnal variation (Pradhan *et al*., 1994). Surface heat flux (H) is evaluated using flux-profile technique and implementing two-layer concept, using 30 minute averaging data. In the present work, for formation of layer structure two different methods are used. One is mentioned as Approach A and another as Approach B. In Approach A, for the pre-monsoon period, the two layers have constructed between 2m & 8m, and between 8m & 30m heights. At the same time, the corresponding layers are between 1m & 15m heights, and between 15m & 30m heights for the monsoon period (Das *et al*., 2001).

In approach B, the lower level and the upper level is kept undisturbed, *i.e*., the lower level is taken at 1m height and the upper level is at 30m. Then the middle level is chosen in the following way. The slow response data at 4m and 8m levels among the six levels are ignored, as temperature gradient is very high between these two levels. The mean of the meteorological parameters of 2m and 15m heights is placed at geometric mean height of these two levels, *i.e*., at 5.477m height. So two layers are being conceived, one is between 1m and 5.477m heights and another between 5.477m and 30m heights. The mean of data at 2m and 15m heights has been considered for the generation of the parameters at 5.77m height (Pradhan *et al*., 1994).

For both the approaches stated above, surface heat flux (H) is calculated for each of the isolated layer separately. Then the surface heat flux for the total 30m height is calculated using the square root of the height weightage (Pradhan *et al.*, 1994). Now, the flux profile technique, by which the surface heat flux calculated, is described in brief.

3. The method of Flux-profile technique for calculation of surface layer parameters

Slow response sensors data for all the six levels are available. For the use of flux-profile technique, wind speed and temperature data are only taken care of.

The non-dimensional wind shear and temperature stratification may be expressed as (Pradhan *et al*., 1994),

$$\Phi_m(\xi) = \frac{kz}{u_*}\frac{\partial u}{\partial z} \quad (1)$$

Where,

z = Height,

k = Von-Karmann constant,

u = Wind speed,

$$\phi_h(\xi) = (kz/\theta_*)\,(\partial\theta/\partial z) \quad (2)$$

Where

θ = Potential temperature,

u_* = Frictional velocity,

θ_* = Frictional temperature,

$\phi_m(\xi)$ = Non-dimensional wind shear

$\phi_h(\xi)$ = Non-dimensional temperature stratification.

ξ = z / L

The flux-profile technique is based on Monin-Obukhov similarity relations (Pradhan *et al*., 1994) for $\phi_m(\xi)$ and $\phi_h(\xi)$. The generally accepted form of the similarity relations are :

$$\phi_m(\xi) = (1 - \gamma\xi)^{-a} \quad (3)$$

and

$$\phi_h(\xi) = (1 - \gamma\xi)^{-b} \quad (4)$$

Where γ is a free constant and it is taken as 5 for Jodhpur region (Chattopadhyay and De, 2000) and a, b are the constants. The widely accepted values for (a, b) are (1/4, 1/2) and (1/3, 1/2). It has been seen that (1/4,1/2) law holds good for Jodhpur region (Chattopadhyay and De, 2000). In the stable condition, the corresponding expressions are,

$$\phi_m(\xi) = \phi_h(\xi) = (1 + \beta\xi) \quad (5)$$

where, β is the constant and the value of β may be taken as 5.

Integrating the profile relations (1) and (2), with the help of 'Similarity', *i.e*., Eqns. (3), (4), or (5), the following relations are generated.

$$u(z) = (u_* / k)\ [\ln (z - d) / z_0 - \Psi m(\xi, \xi_0)] \quad (6)$$

$$\theta(z) = (\theta_* / k)\ [\ln (z - d) / z_0 -] \quad (7)$$

Where,

z_0 = Roughness length,

d = Zero plane displacement,

ξ_0 = z_0 / L,

L = Monin-Obukhov length,

$\Psi_m(\xi, \xi_0)$ = surface layer stability correction term for momentum,

$\Psi_h(\xi, \xi_0)$ = surface layer stability correction term for heat.

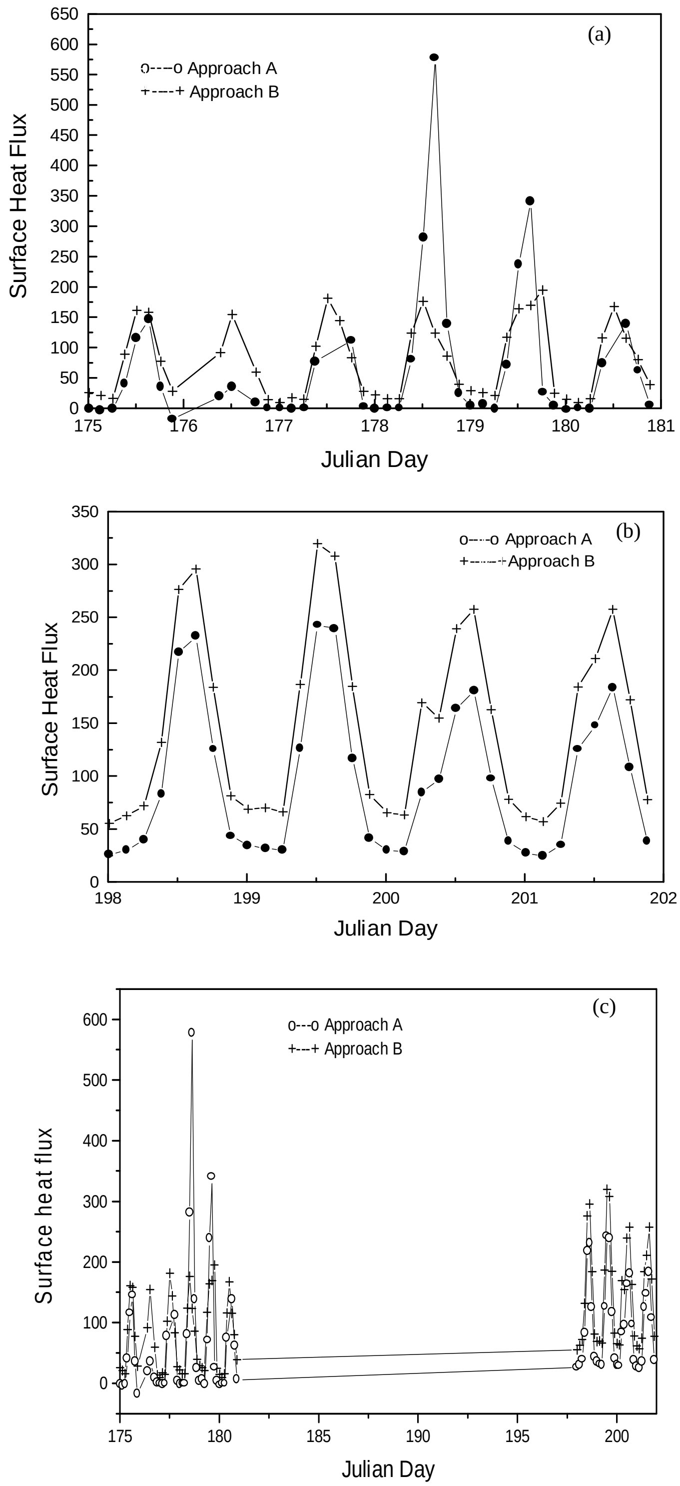
Applying (1/4, 1/2) power law, the expressions are modified as

$$\begin{aligned}\Psi_m(\xi, \xi_0) &= -5 / L\,(z - z_0 - d) \quad \text{for } L > 0\\ &= 0 \quad \text{for } L \to \infty\\ &= 2\ln\{(1+y)/(1+y_0)\} + \ln\{(1+y_2)/(1+y_{02})\}\\ &\quad -2\tan^{-1}\{(y-y_0)/(1+yy_0)\} \quad \text{for } L < 0\end{aligned} \quad (8)$$

and

$$\begin{aligned}\Psi h(\xi, \xi_0) &= -5 / L\,(z - z_0 - d) \quad \text{for } L > 0\\ &= 0 \quad \text{for } L \to \infty\\ &= 2\ln\{(1+y_2)/(1+y_{02}) \quad \text{for } L < 0\end{aligned} \quad (9)$$

Here, $y = \phi_m^{-1}(\xi) = (1 - \gamma\xi)^{1/4}$ (10)



Figs. 1(a-c). Comparison of variation of heat flux obtained from approach A and B using flux-profile method in the (a) pre-monsoon phase, (b) monsoon phase and (c) combination of pre-monsoon & monsoon phase

Obviously, y is the reciprocal of the dimensionless wind shear.

Now following the methodology of Kramm (Kramm, 1989; Businger, 1973; Brook, 1978) and taking d as zero, as the terrain of Jodhpur is flat, one can obtain the converged values of u_*, θ_* and L for a layer formed out of two levels. Then, following the procedure of Pradhan *et al*. (1994), a second iterative process is carried out so that the equations (1) and (3) or (2) and (4) are exactly satisfied. After these two successive iterative processes, stable values of u_*, θ_* and L are obtained. The stable parameters are evaluated for both the layers. From these parameters the surface heat flux can be evaluated for each layer from the following relation 10,

$$H = - \rho C_p u_* \theta_* . \quad (11)$$

Where,

ρ = Density,

C_p = Specific heat at constant pressure for moist air.

4. Heat flux for 30 m layer

For the heat flux of the entire 30m layer, the various weightages for the depth of each isolated layer can be introduced. But here √z weightage for the averaging technique has been accepted for the Indian region (Pradhan *et al*., 1994).

Let us put H_1 and H_2 as the heat flux for the two layers and z_1 and z_2 are the depth of the two layers. Then considering the $\sqrt{z}$ weightage for the depth of each isolated layer, the heat flux of the entire 30m layer can be written as,

$$H = (H_1\sqrt{z_1} + H_2\sqrt{z_2}) / (\sqrt{z_1} + \sqrt{z_2})$$

Approach B is basically identical with Approach A so far as the evaluation of layer parameters are concerned. During the study, the surface heat flux, obtained by both approach, is compared and they show almost similar diurnal variational pattern although the magnitude of the parameters are different. Comparison is done between the surface heat fluxes obtained by both the approach graphically. Separate graph is drawn for pre-monsoon and monsoon period to clearly distinguish the difference between the surface heat fluxes obtained by two approach [Figs. 1(a&b)]. Again, another graph is plotted combining the above mentioned two, to compare the characteristics of pre-monsoon and monsoon period [Fig. 1(c)].

5. Results and discussions

Comparison between the surface heat fluxes obtained from two different types of layer hypothesis has been made and the results are presented in Figs. 1(a&b).

From the Figs. 1(a&b), one finds that both the methods give identical diurnal variational pattern of heat flux though the amplitudes are different. In a previous work (Das *et al*., 2001), it has been noted that, there are two significant days when deep convection is present in the pre-monsoon period (*i.e*., in the month of June) for Jodhpur region. For those two days when a system is present (*i.e*., 27th June and 28th June), eddy correlation method unusually indicates high magnitude of surface heat flux (Das *et al*., 2001). In the present study, for these two particular days, both the methods can not provide satisfactory result, in comparison to eddy correlation output; though from the Figs. 1(a&b), it is evident that for these two days both the approaches exhibit peaks in surface heat flux. Again, one can accept that the eddy correlation method is an ideal one (Chattopadhyay and De, 2000), for calculation of surface layer parameters. In that context, it has been shown that, flux-profile method is in same status with eddy correlation method, but the only deficit is in the amplitude, *i.e*., flux-profile method always lags in amplitude compared to eddy correlation method, which supports the fact that flux-profile method is less sensitive than eddy correlation method. However, for the peak value of the surface heat flux in the Figs. 1(a&b), Approach B is better in monsoon situation as this Approach gives higher magnitude of heat flux. When considering the sensitivity, Approach B is more reliable than Approach A, for monsoon period.

For the pre-monsoon phase Approach B is, in general, more sensitive but for the two deep convective days Approach A indicates high magnitude of surface heat flux. So it has been observed that the Approach A is better only for those days when a system was present, and for the other days, *i.e*., when deep convection is not present, Approach B is better than Approach A.

6. Conclusions

For the flux profile technique, two methodologies for calculation of surface layer parameters have been adopted. Between these two approaches of flux-profile methodology, it has been observed that Approach B is better in both the pre-monsoon and as well as in the monsoon period except for the deep convective situation over Jodhpur region. Therefore, to measure the heat flux for Jodhpur region, Approach B is appropriate for all monsoon days as well as pre-monsoon days except those days with deep convection.

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