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OBSERVATIONAL AND THEORETICAL STUDIES OF TURBULENT FLUXES, TEMPERATURE AND HUMIDITY CONVERGENCE IN CONVECTIVE BOUNDARY LAYER OF FORTALEZA N-E BRAZIL

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1.INTRODUCTION

The importance of land surface processes on atmospheric boundary layer development and larger scale weather has been widely studied for over 30 years. Reviews by Betts et al. (1996) and Pielke et al. (1998) detail how exchanges of energy, moisture and momentum between the atmospheric boundary layer and the land surface are strongly influenced by vegetation and soil moisture. Changes in the land surface and the atmospheric boundary layer impact larger scale weather through entrainment with the troposphere and convective cloud formation (Avissar, 1995 and Garrat 1993). During the past decade land-surface-models (LSM) have improved continuously, especially with the help of field experiments. However, evaluation is still needed for semi arid regions (Burose, et al., 2002).

Because of the increasing awareness that tropical rain forest and the continental rain forest of the Amazon basin in particular, may have an important role in global climatology, there have been a number of international projects on Amazon basin in Brazil as Anglo-Brazilian collaborative study of the micrometeorology and plant physiology of Amazon rain forest; -Amazonian Region Micrometeorological Experiment ARME (Suttleworth, et al., 1984 a., b; 1985; Molion, et al., 1984 a, b; etc.,), ABRACOS- Anglo-Brazilian Amazonian Climate Observation Study (Gash, et al. 1996, etc.) and LBA (Large Scale Biosphere-Atmosphere Experiment in Amazon (da Silva et al., 2002, Sakai, et al., 2002 among others). But in the N-E region of Brazil, the most of the works are confined to the energy balance or studies on the Surface Boundary Layer (Silva et al., 2002, 2000, 1997; da Silva et al.,2002, Paz 2004 a,b, among others) So, it is important to study some characteristics of the Planetary Boundary Layer (PBL) of the N-E a semi arid region of Brazil to better understand the parameterization of turbulent fluxes for applications among others, in regional models.

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2. EXPERIMENTAL SITE AND DATA

The data for this study were collected in Fortaleza (3.77S and 38.60W) a semi-arid region of N-E Brazil, by balloon soundings from the period of 02-04-2002 to 11-04-2002 as a part of the experiment EmfiN Experimento de Microfisica de Nuvens – (experiment of microphysics of clouds) conducted by Universidade Estadual da Ceara-UECE (Costa et al. 2002). The data were collected by 28 balloon soundings during the experiment. But in this preliminary study only two days of the following data are analyzed:

TABLE I DETAILS OF SOUNDINGS USED

Day	Local time	Code
06-04-2002	10:33	06041033
06-04-2002	11:50	06041150
08-04-2002	11:03	08041103
08-04-2002	12:49	08041249

As the data were collected for the microphysical clouds experiments, there are some, limitation in the data for land surface atmosphere interaction work.

2. METHODOLOGY AND DISCUSSION

a) Thermodynamic energy equation method

This method, for estimation of sensible heat flux at the surface and its vertical distribution (profile) in the Planetary Boundary Layer (PBL) is based on the thermodynamic energy equation which in the absence of temperature advection, reduces to

$$\frac{\partial \overline{T}}{\partial t} = \frac{1}{\rho\, c_P}\frac{\partial R_N}{\partial z} - \frac{\partial \overline{w'\theta'}}{\partial z} \qquad (1)$$

where,

ρ is density of air

c_P specific heat of air

R_N is net radiation

$\overline{T}$ is mean temperature

θ ' is temperature fluctuation

w' is fluctuation of the vertical velocity

t is time and

z is height

Here the time-tendency (warming or cooling rate is retained, because it is often found to be significant even when the flow field may be considered quasistationary. It is a manifestation of diurnal heating and cooling cycle, which is responsible for important stability and buoyancy effects in the PBL. From equation (1) one may see that the rate of warming or cooling essentially balances the convergence or divergence of radiative and sensible heat fluxes. The radiative flux divergence is usually ignored in the day time unstable or convective boundary layer, especially in the absence of fog and clouds within the PBL. It becomes more significant in the stably stratified nocturnal boundary layer. For simplification if radiative flux divergence may be ignored the integration of eq. (1) with height yields

$$\overline{w'\theta'} = \int_z^h \frac{\partial \overline{T}}{\partial t}\, dz \qquad (2)$$

or,

$$(\overline{w'\theta'})_0 = \int_0^h \frac{\partial \overline{T}}{\partial t}\, dz \qquad (3)$$

where

$(\overline{w'\theta'})_0$ is sensible heat flux at the surface,

h is the height of the PBL

In obtaining eq. (3) it is assumed that at the top of the PBL the sensible heat flux vanishes.

Similarly, from the conservation eq for water vapor, one may have

$$(\overline{w'q'})_0 = \int_0^h \frac{\partial \overline{q}}{\partial t}\, dz \qquad (4)$$

where,

$\overline{q}$ is mean specific humidity

q' is a fluctuation of the specific humidity

In obtaining eq. (4) it is also assumed that at the top of the PBL $(\overline{w'q'})_h = 0$.

b) Estimation of fluxes by profile method

The corresponding profiles may be written in the form

$$\overline{U} = \frac{u_*}{\kappa}\left[\ln\frac{z}{z_0} - \Psi_M\left(\frac{z}{L_M}\right)\right] \qquad (5)$$

$$(\overline{T} - T_0) = \frac{T_*}{\kappa}\left[\ln\frac{z}{z_0} - \Psi_H\left(\frac{z}{L_M}\right)\right] \quad (6)$$

$$(\overline{q} - q_0) = \frac{q_*}{\kappa}\left[\ln\frac{z}{z_o} - \Psi_E\left(\frac{z}{L_M}\right)\right] \quad (7)$$

$$\Psi_M = \ln\left[\left(\frac{1+x^2}{2}\right)\left(\frac{1+x}{2}\right)^2\right] - 2\tan^{-1}x + \frac{\pi}{2}$$

$$\text{for } \frac{z}{L_M} < 0 \quad (8)$$

$$\Psi_H = \Psi_E = 2\ln\left(\frac{1+x^2}{2}\right), \text{ for } \frac{z}{L_M} < 0 \quad (9)$$

$$x = \left(1 - \frac{z}{L_M}\right)^{1/4} \quad (10)$$

$$L_M = -\frac{\rho\, c_P\, u_*^3\, T_0}{\kappa\, g\, H} \quad (11)$$

where

L_M is characteristic length scale of Monin - Obukhov

U_* is friction velocity or velocity scale

$T_* = -H_0/(\rho\, c_P\, u_*)$ Temperature scale

$q_* = E/(\rho\, u_*)$ specific humidity length scale

κ is von Karman's constant

H is sensible heat flux and

E is water vapor flux.

So the kinematic fluxes for heat flux and water vapor may be written in the form

$$\frac{H}{\rho\, c_P} = -u_*\, T_* \quad (12)$$

and

$$\frac{E}{\rho} = -u_*\, q_* \quad (13)$$

In this study the kinematic fluxes are calculated from the accumulation methods (eqs (3) and (4)) and from profiles methods (eqs. (12) and (13)). As the experiment was performed for the purpose of microphysical research work, so there were no measurements of the height of the Planetary Boundary Layer. In this case, the height of the PBL is estimated as a height where the velocity is maximum in corresponding sounding.

The calculated values by both methods for kinematic heat fluxes (K m s^{-1}) are shown in Table 2 and the kinematic water vapor fluxes (m s^{-1}) in Table 3

Table 2-.Comparison of kinematic heat fluxes.

Heat			
Date	Hour	Eq. (12)	Eq.(3)
6/Apr	10:33 - 11:50	0.030509	0.7232
8/Apr	11:03 - 12:49	1.514075	-1.7956

Table 3- Comparison of the kinematic fluxes for water vapor

Water vapor			
Date	Hour	Eq (13)	Eq.(4)
6/Apr	10:33 - 11:50	-0.91229	-0.7675
8/Apr	11:03 - 12:49	1.338492	1.1137

It can be seen from Tables 2 and 3 that there are reasonable agreements between the results of the two methods especially for 06 April 10:30-11:50 for kinematic heat flux; and 06 April 10:33-11:50 and 08 April 11:03-12:49 hrs for water vapor flux. Similar results are also obtained by da Silva et al. (2002), using the sounding data obtained during the data collection as a part of LBA (Large Scale Biosphere-Atmosphere experiment in Amazon) and the results of eddy correlation methods obtained by Sakai et al. (2OO2) in nearby micrometeorological tower.

The temporal evolution of the Soundings for specific humidity, potential temperature wind speed and direction are shown in figures 1 and 2.

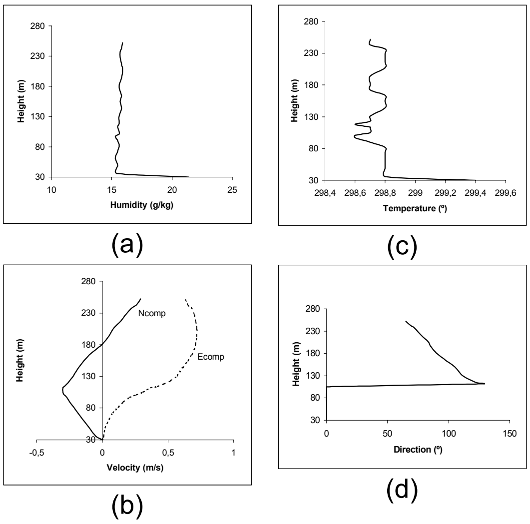

Fig1 Sounding: 06 April 2002 11:50

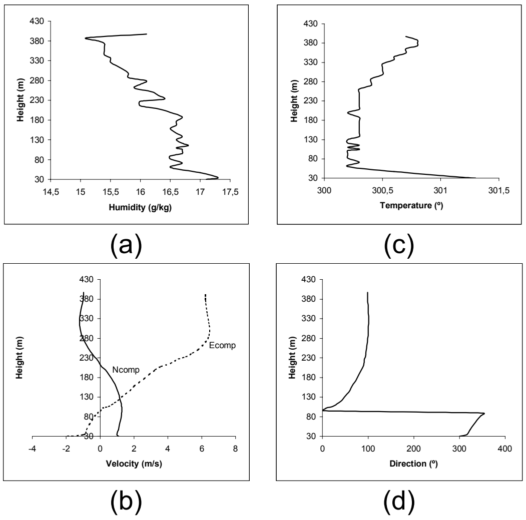

Figure 2 (a) Sounding: 08 April 2002 12:49

So, in the absence of sophisticated fast response turbulence instrumentation and micrometeorological tower measurements, the thermodynamic energy and humidity conservation equations are quite useful in that these are based on the fundamental conservation equations and measurements of mean temperature and humidity profiles without any restrictive assumptions. As mentioned above these data were collected for the research work on microphysics of clouds, so there are some limitations on the data, further this is only a preliminary analysis and further details of the results will be presented in the future paper.

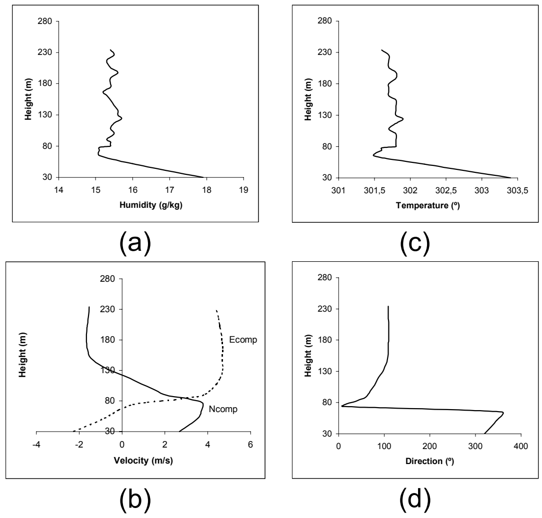

Figure 2(b) Sounding: 08 April 2002 11:03

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