TIME EVOLUTION OF THE NOCTURNAL BOUNDARY LAYER OVER AMAZONIA

Rosa Maria Nascimento dos Santos
Instituto Nacional de Pesquisa Espacial (INPE) – CPTEC/LMO, São José dos Campos – SP
rosa@cptec.inpe.br

Gilberto Fisch
Centro Técnico Aeroespacial (CTA) – IAE/ACA, São José dos Campos - SP
gfisch@iae.cta.br

• INTRODUCTION

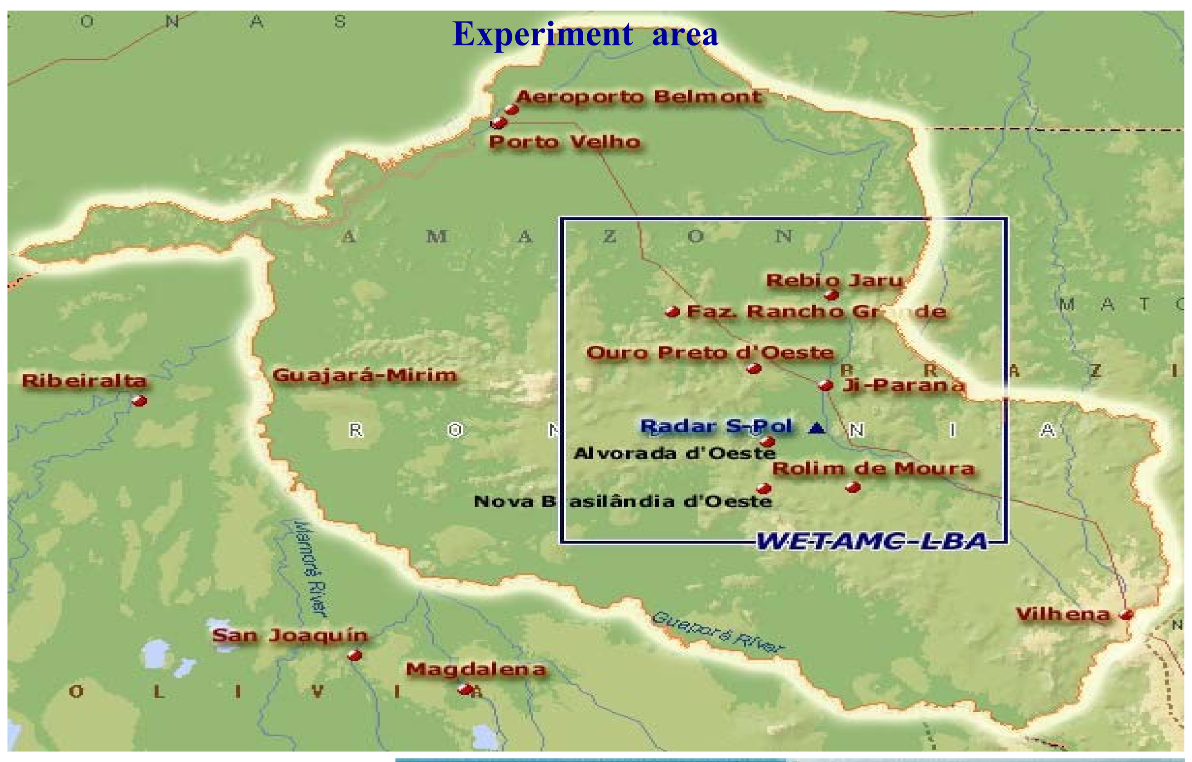
The Atmospheric Boundary Layer (ABL) may be defined as the lowest part of the atmosphere that is more directly influenced by presence of the Earth surface and is characterized by experiences a largest diurnal variation in temperature and turbulent motions which are responsible by the transport of heat, momentum, water vapour and other species into the atmosphere. Typical values to the ABL depth vary between 50-500 m (in the night time) and 1-2 km (during the day). During the daytime is called Unstable (or Convective) Boundary Layers and turbulence is driven by the thermal instability yielded due to the surface heating by the solar radiation (Stull, 1988). At night due to the radiative cooling of the surface the boundary layer presents a stratified-temperature structure, with the coldest temperatures near the surface, increasing upwards and the buoyancy forces tend to work in the same gravity direction. In this case the turbulence is generated only by the mechanical shear of the mean wind and buoyancy forces act to destroy the turbulent motions. Due to this complex nature the NBL has been study issue of many researchers in order to try identifying some of its patterns (see Holtslag e Nieuwstadt, 1986; Smedman, 1988; Derbyshire, 1990; Malhi, 1995; Oyha, et al., 1997; Mahrt, 1998; Mahrt et al., 1998; Mahrt, 1999). In spite of its importance to the knowledge of climate and environmental impacts over differents bioms, NBL characteristics over Tropical areas, specialy in Amazon Forest Region have not been so studied yet. Most of observational and modelling studies (see Martin et al., 1988; Fisch,et al., 1996; Silva Dias e Regnier, 1996; Fu et al., 1999; Oliveira, 2000; Fisch et al., 2001; Souza e Lyra, 2002), that have been carried out in that region is worried about the ABL at the daytime

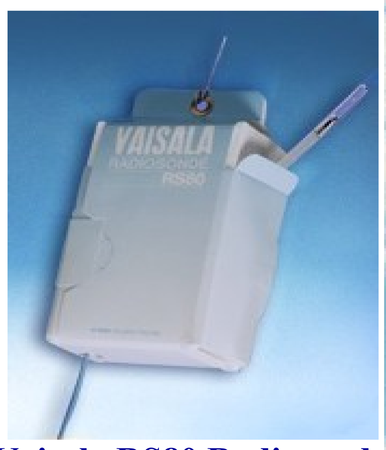
•DATA AND EXPERIMENTAL SITES

Tethered balloon profiles, energy surface fluxes and automatic meteorolo-gical stations data were used, from three representative sites in Rondônia in the western part of Amazon region in Brasil: Fazenda N.S.ª (10º 46' S, 62º 20' W, 293 m), Rebio Jaru (10º 05' S, 61º 55' W, 120 m) and Rolim de Moura (11º 42' S, 61º 46' W, 225 m) - hereinafter called forest, FNS and RM, respectively. Have been used 358 tethered balloon profiles and 326 radiosondings. Radiosondings were performed by the VAISALA system (Finland) in Rolim de Moura and Rebio Jaru and by the VIZ system (USA) in the Fazenda N. S.ª site and got information about air temperature, relative humidity, air pressure and wind (speed and direction). Data were collected six timesper day during the nigthtime (02, 05,08,17, 20 and 23 LT). Tethered balloon soundings were performed by the Atmospheric Data Acquisition System (ADAS) of the A. I. R. Inc. (EUA) which collected information about dry and wet air temperatures, air pressure and wind velocity and direction. Were used data from 15 diferent times – 01, 04, 05, 06, 07, 08, 09, 10 (only in the FNS), 16,17, 18, 19, 20, 21 and 22 LT – in the nigth period (see Longo et al, 2002).

•METHODOLOGY

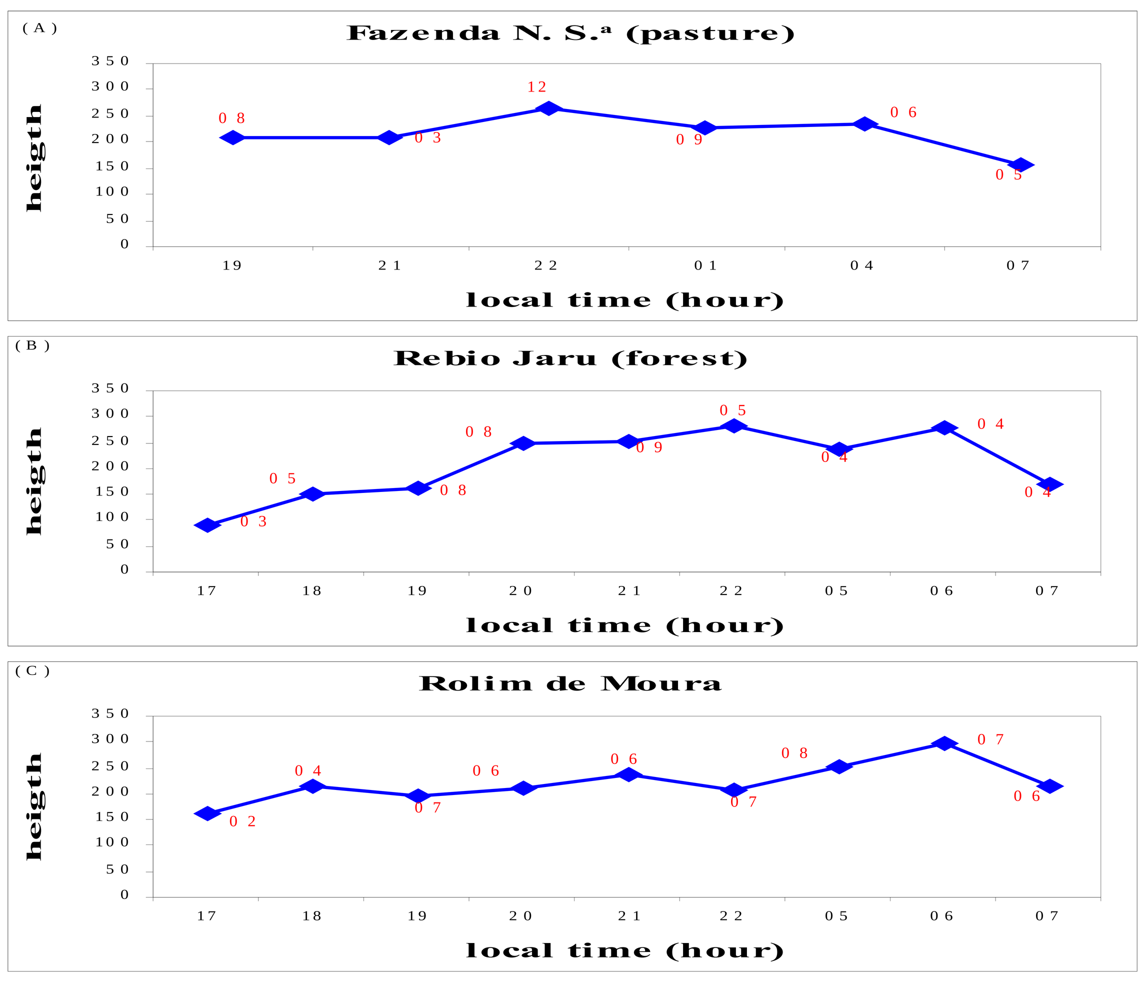
The CLN time evolution was studied based on vertical profiles of potential temperature, humidity (q) and wind (direction and speed), gotten from soundings with tethered balloon, over 3 sites (forest, RM and FNS), during the field experiments wetAMC-LBA (wet season) and RBLE3 (dry season). Mean characteristics – depth (h_i), temperature on the top of CLN, thermal discontinuity, and the intensity nocturnal inversion – were determined for these two periods, and a comparative study was carried out. NBL height - hi - is defined as the height in which the θ gradient is null or lower than 0.01K.m^{-1} (value determined as a function of the temperature data set measures precision) and θ(i) is the temperature in the layer's top, that is the temperature in the height z = hi. The difference between θ(i) and θ in the surface defines the thermal discontinuity – Δθ. The thermal inversion (Nocturnal inversion) intensity, in K.m^{-1}, is equal to the Δθ divided for the layer's thickness (Δθ/ hi).





Vaisala RS80 Radiosonde

Tethered balloon hoisting – Rondônia, Feb/99



NBL mean depth (<hi>) during the WETAMC-LBA: (A) Fazenda N. S.ª; (B) Rebio Jaru and; (C) Rolim de Moura.
nn - number of profiles used to compute the mean

Rebio Jaru (Forest) – WET SEASON					
HORA	h_i	θ(*i*)	<q> (g.kg^{-1})	Δθ(*i*)	K.km^{-1}
17	90	301,1	15,40	1,1	12,59
18	152	301,5	15,39	2,8	18,29
19	161	300,1	15,48	2,5	15,35
20	248	300,6	15,02	3,8	15,45
21	251	299,8	15,06	3,6	14,25
22	282	300,1	15,03	4,4	15,53
05	238	298,4	14,00	3,4	14,32
06	278	298,8	13,94	4,0	14,59
07	170	296,8	14,03	1,7	10,00
Rolim De Moura (Pasture-Forest Transiction) – WET SEASON					
HORA	h_i	θ(*i*)	<q> (g.kg^{-1})	Δθ(*i*)	K.km^{-1}
17	160	303,3	10,97	3,0	18,44
18	215	302,4	11,72	2,5	11,63
19	197	301,9	12,01	2,5	12,61
20	210	301,4	11,80	3,1	14,76
21	237	301,5	11,42	3,4	14,30
22	207	301,0	11,55	3,8	18,14
05	253	299,9	11,24	4,0	15,74
06	296	300,6	11,26	4,8	16,09
07	215	298,7	11,59	2,4	11,16
Fazenda N^{sa} S^{ra} (Pasture)– WET SEASON					
HORA	h_i	θ(*i*)	<q> (g.kg^{-1})	Δθ(*i*)	K.km^{-1}
19	210	302,3	17,62	3,0	14,11
21	207	300,4	17,68	2,6	12,58
22	264	301,7	17,47	3,5	13,44
01	227	301,0	17,70	3,0	13,19
04	235	300,8	17,77	3,5	15,04
07	156	299,9	17,94	0,6	3,97

• NBL CHARACTERISTICS IN RONDÔNIA

DRY SEASON

In this period the CLN was deeper in the forest - mean values between 180m (at 06 p.m. local time) and 420m (at 05 a.m.). In the pasture NBL height (hi) mean values were 110m minimum (at 07 p.m.) and the 320m maximum (between 05 and 07 a.m.). The temperature in the top of the layer - θ (hi) - was on average 1,4K higher over the pasture related to the forest, in agreement to previous studies of Souza and Lyra (2002) that pointed out the highest heating of the pasture during the dry season. It was also noticed that the thermal inversion was much more strong on the pasture for all observation times, with maximum intensity occurring at 07 a.m. (50,5 K.km^{-1}), indicating the NBL strongest stability over the pasture during the dry time (about 8 K.km^{-1} higher than over the forest).

WET SEASON

May be observed a shallow depth layer developing on three sites remaining below of 300 m most of the time. Also have been observed that the pasture was wetter than the forest and RM (see at table 1) this is probably related to a combination of factors as such physical characteristics of the pasture soil (infiltration, compaction, water retention capacity), vegetation (effective root area, etc.) and local topography, that together playing an essential role on the control of the surface moisture content (see Hodnett et al, 1996), could lead to a larger runoff during the studied period (wet season) leaving more moisture available to evaporation and transpiration in that site. Temperature march during the nighttime was similar for all sites (Forest, RM and FNS), with the highest values occurring at the beginning of the night (between 17 and 18 LT) and the lowest ones in the early morning, 07 LT (transition time from nocturnal to convective conditions). The humidity, otherwise, had presented its lowest nocturnal mean values at 06, 05 and 22 LT (in the forest, RM and FNS, respectively), and the highest ones at 19 LT (forest and RM) and 07 LT (FNS).

FOREST – DRY SEASON					
HORA	hi	θ (hi)	<q> (g.kg-1)	Δθ	K.km^{-1}
18:00	180	304,3	15,8	5,0	27,7
19:00	240	303,9	15,4	7,5	31,3
21:00	300	303,5	14,5	8,3	27,8
24:00	330	303,2	13,8	9,9	29,9
05:00	420	303,2	13,3	11,6	27,6
07:00	300	300,9	13,4	9,3	30,9
PASTURE - DRY SEASON					
HORA	hi	θ (hi)	<q> (g.kg-1)	Δθ	K.km^{-1}
18:00	120	305,7	7,2	3,0	25,4
19:00	110	304,5	7,3	5,6	50,5
21:00	260	307,3	10,0	10,4	39,8
24:00	230	303,3	9,0	9,1	39,4
05:00	320	303,5	8,2	11,4	35,7
07:00	320	303,3	8,2	10,4	32,4

• REFERENCES

DERBYSHIRE, H. Nieuwstadt's stable boundary layer revisited. Quart. J. Roy. Meteorol. Soc., 116, 127-158, 1990.
FISCH, G.; Culf, A. D.; Nobre, C. A. Modelling convective boundary layer growth in Rondônia. In: Gash, J. H. C., Nobre C. A., Roberts, J. M. e Victoria, R. L. ed. Amazonian deforestation and climate. Chichester: England, 1996. cap. 25, p. 425-435.
FISCH, G.; Tota, J.; Machado, L. A. T.; Silva Dias, M. A. F.; Lyra, R. F. Da F.; Nobre, C. A.; Dolman, A. J.; Culf, A. D.; Halve Rson, J.; Fuentes, J. D. The convective boundary layer over pasture and forest in Amazonia. JGR., 2001. (submetido)
FU, R.; Zhu, B.; Dickinson, R.E. How do the atmosphere and land surface influence seasonal changes of convection in the tropical Amazon?, *Journal of Climate*, 12(5), 1306 – 1321, 1999.
HOLTSLAG, A. A. M.; Nieuwstadt, F. T. M. Scaling the atmospheric boundary layer. Boundary-Layer Meteor., 36, 201-209, 1986.
LONGO, M.; Albrecht, R. I.; Machado, L. A. T.; Fisch, G.; Silva Dias, M. A. F (2002). Controle de qualidade dos dados de radiossondagem da Campanha WET-AMC/LBA. Submetido a Revista Brasileira de Meteorologia.
MAHRT, L. Stratified atmospheric boundary layers. Boundary-Layer Meteor., 90, 375-396, 1999.
MAHRT, L.; Sun, J.; Blumen, W.; Delany, T.; Oncley, S. Nocturnal boundary-layer regimes. Boundary-Layer Meteor., 88, 255-278, 1998.
MALHI, Y. S. The significance of the dual solutions for heat fluxes measured by the temperature fluctuations method in stable conditions. Boundary-Layer Meteor., 74, 389-396, 1995.
MARTIN, C. L.; Fitzjarrald, D. R.; Garstang, M.; Oliveira A. P.; Greco S.; Browell, E. Structure and growth of the mixing layer over the Amazonian rain forest. JGR., 93(D2), 1361-1375, 1988.
OYHA, Y. D.; Neff, E.; Meroney, R. N. Turbulence structure in a stratified boundary layer under stable conditions. Boundary-Layer Meteor., 83, 139-161, 1997.
OLIVEIRA, P. J. Estudo do vento e da turbulência na Camada Limite Atmosférica em áreas de floresta e pastagem na Amazônia. São José dos Campos. 80p. Dissertação (Mestrado em Meteorologia) – Instituto Nacional de Pesquisas Espaciais, 2000.
SILVA DIAS, M. A. F.; Regnier, P. Simulation of mesoscale circulations in a deforested área of Rondônia in the dry season. In: Amazonian Deforestation and Climate. Ed.: GASH, J. H. C.; NOBRE, C. A.; ROBERTS, J. M. e VICTORIA, R. L., pp. 531-547, John Wiley & Sons, Chichester, 1996.
SMEDMAN, A-S. Observations of a multi-level turbulence structure in a very stable atmospheric boundary layer. Boundary-Layer Meteor., 44, 231-253, 1988.
Souza, S. S.; Lyra, R. F. da F. A Substituição da floresta Amazônica por pastagem e sua repercussão ao nível da termodinâmica da Camada Limite Atmosférica: PROJETO RBLE. Revista Brasileira de Meteorologia. 2002 (aceito)
STULL, R. B. (1988) *An introduction to boundary layer meteorology*. Kluwer Academic Publishers, Dordrecht, 666 pp.