TROPOSPHERIC STRUCTURE IN THE AMAZON BASIN WITH AN ENHANCED RADIOSONDE NETWORK

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Summary: This paper contains a description of the large-scale radiosonde network which was operational during the Amazon Boundary Layer Experiment 2b which took place between April 13 and May 13, 1987. The preliminary results on the vertical and horizontal structure of the tropospheric circulation are described. Special attention is given to the diurnal variation and to transient bursts of convection.

1. INTRODUCTION

The role of the Amazon region as a source of trace gases to the atmosphere is the primary objective of the Amazon Boundary Layer Experiment IIb (ABLE-2b) which is part of the Global Tropospheric Experiment, a NASA initiative in the area of tropospheric chemistry. However, in order to understand the vertical and horizontal transport of the trace constituints it is necessary to study the turbulent processes associated with the vertical exchange of energy between the forest and the atmosphere including the micrometeorological processes and the moist convective transport associated with the cumulus acitvity. In fact, most of the tropical field experiments conducted previously were aimed towards the understading of the role of convection over oceanic areas. However, the energy associated with the precipitation in the Amazon region has a considerable amplitude in comparision with the Indonesian and the African sources.

Current research topics based on ABLE data are: (a) regional energy and water budget, (b) diurnal variation, (c) diagnostics of the vertical mass transport, (d) relationship between tropopause height and convective activity, (e) organization of convective systems in the area (such as sea breeze instability lines and organized cloud clusters), (f) tropospheric flow response to transient convection, (g) precipitation regime transition as the sun moved northward

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during the experiment, (h) impact of ABLE2-b data on data assimilation, analysis and tropical forecasts.

The objective of this paper is to discuss: (a) observational evidences of the adjustment processes undergone by the tropical atmosphere under the presence of transient convection (diurnal to a few days time scale) in the Amazon region and (b) some differences between diagnosed fields based on the radiosonde data and the National Meteorological Center. Previous model studies by Silva Dias et al (1983) and Silva Dias et al (1987) indicated that a large percentage of the energy associated with convective bursts are transfered to high frequency modes (gravity and Kelvin waves). The slow response, associated with the Rossby projection of the perturbation, is associated with the upper anticyclonic circulation which is symmetric about the equator when the heat source is centered at or near the equator and with the Bolivian High during the summer season when the heat source in located over the central part of South America. During the Amazon Boundary Layer Experiment 2b (ABLE-2b), several episodes of transient organized convection were observed with a very strong diurnal signal, associated with organized convective lines generated by the sea breeze. Monitoring of the tropospheric circulation was possible trough a special network of radiosonde stations.

2. EXPERIMENT DESIGN

The observational data for this study are based on the radiosonde observations collected during ABLE-2b from April 13 to May 13, 1989. The special upper air network operated 4 times per day at six locations: Belém (1.4^{0}S,48.5^{0}W), Boa Vista (2.5^{0}N,60.7^{0}W), Leticia (4.2^{0}S,70.3^{0}W), Vilhena (12.7^{0}N,60.1^{0}W), Alta Floresta (9.9^{0}N,56.1^{0}W) and Embrapa (2.5^{0}S,60^{0}W). Approximately 665 usefull radiosonde profiles were collected during the field experiment.

The exact number of soundings at each station and time are shown in Table 1. Quality control on the radiosonde data was performed based on vertical and temporal consistency and inspection of horizontal consistency through the objectively analysed fields (a simple successive correction scheme based on Doswell, 1977). The Embrapa data is still preliminary because of the on-going special quality control required in this case due to the use of a different radiosonde equipment. The VAISALA RS21 equipment with manual tracking was used in Belém, Vilhena and Alta Floresta. Leticia used the same type of radiosonde but with automatic tracking. Boa Vista was equipped with the VIZ RD65 system with automatic tracking and A.I.R sondes were launched from Embrapa with the VIZ automatic tracking system. A comparision between some of the radiosonde equipments avalilable at the largescale network can be found in McBean et alli (1986).

Table 1. Number of soundings during ABLE-2b at each observation time. The number in brackets represents the percentage of soundings effectively launched in relation to the maximum possible number of sondings).

TIME STATION	00 UTC	06 UTC	12 UTC	18 UTC	TOTAL
BELÉM	30 (100)	30 (100)	31 (100)	30 (100)	121 (100)
BOA VISTA	26 (87)	19 (63)	27 (87)	19 (63)	81 (84)
LETICIA	26 (87)	26 (87)	27 (87)	25 (83)	104 (86)
VILHENA	30 (100)	29 (97)	31 (100)	30 (100)	120 (99)
A. FLORESTA	30 (100)	29 (97)	31 (100)	30 (100)	120 (99)
EMBRAPA	26 (87)	25 (83)	29 (94)	29 (97)	109 (90)
TOTAL	168 (94)	158 (88)	176 (95)	163 (91)	665 (92)

The precipitation regime during ABLEIIb was characterized by slightly below normal precipitation in the southern and eastern parts of the basin and slighly above normal in the northern part. The migration of the rainy areas from the central portion of the basin to the northern part, with the associated tropospheric drying in the south was very well captured during the experiment. The tropospheric circulation during the experiment was characterized by several organized episodes of precipitation systems such as: convective lines generated by the sea-breeze and mesoscale convective systems locally generated or induced by the penetration of Southern Hemisphere cold fronts. During the first week of the experiment convection was fairly well distributed over the area with an upper cold low centered over the eastern coast of Brazil. On 27th of April, deep convection developed over the central part of Brazil producing an upper tropospheric ridge which eventually developed into an upper anticyclonic circulation very similar to the typical summertime pattern. At the begining of May, intense sea breeze generated squall lines with organized convective systems near the equator, with strong upper level divergence and the upper anticyclonic couplet. The remaining part of the experiment presented reduced convection except in the northern and western regions.

3. RESULTS

Objective analysis of the radiosonde data reveals consistent patterns of the divergence field. Intense lower level moisture convergence appears in the extreme eastern part along the coast, northern and western regions . The diurnal variation of the basin circulation is clearly shown. The easterlies at 850 mb decrease in intensity at 18 UTC and are stronger at 12 UTC all over the central and estern basin. An east to west propagation of the lower level convergence and upper level divergence can be clearly detected. The flow along the western edge of the basin also show significant diurnal variation, with reversal of the sign of the meridional component of the wind (southerly by 12 UTC and northerly by 18

UTC). The convergence/divergence patterns are consistent with the propagation of the convective lines which develop in response to the sea-breeze, from the Amazon mouth towards the Andes. How much of the diurnal variation is governed by dry dynamics and how much is associated with the moist convection remains an intriguing question.

An inspection of the time series of the zonal component of the wind at Belém shows several bursts of easterly and westerly jets at the upper troposphere. The diurnal variation of the upper zonal flow is also quite pronounced and is associated with the sea breeze convective lines which propagate inland with a life cycle of a few days in some cases. Complete reversal of the upper zonal flow in Belém are associated with very strong bursts of convection in the central part of the Amazon Basin.

A preliminary analysis of the moisture budget based on the radiosonde data reveals that: (a) large diurnal variation, (b) strongest moisture convergence occurs at 00 UTC and continues through the nighttime, (c) estimates based on a single observation time maybe significantly distorted (such as 00 UTC and 12 UTC for the precipitation minus evapotransiration), (d) The mean precipitation over the area is of the order of 265 mm or 8.8 mm/day (from April 13 to May 13, 1987). Mean evapotranspiration minus precipitation if of the order of -3.7 mm/day. Thus, mean evapotranspiration is 5.1 mm/day and the ratio E/P=0.6. These numbers indicate that the evapotranspiration has a significant role in the water budget in the area.

Two major episodes are discussed in more detail: (a) a typical equatorial heat source, associated with an intense convective line, which propagated through the Amazon Basin from April 30 to May 2 and (b) a period with active convection over the Central part of Brazil, from April 26 to April 28.

The first case was characterized by the pair of anticyclones symmetric about the equator and strong upper westerlies to the east of the heat source. The upper level divergence indicates the westerly displacement of the heat source during a period of 2 days. The intensification of the subtropical jet in the southern hemisphere is clearly observed during this episode. Abrupt changes in the upper level circulation are observed in this case as identified in a sequence of upper level wind analysis every 6 hours.

The upper circulation in the second case was characterized by the development of an upper anticyclonic circulation which is a typical summertime pattern (Kousky and Kagano, 1981). The coupling between the upper and lower atmosphere shows that the circulation is associated with a baroclinic mode with phase reversal in the midtroposphre. The time scale associated with the convective burst in this case is of the order of 2 days.

Comparisions between the radiosonde and NMC fields was also performed. The analysis shows that the mean NMC divergence over the experiment area is a factor of two smaller than the

radiosonde estimate. The NMC convergence is concentrated at the lowest 200 hPa and the upper tropospheric divergence is also concentrated in a relatively thin layer (200 hPa). The diurnal variation of the NMC divergence is also much smaller than the estimate based on the radiosonde data. Temperature comparisions indicates severe problems with the post-processing method at NMC (recently corrected).

4. CONCLUSIONS

ABLE provides the first radiosonde data set with high temporal and spacial resolution over the Amazon region, one the most active regions over the globe in terms of moist convection. During ABLE several episodes of strong upper level divergence where observed, indicating strong convection in the equatorial region. The observed time evolution finds strong theoretical support from the point of view of the wind/mass adjustment in the tropical region. The divergent component of the wind is of the same order of the rotational componet during the convective burst. Severe impact is expected in terms of assimilation of strongly divergent wind fields in the presence of active convection. Thus, the evidences shown in this paper reinforces the need for an appropriate estimate of the divergent component of the wind in an operational assimilation cycle. The use of longwave outogoing radiation is strongly recommended.

5. REFERENCES

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