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Synoptic scale features of the tropospheric circulation over tropical South America during the WETAMC TRMM/LBA experiment

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RESUMEN

Este trabajo analiza las características sinópticas de la circulación de los niveles altos y bajos de la troposfera sobre América del Sur, durante la primera campaña para colecta de datos atmosféricos en mesoescala en la época húmeda (Atmospheric Mesoscale Campaign in the Wet Season - WETAMC) del Experimento de Gran Escala en la Biosfera-Atmósfera de la Amazonia (LBA). Esta campaña fue realizada entre los meses de enero y febrero de 1999 simultáneamente con la validación de los datos del satélite Tropical Rainfall Measuring Mission (TRMM) sobre Brasil. Fueron utilizados datos puntuales reticulares de los National Centers for Environmental Predictions (NCEP) para analizar los vientos y sus campos de divergencia asociados, a manera de definir los patrones prevalecientes de la circulación troposférica en la región. Las imágenes TRMM fueron utilizadas para delinear los patrones de lluvia. Los resultados muestran que ocurrieron por lo menos cuatro patrones diferentes en los campos de viento en la alta troposfera, durante el período estudiado. Estos patrones están asociados, principalmente, a la circulación anticiclónica de Bolivia y a los vórtices ciclónicos en el noreste de Brasil. Los resultados también indican que, en general, la actividad convectiva sobre extensas áreas de América del Sur es dinámicamente sustentada por divergencias a niveles altos. Dos de los seis vórtices observados, presentaron desplazamientos anómalos en la Amazonia durante el período de estudio. En los niveles bajos de la Zona de Convergencia del Atlántico Sur (ZCAS) no hubo actividad, a excepción de la primera quincena de enero; adicionalmente, incursiones en dirección ecuatorial de sistemas frontales de latitud media modularon la actividad convectiva en la región occidental de la Amazonia. Durante el período de estudio, el flujo convergente de vapor de agua de nivel bajo derivado de los datos del NCEP presentó un patrón parcialmente consistente con los campos de lluvia del TRMM.

ABSTRACT

This paper analyzes the synoptic scale features of the upper and lower level tropospheric circulation over tropical South America during the first Atmospheric Mesoscale Campaign in the Wet Season (WETAMC) of the Large Scale Biosphere – Atmosphere Experiment in Amazonia (LBA). This campaign occurred in January

and February, 1999 and concomitantly with the validation of the Tropical Rainfall Measuring Mission (TRMM) satellite over Brazil. National Centers for Environmental Predictions (NCEP) grid point data were used to analyze the winds and its associated divergence fields and define the prevailing patterns of the tropospheric circulation in that region. TRMM images were used to depict the rain patterns. The results show at least four distinct patterns in the upper air winds fields during the WETAMC-TRMM/LBA, involving mainly the Bolivian anticyclonic circulation and cyclonic vortices in the vicinity of Northeast Brazil. The results also suggest that, in general, the convective activity over vast areas of South America is dynamically supported by upper level divergence. Two out of a total of six vortices were observed to have anomalous displacements into the Amazonia during the study period. At lower levels, the South Atlantic Convergence Zone (SACZ), except for the first half of January, was not active but equatorward incursions of midlatitude frontal systems disturbed the convective activy in the Southwestern Amazon basin. Besides, during the period of the study, the low-level moisture divergence as derived from NCEP data does not show convergence where the TRMM rain field clearly reveals the existence of precipitation areas.

Key words: Cyclonic vortices, TRMM, South Atlantic convergence zone, Bolivian High

1. Introduction

The first Atmospheric Mesoscale Campaign in the Wet Season (WETAMC) of the Large Scale Biosphere – Atmosphere Experiment in Amazonia (LBA) (Silva Dias *et al*., 2002) occurred in Rondonia, Brazil during the southern summer, from January to February, 1999. This season was chosen because typically it is characterized by a pronounced tropospheric circulation variability with great impact on the regional rainfall regimen. Rutledge *et al.* (2000) noticed that during the WETAMC, the development of the mesoscale convective systems (MCSs) occurred under two distinct meteorological regimens: monsoon and break. In the former case, low level westerly/ northwesterly winds prevailed with humidity relatively large and abundant precipitation; in the latter, the convective activity was under low-level easterly flow, with a much drier troposphere. In addition, Cifelli *et al*. (2002), suggest that the distinct wind regimens (easterly and westerly) observed in Rondonia during the WETAMC control the local rainfall and are associated with the displacements of frontal systems in Southeastern Brazil.

Several studies have shown that many of the large scale characteristics of the circulation over South America can be simulated using three dimensional and time varying tropical heat sources (Silva Dias *et al*., 1983; Gandu and Gesiler, 1991) as well as with a forcing due to the extratropical convection (Belassiano, 2000). Gandu and Silva Dias (1998) showed that during the austral summer both the convective activity over the western and central Pacific as well as over Africa have an impact on the high level tropospheric circulation and the subsidence patterns in the middle troposphere over South America and adjacent oceans. Thus, from the synoptic point of view, the tropospheric circulation over tropical South America and neighboring areas is more easily understood by considering the dynamics of the upper and lower troposphere separately. In this context the main features of the upper level circulation in this region are the interhemispheric bifurcation of the flow over the Eastern Pacific, the anticyclonic circulation known as the Bolivian High (BH) (Virji, 1981), the

upper level cyclonic vortices in the vicinity of Northeast Brazil (CVNE) (Kousky and Gan, 1981; Mishra *et al*., 2001), the troughs originated from the Southern Hemisphere mid-latitudes (TRs), the tropical troughs over the Northern and Southern Pacific Ocean and the troughs over the Northern Atlantic Ocean (Ramírez *et al*., 1999). On the other hand, at lower levels the outstanding features include the South Atlantic Convergence Zone (SACZ) (Kodama, 1992; Carvalho *et al*., 2002), the convective activity over the Amazonia (Greco *et al*., 1990) and the stable semi-arid climate of Northeast Brazil (Rao and Hada, 1999).

During the WETAMC-TRMM/LBA experiment the main scientific interest was on the mesoscale features of the regional circulation. As a consequence, there was a significant effort addressed to understanding the local interactions involving the biosphere/atmosphere, cloud dynamics and microphysics, TRMM-satellite precipitation radar and micrometeorology (e.g., Cifelli *et al*., 2002; Petersen and Rutledge, 2001). However, it was deemed that a diagnostic study of the most important synoptic scale features of the atmospheric circulation during the WETAMC-TRMM/LBA experiment would certainly be useful to acquire a better understanding of the acting mesoscale processes. Thus this work is concerned with the dominant synoptic aspects of the atmospheric circulation over tropical South America during that time period. Emphasis was given on the diagnosis of the upper and lower tropospheric winds and the analysis of the TRMM-derived rainfall fields.

2. Data and methodology

The variables used in this study were the daily air temperature (T), zonal (u) and meridional (v) wind components and specific humidity (q) obtained from the global model reanalysis project NCEP/NCAR (National Centers for Environmental Prediction/National Center for Atmospheric Research) (Kalnay *et al*., 1996). They have a $2.5^{o} \times 2.5^{o}$ lat – lon resolution and are given at 1000-, 925-, 850-, 700-, 500-, 250-, 200- and 100-hPa isobaric levels. The spatial domain extends from 15^{o}N to 4^{o}S and 95^{o}W to 15^{o}W and the studied period includes the months of January and February, for which monthly means (using data from 1978 to 1999) and daily analyses during the WETAMC–TRMM/LBA period were analyzed. The moisture flux and wind divergence were also examined. The first variable is given in spherical coordinates by

$$\nabla \cdot q\vec{V}_H = \frac{1}{a\cos\varphi}\frac{\partial qu}{\partial \lambda} + \frac{1}{a}\frac{\partial qv}{\partial \varphi}$$

where:

$\vec{V}_H$ is the wind, a is the Earth's mean radius, and λ and φ are the latitude and longitude, respectively.

The software GrADS – Grid Analysis and Display System (Doty, 1997) was used for processing and graphical visualization of the results. A script was also used to plot CVNE trajectories reading the daily lat-lon vortex center coordinates from an ASCII file with the GrADS "read" scripting command, and appropriate commands to analyze and plot the data over a map background.

The analyses of rainfall fields over South America were based on gridded daily rainfall data obtained using the "3B42-TRMM- Adjusted Merged-Infrared Precipitation" algorithm which calibrates VIRS (Visible and Infrared Sounder) infrared measurements with precipitation estimates given by TMI (TRMM Microwave Imager). The calibration parameters were then used to obtain a daily composition of IR data from the available meteorological geostationary satellites. The algorithm yields estimates of precipitation near the surface with a $1^{o} \times 1^{o}$ lat - lon resolution, within the tropical belt between 40^{o}N and 40^{o}S. Details of this methodology are described in Huffman *et al.* (1995) and in the User´s Guide, made available by the TRMM Data and Information System (TSDIS) at http://tsdis.gsfc.nasa.gov. The 3B42 data were obtained from NASA (National Aeronautics and Space Administration) via File Transfer Protocol (FTP), at the following address: http://daac.gsfc.nasa.gov/.

3. Results

Next a brief description of the climatological characteristics of the upper and lower levels tropospheric circulation over tropical South America during the first two months of the austral summer is presented. The dominant features are compared with those of January/February 1999, the period during which the WETAMC – TRMM / LBA experiment was carried out.

3.1. Upper level features

The upper level circulation in tropical South America in January (Fig. 1a) is governed by BH and CVNE. Strong divergent areas are observed in the Southeastern Atlantic Ocean, associated with the SACZ and along the Inter-Tropical Convergence Zone (ITCZ). The most pronounced areas of divergence over Brazil are induced by the BH/CVNE circulation system. Since the convective activity in these areas is strong (not shown), the divergence may be responsible for the organization of the rainfall in Amazonia and Central and Southeastern Brazil. Therefore, eventual displacements of the BH/CVNE system would imply shifts of the convective activity. Furthermore, the observed differences in the divergence fields over the continent and Southwestern Atlantic Ocean suggest that the SACZ dynamics may be modulated by distinct processes over these regions. On the other hand, during January 1999 (Fig. 1b), the 250 hPa flow in tropical South America showed a slightly different pattern. Instead of the typical anticyclonic circulation center and the associated downstream trough, one observes a pair of anticyclones and the CVNE. The anticyclonic circulation over western Bolivia is the BH and the other downstream anticyclonic circulation (AT) appears when BH extends eastward. Ramírez *et al*. (1999) suggest that this type of situation favors the inland displacement of CVNE and is associated with the presence of the SACZ or the passage of troughs in Southeastern Brazil. It becomes evident from the comparison between the climatological pattern and the January 1999 conditions (Fig. 1b) that most of the tropospheric circulation in South and Southeastern Brazil was under the influence of the AT, thus with anomalous characteristics. A closed circulation, instead of a trough, was the dominant feature over the Tropical Atlantic Ocean near NE, due to the high frequency of occurrence of vortices in that region.

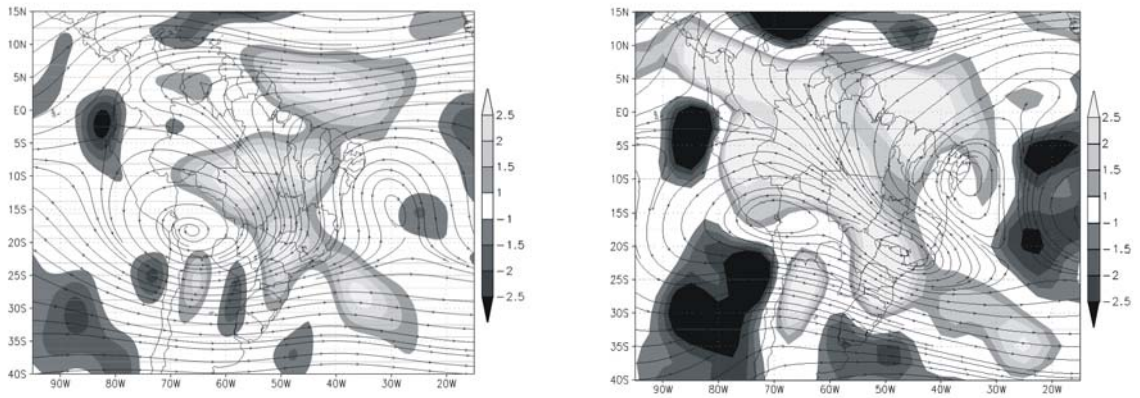

Fig. 1. Streamlines and horizontal divergence (1×10^{-6} s^{-1}) of the mean 250 hPa wind for (a) January, 1978 – 1999 and (b) January, 1999.

Except for a zone of weaker divergence along the SACZ, the mean upper tropospheric circulation in February, 1999 (Fig. 2a) is quite similar to that of the preceding month. On the other hand, during the WETAMC – TRMM/LBA (Fig. 2b) one can notice that the BH had shifted slightly southward and the trough near NE, not yet clearly defined, had a smaller meridional amplitude with a southeastward orientation. The observed divergence field suggests weak convective activity along the SACZ, but not along the ITCZ over the tropical Western Atlantic Ocean.

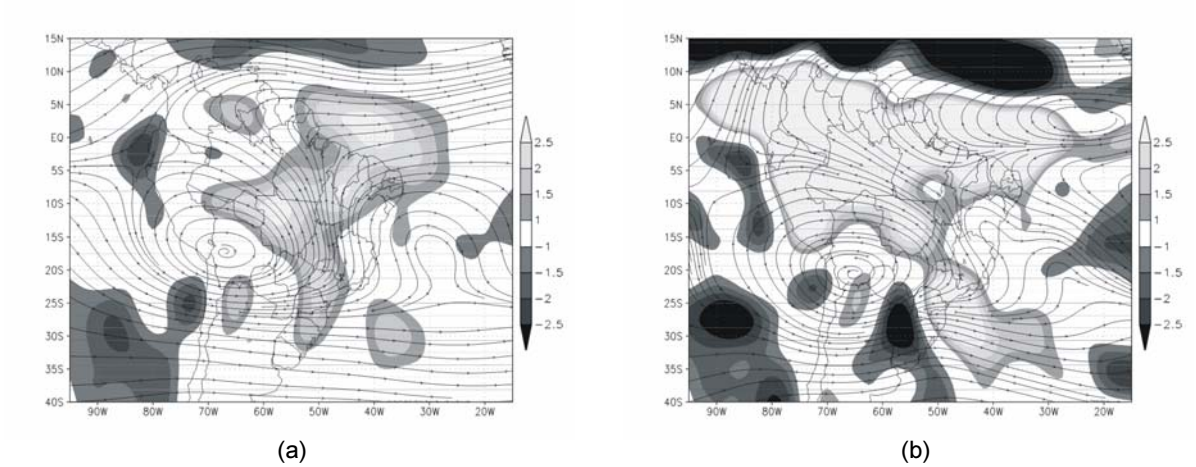

Fig. 2. As in Fig. 1, but for (a) February, 1978 – 1999 and (b) February, 1999.

3.2. Lower level features

The mean 850 hPa circulation over tropical South America during the austral summer is dominated by the trade winds at low latitudes and the subtropical South Atlantic Ocean High (SAH). Under this circumstance, the trade winds have an important role in advecting moisture from the tropical Atlantic Ocean into NE and Amazonia (Rao and Marques, 1984). This moisture feeds the convective activity over land. On the other hand, the northeasterly winds in the occidental sector of the SAH are important for establishing and maintaining the SACZ´s oceanic branch.

The mean 850 hPa water vapor flux divergence fields during January and February (Figs. 3a, 4a) show high values along the northern/northeastern coast of Brazil. Moisture convergence is also observed along portions of the SACZ, the slopes of the Andes in Southwestern Bolivia (topographic effect), western NE and over the Brazilian Amazonia. The main observed feature of the lower level circulation during WETAMC – TRMM/LBA (Figs. 3b, 4b) is the vast region of moisture convergence in the Amazonia and along the SACZ, although other centers were also observed to the west of NE and Central Amazonia. The 850 hPa moisture flux convergence was slightly pronounced, extending from the southern part of the Amazonia to the Southeastern Atlantic Ocean (due to the passage of frontal systems), despite the absence of SACZ events in February 1999.

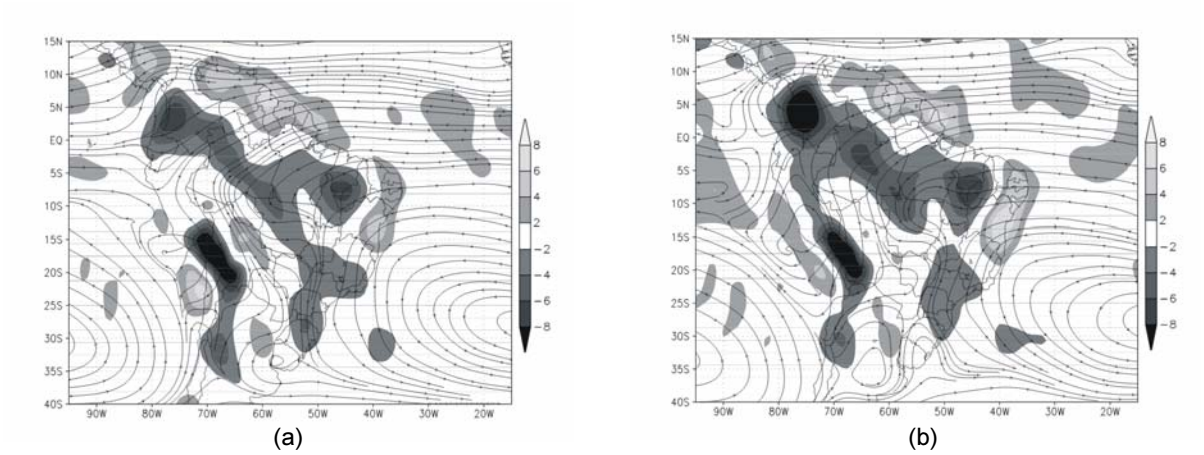

Fig. 3. Mean 850 hPa streamlines and horizontal moisture flux divergence ($1 \times 10^{-5} gKg^{-1}s^{-1}$) for (a) January, 1978 – 1999 and (b) January, 1999.

The moisture flux convergence patterns over Amazonia and Southeastern and Northern Brazil during January and February 1999 are partly consistent with the rainfall field retrieved from TRMM data (Figs. 5a-b). For several areas (e.g. the eastern slopes of the Andes Mountains near Southwestern Bolivia, ITCZ, the north/northeast Brazilian coast, western portions of NE Brazil and the Southwestern Atlantic Ocean) NCEP data do not show convergence where the satellites

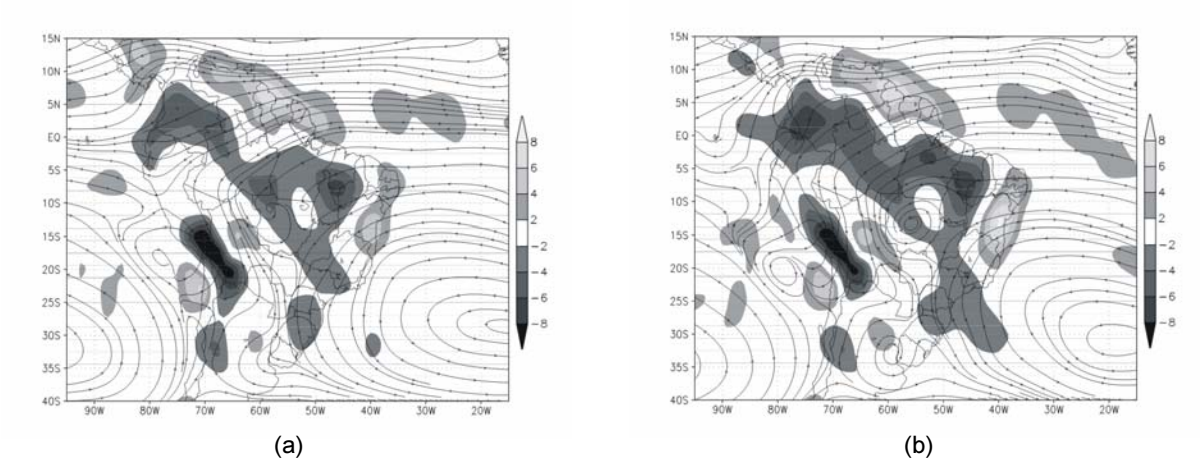

Fig. 4. As in Fig. 3, but for (a) February, 1978 – 1999 and (b) February, 1999.

indicates the existence of precipitating areas. It is likely that this disagreement may be associated with the model's space resolution, parametrization schemes and the representativeness of the assimilated data. It should be pointed out that the conventional meteorological network over tropical South America is quite sparse.

A Hovmöller diagram of the daily 3B42 TRMM rainfall data (Fig. 6), from Southern Amazonia to the Southwestern Atlantic Ocean (following SACZ axis), during January and February 1999

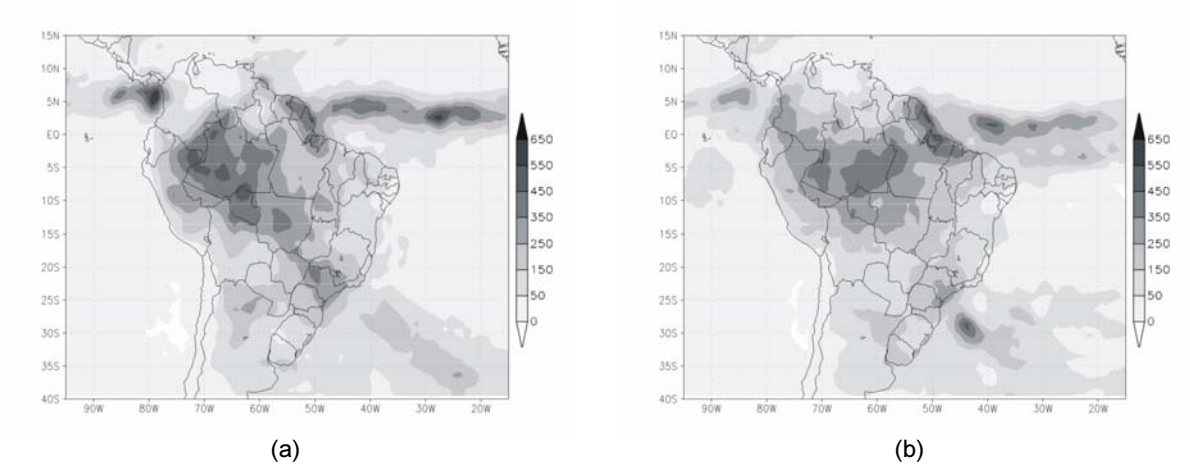

Fig. 5. 3B42 Rainfall (mm) retrieved from TRMM data for (a) January, 1999 and (b) February, 1999.

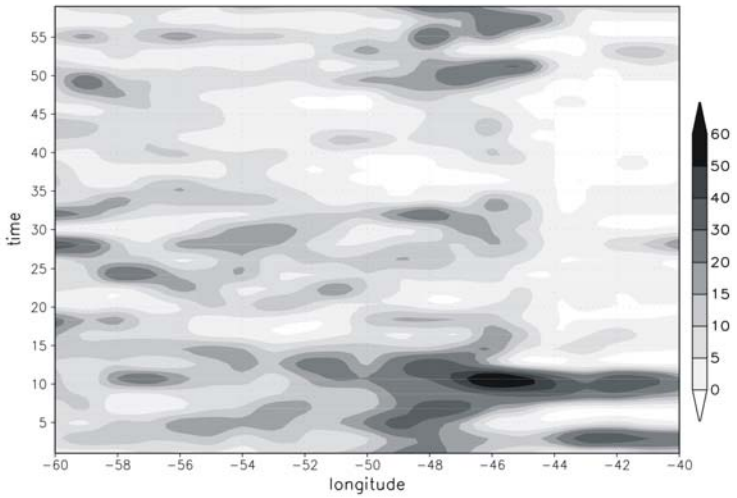

Fig. 6. Hovmöller diagram of the daily rainfall data (mm) derived from TRMM data, from Southern Amazonia (5˚ S, 60˚ W) to Southwestern Atlantic Ocean (-30˚ S, 30˚ W), during January 1st to February 28th, 1999.

reveals that: a) the SACZ was present only during the period of the 6th-18th of January when the rainfall was heavier (about 60 mm) between 44°W and 48°W, over São Paulo state and b) SACZ episodes were not observed in February although there were two situations of heavy rainfall due to the penetration of frontal systems (Feb. 18 and Feb. 26), along the coast of São Paulo state. In all these events, frontal displacements in Southeastern Brazil prompted rainfall in Rondonia and Southern Amazonia, in agreement with the findings of Rickenback *et al*. (2001), and Cifelli *et al*. (2001). As they suggested the large scale modulates the convective activity in Rondonia, so that low-level westerly (easterly) winds tend to yield larger (smaller) areas of weak (strong) precipitation.

3.3 Upper level circulation patterns during the WETAMC–TRMM/LBA

The upper level circulation during the WETAMC–TRMM/LBA was characterized by BH, CVNE, troughs and an anticyclonic system (AT) located between Southeastern Brazil and adjacent oceanic areas. The BH position was observed to be quite variable, oscillating between 90°W and 55°W. This displacement was associated with CVNEs moving inland, the formation of AT and equatorward incursion of middle latitude troughs (TRs). Six major events of CVNEs (Fig.7) were observed during the studied period, with a mean life time of approximately 6.9 days and most of them showing a vertical extension between 200 and 400 hPa.

The first vortex (V1) appeared on January 2nd, 1999 at approximately 12°S and 30°W, over the NE eastern coast and gradually shifted toward the Amazonia where by January 13th it had dissipated. During this movement, its associated subsidence and sensible heat flux were responsible for an evident suppression of the convective activity over the Amazonia. Concomitantly, the BH had also

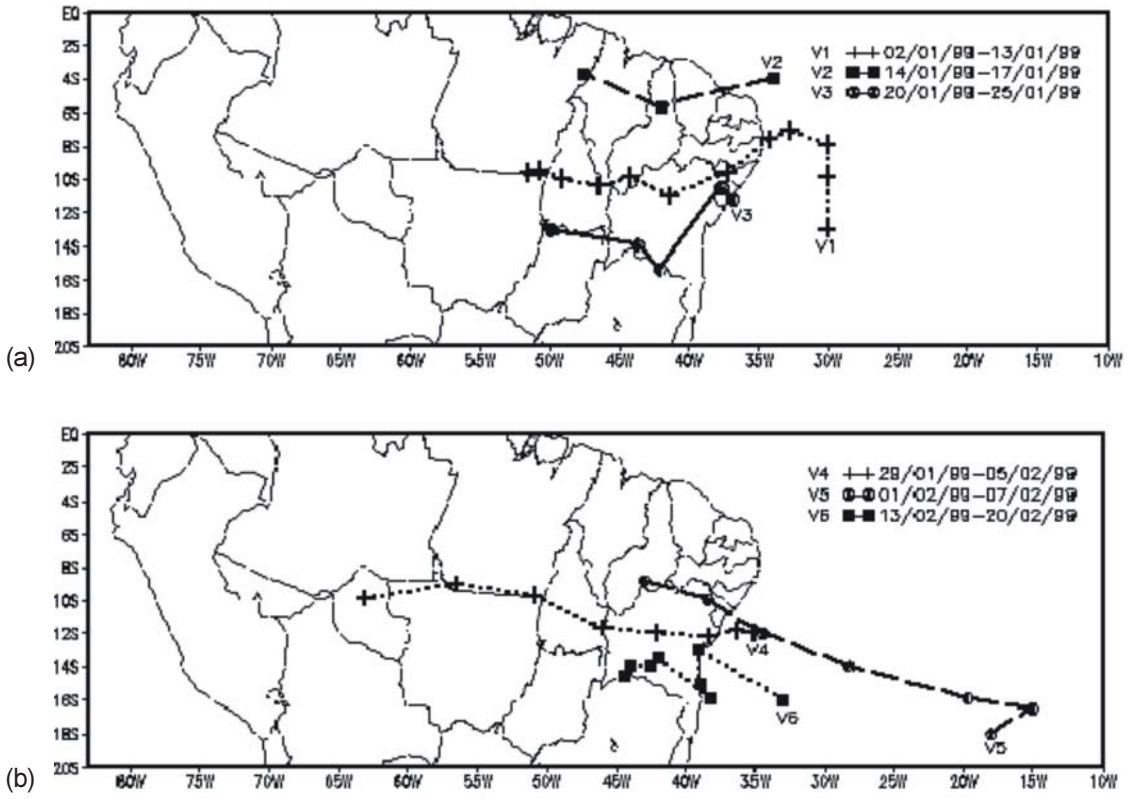

Fig. 7. Trajectories of the CVNEs during the WETAMA – TRMM/LBA Experiment for (a) January, 1999 and b) February, 1999.

shifted westward reaching the Southeastern Pacific Ocean (Southwestern Perú). The displacement of V1 into Amazonia may indeed be regarded as an anomalous situation, for just a few percent of the vortices originating in the NE region move inland (Ramírez *et al*., 1999).

The second vortex (V2) had a shorter life time (3 days); it originated between the coast of Rio Grande do Norte state and the Equator, on January 14th, 1999. It also moved westward reaching Northeastern Pará state where it dissipated on the 17th. The origin of V2 was associated with a southwestern amplification of a ridge, in its turn, to an anticyclonic circulation over Northwestern Africa. The genesis of vortices over the NE, linked to this kind of circulation was studied by Paixão and Gandu (2000). During the active stage of V2, the BH was found in the southwest of Perú, over the Pacific Ocean, and connected to the anticyclonic circulation of the Southwestern Atlantic Ocean. The atmospheric circulation pattern during this period affected the convective activity over tropical Brazil.

The third vortex (V3), contrasting to the usual genesis, originated over the continent, 13°S, 49.5°W (north of Goiás state) on January 20th, 1999 and shifted eastward reaching the Sergipe state (eastern coast of NE) by January 25th, 1999 where it dissipated. During this period, the BH moved eastward, toward Bolivia and the AT position was over the Southern Paraná state (Southern Brazil).

The fourth vortex (V4) originated over the eastern coast of NE, approximately 12°S on January 29th, 1999. This vortex had a westward displacement, reaching the northern part of Rondonia state, where it dissipated. At the same time the BH was between Southern Paraguay and Northern Argentina, thus further south of its climatogical position. This is a situation that potentially could decrease rainfall along the trajectory of the vortex center.

The fifth vortex (V5) originated over the Atlantic Ocean (18°S, 20°W) on February 1st, 1999. This vortex also moved westward and dissipated seven days later over the Southern Piaui state (northern NE). The BH was located during this event over Northern Argentina, further south than its climatological position. Finally, the sixth vortex (V6) appeared at the eastern side of Southern Bahia state on February 13th, 1999, due to the expansion of a trough to the east of the BH. This vortex had a westward displacement, dissipating over the northern part of Minas Gerais state (Southeastern Brazil) nine days later.

An analysis of the prevailing upper circulation patterns over tropical South America during the WETAMC–TRMM/LBA period is presented next. The observed four main patterns are quite distinct, regarding the relative positons of the BH and CVNEs.

3.3.1 BH/CVNE circulation pattern

The BH/CVNE circulation pattern dominated the first days of the first, fourth and sixth events of CVNE. Under this kind of situation, the vortex geneses is due to the amplification of an upper level ridge associated with equatorward-moving cold fronts over South America (Kousky and Gan, 1981). The BH is well defined and is situated over the Southwestern Amazonia near Bolivia, and the CVNEs are found over the Southwestern Atlantic Ocean (Fig. 8). By the beginning of January 1999, the rainfall associated to the BH/CVNE circulation extended from the Southern Amazonia to the Southwestern Atlantic Ocean due to a cold front in the region. The highest daily rainfall values (30 to 40 mm) occurred in Southeastern Brazil where the cold front advanced into the states of Minas Gerais and Rio de Janeiro (Fig. 9). Fair weather was observed in the NE when the CVNE was still located over the ocean. As mentioned before, the rainfall at this time of the year seems to be associated with the presence of upper level divergence in the transition region between the two opposite circulation systems: the BH and the CVNE. Therefore, eventual oscillations of the BH/CVNE system (not shown) are accompanied by northeastward/southeastward displacements of frontal systems in Southeastern and Southern Brazil.

3.3.2 BH /CVNE/AT circulation pattern

This type of pattern, identified by Ramírez *et al*. (1999), is more evident when the CVNE is in its

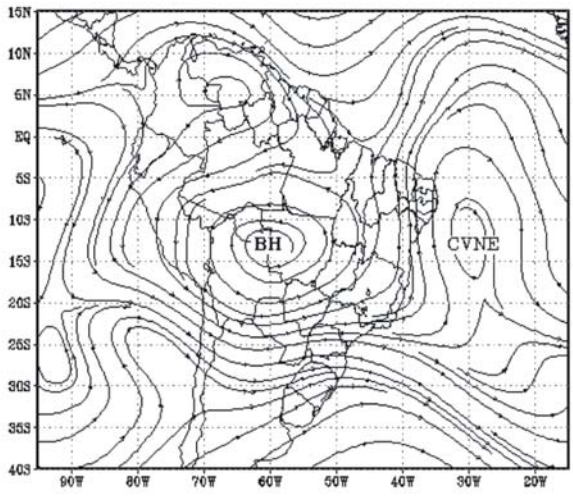

Fig.8. 250 hPa streamlines for January 2nd, 1999, associated to the BH/CVNE circulation pattern.

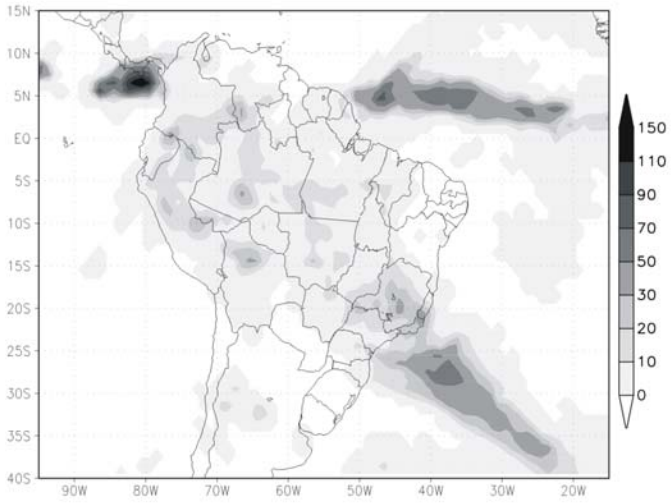

Fig. 9. 3B42 rainfall (mm) retrieved from TRMM data, associated to the BH/CVNE circulation pattern for January 2nd, 1999.

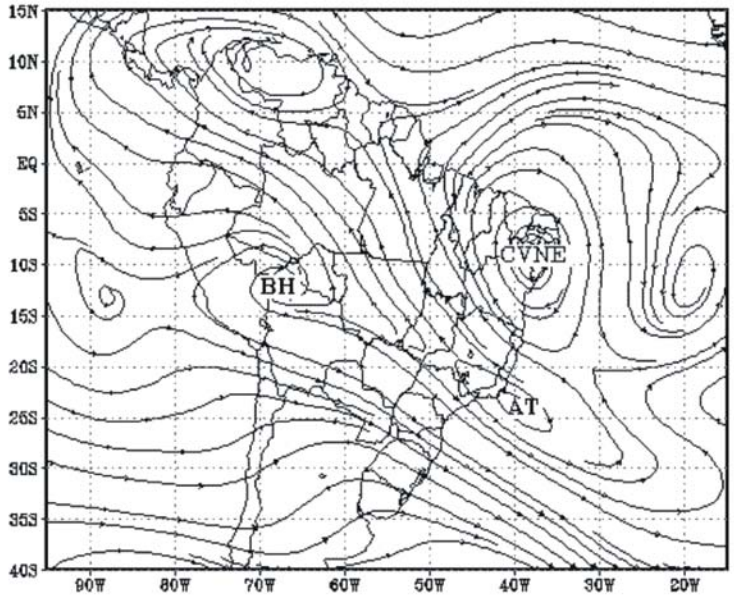

Fig.10. 250 hPa streamlines for January 7th, 1999, associated to the BH/CVNE/AT circulation pattern.

intensification stage and during its displacement inland. In this situation the BH generally acquires a northwest/southeast orientation as the CVNE initiates its movement. The BH elongates over Southeastern Brazil as the CVNE moves inland (Fig. 10). Depending on the intensification of the ridge, the BH may split into two parts, with the eastern flank forming a new anticyclonic center (AT) over Southeastern Brazil and adjacent oceanic areas.

The amplification of the ridge along the southeastern side of the BH for the V1 event mentioned, occurred with the arrival of a frontal system from Argentina, which remained stationary for five days (Jan. 6–10) and established the SACZ. As a consequence, warmer air advection in the lower levels contributed to the intensification of the upper level ridge, creating favorable conditions for enhancing the convection in Northern São Paulo state and Western Amazonia (Fig. 11). During this period, the ridge amplification favored the formation of an AT to the south of the CVNE, thus establishing the circulation pattern involving the BH (with a westward shift toward the Southern Pacific Ocean), the CVNE (moving into the continent) and the AT. Although the SACZ is a dominant feature in the lower levels of the summer circulation over Brazil, only one SACZ episode was observed during the January–February 1999 period.

Related to the BH/CVNE/AT pattern, it was observed that despite the existence of a vortex, a new one may form to the northeast of the AT, as exemplified by V2, V4 and V6. Ramírez *et al*. (1999) performed a climatological study on the formation mechanisms of tropical vortices and

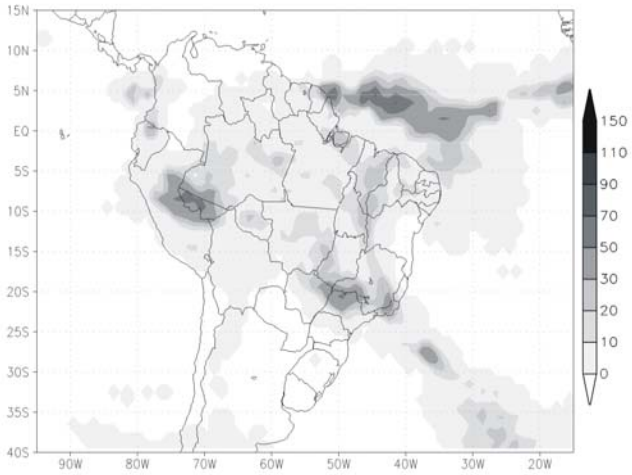

Fig. 11. 3B42 rainfall (mm) retrieved from TRMM data, associated to the BH/CVNE circulation pattern, for January 7th, 1999.

concluded that 27 % of the CVNEs are associated with the occurrence of ATs. During this type of situation, the release of latent heat from stationary frontal systems or the SACZ would maintain the AT and the associated upper level region of divergence.

Whenever there is an intensification of the southeastern sector of the BH over Southeastern Brazil and adjacent oceanic areas, the spatial rainfall pattern resembles a convective cloud band with an NW–SE orientation to the west of the ridge and a mid-latitude trough in the upper levels (Fig. 9). This rainfall band is generally associated with a frontal system. Once the cloudiness of the western and northern sectors of the CVNE reaches the NE coast, it interacts with the convective activity associated with the BH and frontal systems, frequently forming a Y pattern of cloudiness (Ferreira *et al*., 2001). The Y pattern follows the CVNE during its inland displacement.

3.3.3 BH/AT circulation pattern

The establishment of the BH/AT pattern, which lasts a few days, is generally observed after the dissipation of a CVNE over the central continent. The observed circulation between Jan. 18–19 (Fig. 12) is a good example of this type of situation, when the BH moves westward off the Peruvian coast and the AT is found over the Southwestern Atlantic Ocean near Southeastern Brazil. In addition, a trough forms between the two anticyclonic circulations over Argentina, favoring the convection in Southeastern Paraguay. In this case, the prevailing rainfall pattern consists of a convective band to the southwest of the AT and stratiform rainfall over vast areas in the Amazonia (Fig. 13).

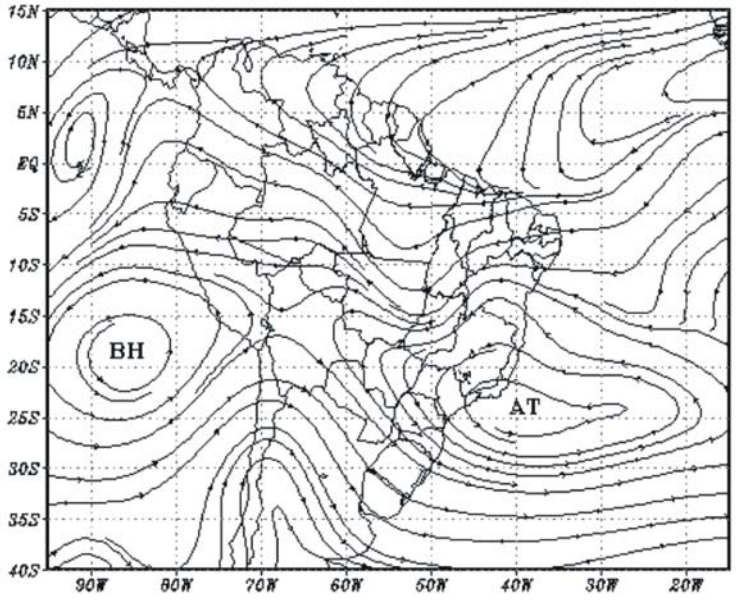

Fig.12. 250 hPa streamlines for January 18th, 1999, associated to the BH/AT circulation pattern.

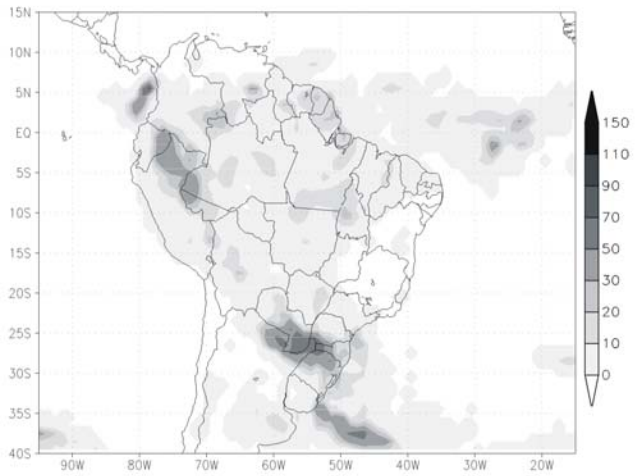

Fig. 13. 3B42 rainfall (mm) retrieved from TRMM data , associated to the BH/AT circulation pattern, for January 18th, 1999.

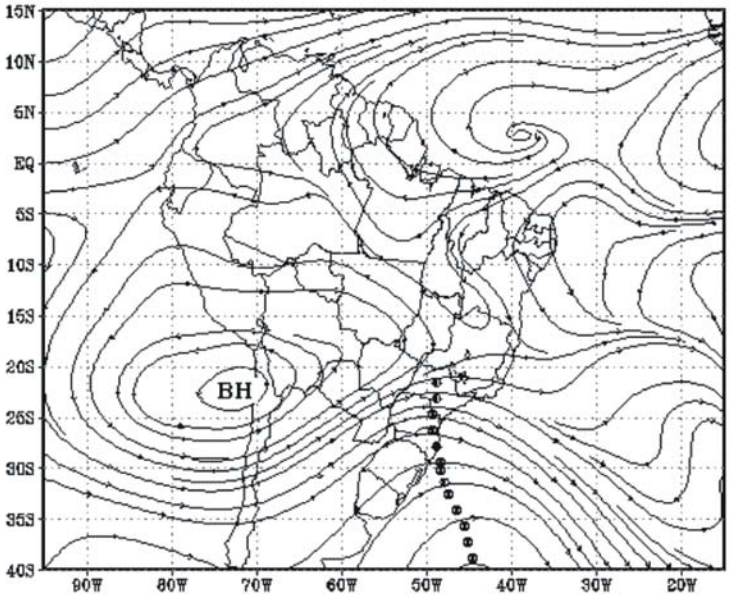

Fig.14. 250 hPa streamlines for January 12th, 1999, associated to the BH/TR circulation pattern.

3.3.4 BH/TR circulation pattern

Two episodes involving BH and TR were observed during the WETAMC-TRMM/LBA experiment. The first one occurred between Feb. 11 – 12 when the BH showed an almost symmetric configuration extending zonally as far as Goiás state (central Brazil), with its core centered near Northern Chile (Fig.14). A pronounced mid-latitude trough stretching from Northern São Paulo state to the Southwestern Atlantic Ocean (see marked line, Fig 14), was associated to a band of moderate rainfall produced by a frontal system (Fig. 15). Under this situation, the CVNE is not present and the frontal system is free to move northeastward. Similarly, during the second episode (Feb. 23 – 28) the BH was over Northern Chile, favoring the penetration of two mid-latitude troughs in Southern Brazil (not shown). As mentioned earlier, this pattern synchronizes the displacements of the rainfall band northeastward in Southeastern Brazil and southwestward in Amazonia. In other words, by the time it reaches Southeastern Brazil, the frontal system interacts with the convection in Amazonia, organizing and making it shift northeastward. This feature also favors the formation of troughs with a "NW/SE" inclination over the Atlantic Ocean, near the eastern coast of the NE and the formation of AT in central Western Brazil.

4. Concluding remarks

This study analyzes the synoptic scale features of the upper and lower levels tropical circulation

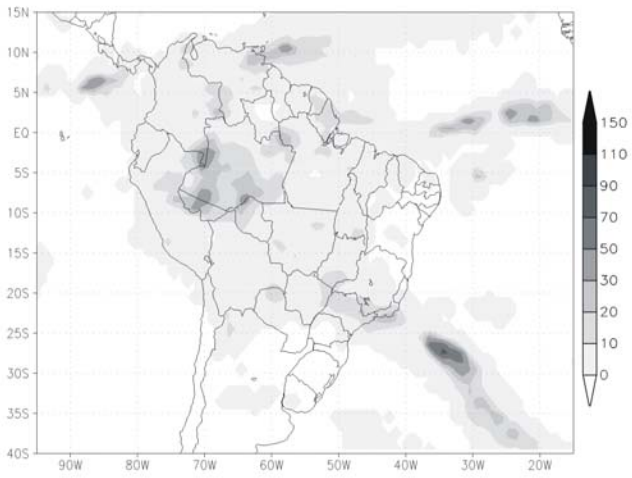

Fig. 15. 3B42 rainfall (mm) retrieved from TRMM data, associated to the BH/TR circulation pattern, for January 12th, 1999.

over South America during the first Atmospheric Mesoscale Campaign in the Wet Season (WETAMC) of the Large Scale Biosphere – Atmosphere Experiment in Amazonia (LBA). The analyses were carried out using the National Centers for Environmental Predictions (NCEP) data and rainfall fields derived from TRMM (Tropical Rainfall Measuring Mission) data. During the studied period (January and February 1999) the tropospheric circulation in the region showed distinct features from the climatological pattern. At least four distinct flow patterns were identified in the upper troposphere, mainly related to the Bolivian High (BH) and cyclonic vortices in the vicinity of Northeast Brazil (CVNEs). In two observed events, CVNEs moved from the NE coast into Amazonia and their associated subsidence and changes in the circulation pattern may have impaired the precipitation in some parts of Amazonia.

It was also observed that from the synoptic point of view the instability in the region is dynamically supported by upper level divergence in the transition zone of the Bolivian anticyclone (BH) and the cyclonic circulation in the vicinity of NE Brazil (CVNE) in the upper troposphere. Kousky and Gan (1981) suggested that the convective activity associated with CVNEs depends on thermal direct circulation, the position of the vortex and the direction of their movement. In the present study, it is suggested that the convective activity depend on the interaction between the BH/CVNE circulations and not only on CVNE dynamics. At lower levels moisture convergence derived from NCEP data coincides only partially with the rain areas detected by TRMM satellites. Also, significant interaction involving frontal systems and convective activity in Southwestern Amazonia was evident.

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