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Analysis of the Troposphere in the Congo Basin from the Radiosonde Investigations at Ouesso

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ABSTRACT

Our study was realized from the thermodynamics and dynamics parameters obtained from the radiosondes at Ouesso station (northern Congo). In the tour of 100 hPa, at the top of the troposphere of the cuttings they are observed with East winds and Northeast, are responsible for the appearance of a two tropopauses; this phenomenon remains however short-lived. Until approximately 300 hPa, the decrease of the temperature is weak with a temperature and pressure gradient superior to 5°C km^{-1}, which prove that the equatorial atmosphere remains relatively warm even in height; the humidity of this atmosphere remains high, superior to 60% up to 600 hPa.

Key words: Congo basin, tropospheric dynamics, radiosonde investigations, double tropopauses, toposphere

INTRODUCTION

The Congo basin lies between 10°N and 30°S latitude and 10 and 30°E longitude and is part of the Atlantic Equatorial Africa (AEA), which regroups the Central Africa republic, republic of Congo, republic of Gabon, republic of Cameroon and the Democratic republic of Congo (Nganga and Samba, 2011). The Congo basin and the Amazonia play an important role of the dynamics towards the climate change. The presence of the Mayombe (800 m) and Nambemba (1000 m) mountains in the Congo republic do not prevent the penetration in the Congo basin outside influences into the low troposphere (Nganga and Samba, 2011). Two types of ecosystems exist in the AEA: rain forest and savannah, but the rain forest occupies the largest portion. In AEA, the dominant climate is the equatorial regime. All the year the Congo basin constitutes a shallow low-pressure area. Rainfall is associated with the south-western pseudo-monsoon winds, which come from the Atlantic Ocean and the south-eastern winds flowing from the Indian Ocean (Samba and Nganga, 2012).

The Congo basin forest at the global scale plays a major role on the exchange states of surface forest atmosphere, even at regional or global climate. These exchanges forest atmosphere are determining in the refill of humidity of the air masses and also in the sequestration of the Carbon. The Congo basin remains a very complex climatic zone in terms of atmospheric dynamics, because it is under the influence of the disturbances of lines of grains or waves, trade winds maritime Atlantic Ocean or pseudo-monsoon and sometimes Indian trade winds. This climatic situation and with its atmospheric profile or its unknown geopotential, the radiometric analysis gives useful information in the understanding of some rainy mechanisms. On average, the low tropospheric layers in the Congo basin are characterized, by a barometric marsh with the zonal and meridian invalid constituents of winds on the ground as described by Samba and Mpounza (2005). Although, Leroux (1975, 1980) and Suchel (1988) found that the Congo basin still require to be studied for better understanding; because it misses so much information in the analysis of the profile of the temperatures, the wind speed and the direction. It's the same on the tropopause. We know that the troposphere remains a very important layer of the atmosphere in the understanding of rainy mechanisms. The atmospheric dynamics at the level of this low layer determines the track to the ground of the Inter Tropical Convergence Zone (ITCZ). Many authors pointed out the existence of several tropopauses in the high troposphere (Bischoff *et al.*, 2007; Stohl *et al.*, 2003; Satyamurty *et al.*, 2002; Randel *et al.*, 2007; Garreaud, 2000; Pan *et al.*, 2004; Spenger *et al.*, 2003; Varotsos *et al.*, 2004; Fu *et al.*, 2006; Leroy *et al.*, 2006; Castanheira and Gimeno, 2011).

The presence of multiple stable layers and multiple tropopauses in upper troposphere/low stratosphere region has been known since the advent of upper air soundings 'e.g., Bjerknes and Palmen (1937), Kochanski (1955), Shapiro (1978) and Keyser and Shapiro (1986). These studies show that the presence of double tropopauses has been documented; the double tropopauses phenomenon has been discussed by Randel *et al.* (2007) and Wang and Polvani (2011). According to these authors, the double tropopauses exist in all seasons and at all longitudes.

The purpose of this study is to analyze profiles of radiosonde investigation in Ouesso station. It is also to compare the state of the troposphere in the rainy and dry days. For rainy days, the analysis related to several cases: troposphere after the rain, before the rain and during the rain. Certain days were analyzed because of their exceptional rain. We also studied the dynamic of the tropopause.

MATERIALS AND METHODS

We used data coming from the Congo National Meteorological services. Data used in this study include daily station radiosonde and rainfall in Ouesso (1°37'N and 16°3'E). From the daily data of radiosonde investigation, we have access to the pressure, the wind (speed, component zonal and meridian line), the relative humidity of the air and the temperatures. These data was obtained from the radiosonde recording in Ouesso by ASECNA (Agence pour la Securité et la Navigation Aérienne). We used the raw values over the period 2001-2005. Radiosondes investigations were often made at 10 UTC.

Rainfall data used in this study consisted of daily rainfall records from two stations distributed throughout the Congo basin within the period 2001 to 2005. Daily rainfall dataset has been developed by the Centre de Recherches et d'études en environnement(CR2E) at the Marien Ngouabi University (Brazzaville-Congo). It was about the characteristics of the daily precipitation: the times of the beginning and the end and the quantity of rainfall. The daily rainfall records were used to compute seasonal records for the standard seasons (summer, winter, autumn and spring). We were able to compare two marked astronomical seasons: the season DJF (summer southern, winter boreal) and JJA (summer boreal, winter austral) on the dynamics of the troposphere. The influences of the equatorial forest of the ITCZ and its marsh barometric were examined.

CLIMATIC CHARACTERISTICS

Figure 1 presents the organization of the precipitation at the Ouesso station. The main equatorial regime of the precipitation (data here in normalized values) draws the main part of the seasonal regime. The December/January/February (DJF) season is characterized by low rainfalls with 220 mm. This season corresponds to the small rainy season. March/April/May (MAM) is the first long rainy season of the year with an average of 460 mm of the rainfalls. June/July/August (JJA) marks a recession of the rainfall with a seasonal average of 380 mm. At the end, September/October/November (SON) corresponds to the second long rainy season of the year with 640 mm. In fact, the Ouesso station is a typical equatorial climatic area.

RESULTS AND DISCUSSION

Troposphere characteristics: Figure 2 presents the tropospheric profiles of a day in Ouesso. The profile of temperature (Fig. 2a) shows the evidence of three inversions that clearly appear at 650, 600 and 480 hPa. The air mass in contact with the surface of the ground undergoes a reheating of the base which pulls a convective instability and could justify the first inversion which appears on the curve of state. This inversion is responsible for the spreading of clouds cumulus/stratocumulus by blocking their vertical development; the curve of humidity (Fig. 2b) confirms their presence, around 80% of humidity at 900 hPa. Approximately at this altitude, a cloudiness of 4/8 is observed. The second inversion which is situated around 400 hPa (Fig. 2a) is responsible for the spreading clouds: altocumulus and stratocumulus by blocking their vertical development. The presence of these clouds is confirmed by the curve of humidity which borders 60% until to 400 hPa (Fig. 2b). The dominant winds in the low layers (subordinates in 800 hPa) are SW to NW (Fig. 2d) with speed of wind ranging 5 m sec^{-1}. While between 800 and 100 hPa the dominant winds are from the East. At the level of 100 hPa, of the tropopause we notice the presence

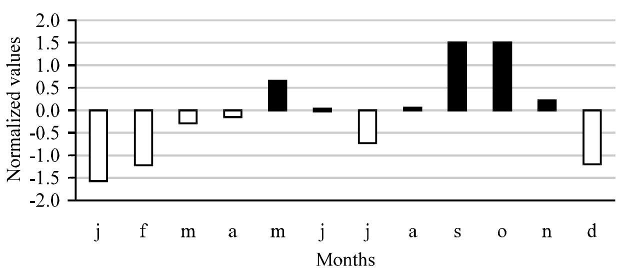

Fig. 1: Average monthly rainfall at Ouesso expressed in normalized anomalies

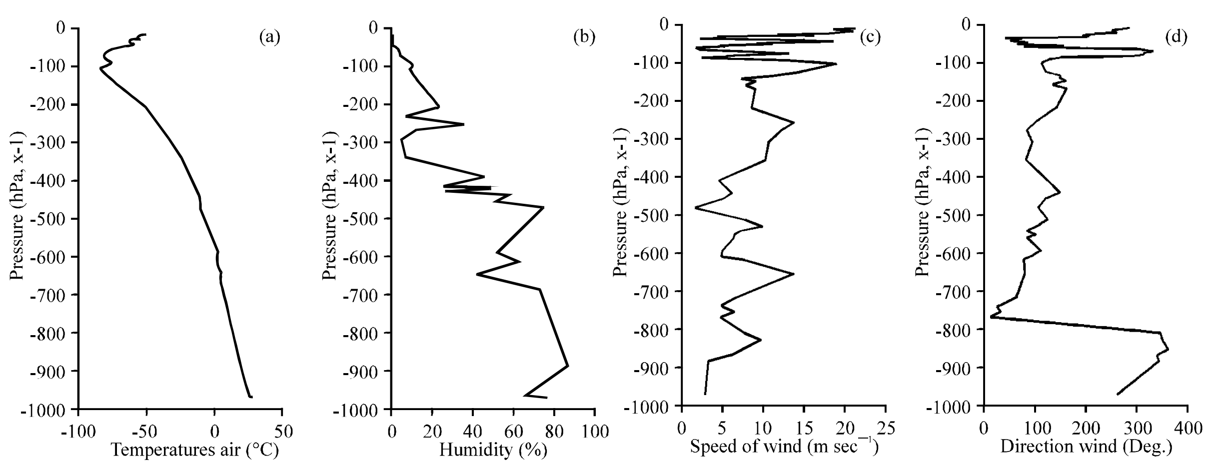

Fig. 2(a-d): Profiles verticals atmospheric, (a) Temperatures, (b) Humidity, (c) Wind speed and (d) Wind direction on January 23, 2002 (not for rainy day) of winds NW. The superimposing of the two air masses of different origin creates around 100 hPa of two tropopauses. In the first tropopause, the wind has 18 m sec^{-1} of average speed; the second (Fig. 2c) is from the North with 10 m sec^{-1} (Fig. 2d) average wind.

The profiles of Fig. 3a-d are representative of the tropospheric atmosphere before the rain. Figure 3a which is the profile of temperature shows low pressure gradient with an inversion between 500 and 400 hPa. The air mass in contact with the surface of the ground undergoes a reheating of the base which pulls a convective instability. This inversion is responsible for the spreading of clouds cumulus/stratocumulus by blocking their vertical development, the curve of humidity (Fig. 3b) confirms their presence, approximately 80% of humidity of the ground at 500 hPa. This humidity remains superior to 60% up to 450 hPa before the fall at least 20% of 350 at 100 hPa. Winds remain lower in 10 m sec^{-1} of the ground up to 5500 hPa. Winds direction is SW between 1000 and 800 hPa and of 700 at 100 hPa (Fig. 3d).

The profile of temperature (Fig. 4a) shows the evidence of the instability, the pressure gradient being superior to 5°C km^{-1}; this instability is more visible between 400 and 180 hPa than between

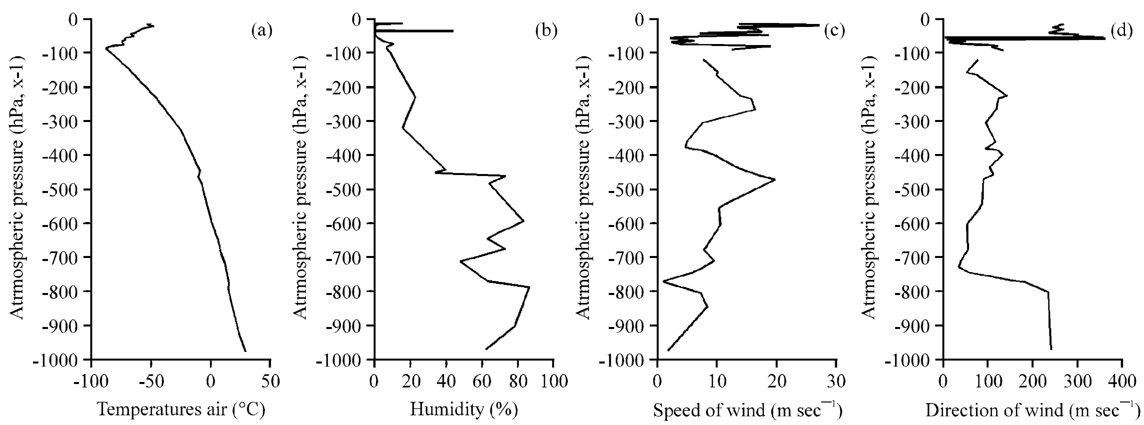

Fig. 3(a-d): Profiles verticals atmospheric, (a) Temperatures, (b) Humidity, (c) Wind speed and (d) Wind direction on March 18, 2002 (before rainy day)

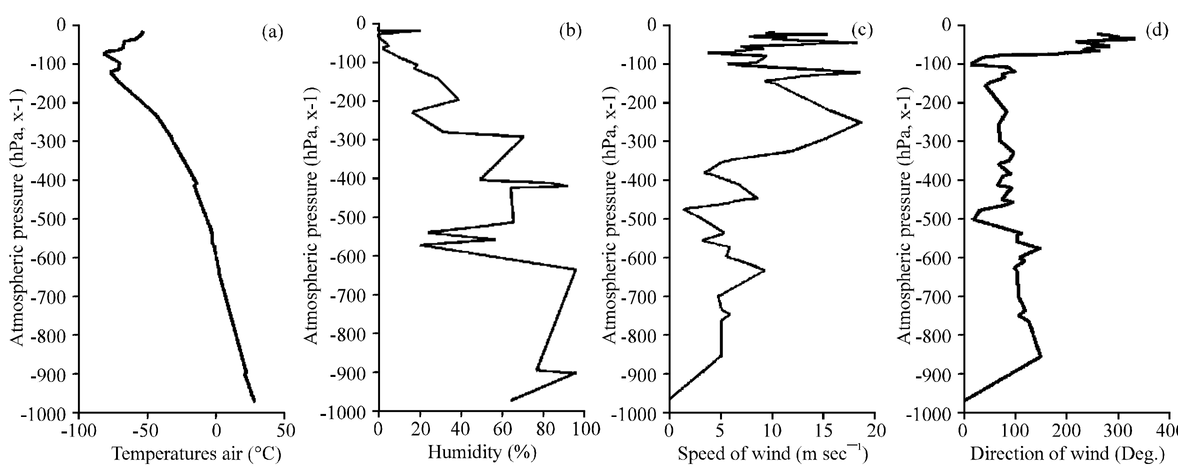

Fig. 4(a-d): Profiles verticals atmospheric, (a) Temperatures, (b) Humidity, (c) Wind speed and (d) Wind direction on June 6, 2002 (during rainy day)

900 and 400 hPa. Two inversions appear clearly at 900 and 400 hPa. The air mass in contact with the surface of the ground undergoes a reheating of the base which pulls a convective instability and could justify the first inversion which appears on the curve of state. This inversion is responsible for the spreading of clouds cumulus/stratocumulus by blocking their vertical development, the curve of humidity (Fig. 4b) confirms their presence, approximately 80% of humidity in 900 hPa. At approximately this height, a cloudiness of 4/8 is observed. The second inversion which is situated around 400 hPa (Fig. 4a) is responsible for the spreading of clouds altocumulus and stratocumulus) by blocking their vertical development. The presence of these clouds is confirmed by the curve of humidity which borders the 80% in 400 hPa (Fig. 4b) and a strong cloudiness of 7/8. The condensation which participates in forming of these clouds comes along with liberation of energy. The profile of temperature creates at around 100 hPa two tropopauses (Fig. 4a). It is due to the superimposing of two air masses of different origins. In the first tropopause, the wind goes to the East (Fig. 4b) measuring 18 m sec^{-1} (Fig. 4a); the second (cf. Fig. 4b), goes to the North with a weaker wind measuring of 10 m sec^{-1} (Fig. 4a).

The profiles of Fig. 5 symbolize when the rain proceeds the hour of the radiosonde 10 UTC. The speed of the profile of the temperatures (Fig. 5a) puts in evidence of instability on the ground accompanied with average winds of 10 m sec^{-1} (Fig. 5c) in the South to SW direction (Fig. 5d). The curve of humidity shows a rate of more than 60% until 500 hPa (Fig. 5b).

The profiles of Fig. 6a-d, like Fig. 2 and 4 point out the presence of two tropopauses associated with the superimposing of two air masses of different origins. This phenomenon appears in DJF and JJA seasons. It does not appear in MAM and SON seasons.

Generally, in the low troposphere the wind speed s are weak and exceed 10 m sec^{-1}, their directions do not vary fundamentally, the SW winds dominate in the low troposphere and the winds are scare the high troposphere. The profiles of the troposphere are characterized by a slight decrease of temperatures; this is the evidence that the equatorial atmosphere zone remains relatively warm even in the altitude. These profiles of temperatures frequently present enough inversions of temperatures that show the instability within the troposphere. The peak of the troposphere or the tropopause is located on average at 70 hPa in Ouesso. At the level of tropopause we can register segments which mark a double tropopause. Although the presence of multiple stable

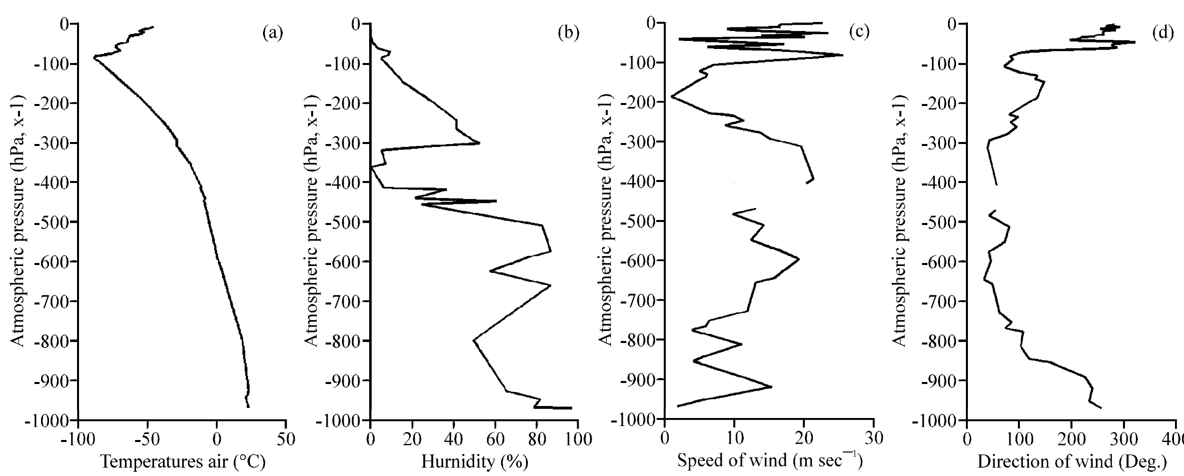

Fig. 5(a-d): Profiles verticals atmospheric, (a) Temperatures, (b) Humidity, (c) Wind speed and (d) Wind direction on April 10, 2002 (after rainy day)

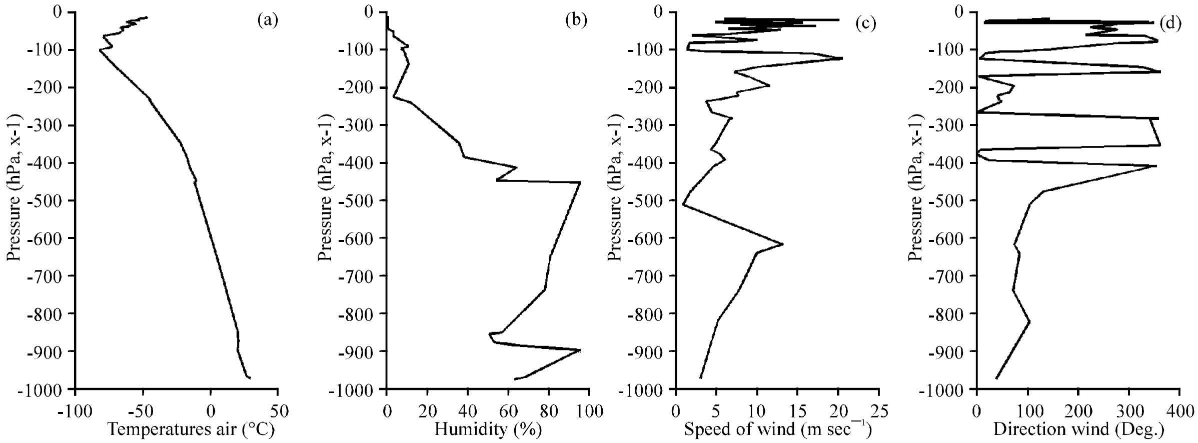

Fig. 6(a-d): Profiles verticals atmospheric, (a) Temperatures, (b) Humidity, (c) Wind speed and (d) Wind direction on October 19, 2002 for not rainy

layers and Multiple Tropopauses (MTs) in the upper troposphere/lower stratosphere region has been known since the advent of upper air soundings (Bjerknes and Palmen, 1937; Kochanski, 1955), their synoptic structure was studied systematically during the 1970's using research aircraft observations (Shapiro, 1978; Keyser and Shapiro, 1986). It is the first time we pointed out this phenomenon in the AEA, particularly in the Congo basin. Randel *et al.* (2007) linked the presence of the double tropopauses to a subtropical jet, that shows a strong seasonal variation over NH mid latitudes.

The presence of double and multi tropopauses in the troposphere in the tropics are well documented (Pan *et al.*, 2009; Wang and Polvani, 2011), it can be explained by the presence of clouds. Some authors such as Noel and Haeffelin (2007) suggested that the occurrence of intertropopause cirrus clouds is correlated with the frequency of multiple tropopauses.

The atmosphere, hanging before and after the rain, marks the dynamics of the balance of energy in this wet equatorial forester zone. The directions of the wind mark the climatic complexity in term of atmospheric traffic of this zone of the Congo basin. Until 700 hPa the dominant winds are SW. These winds seem to be a penetration of the Atlantic maritime winds or the pseudo-monsoon (Samba and Mpounza, 2005). Above is an East wind or disturbances of 500 hPa. In Ouesso exists a wind of NE comparable to the north winds (Harmattan). The emergence in rainy days of a NW wind at 300 hPa is a particular situation. It seems to be a situation of winds diverted eastward and which changes direction. At the level of the Troposphere the rate of humidity remains important in the low layers of the troposphere (subordinate in 600 hPa). The humidity abounds in the first level especially before the rain and the same after the rain. The relative humidity of the air is very high, often superior to 70%. With a thermometer which rises around 20°C or beyond, the report of saturating mixture can be considerable.

Tropopause fluctuation: The instability of the temperatures in the tropopause signs a big convective activity in this zone (Fig. 7a,b). The temperature trends of the tropopause shows a seasonal evolution in this zone of the atmosphere. This seasonal evolution was also observed by Randel *et al.* (2007) over NH mid latitudes.

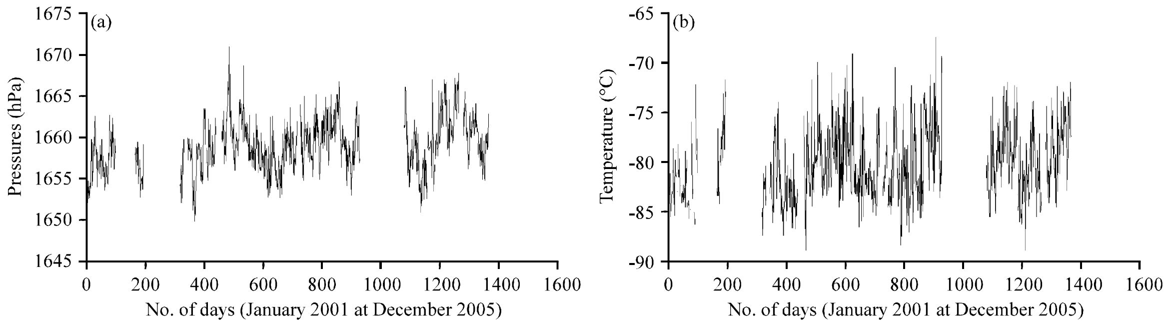

Fig. 7(a-b): Evolution of temperatures in °C (a) Pressure in hPa at Tropaupose and (b) Y axis's T or P° and X axis's number of days 2002-2005

CONCLUSION

The main goal of this study was to analyze the atmospheric dynamics in Ouesso, from the characteristics of pressure, winds, temperatures and humidity. This scenario integrates rainy and dry days. The various types of profiles, temperature, relative humidity and wind point out the seasonal cycle, in particular they point out the presence of two tropopauses associated with superimposing of two masses of different origins; this phenomenon is seasonal. All this shows that the Congo basin has an atmospheric layer filled with humidity especially in the low layers of the troposphere. It is the first condition to generate the condensation. The abundant steam (vapor) contained in the air of the Congo basin creates the turbulence which explains the degree of the stability or instability. With the relative increase of temperatures, the power of keeping steam (vapor) back is high. The vertical pressure gradient of the troposphere is connected to the humidity.

The Ouesso space does not elaborate on its ground an air mass, a synonym for warm and wet air under its latitudes. These regions often proceed to a refill in humidity in the troposphere through the strong vapor transpiration. The region of Ouesso receives the African northeast air stemming from the anticyclone Egypt-Libyan, responsible for strong temperatures. The air masses which cross this region flowed for a long time in the low layers tropospheric thus susceptible to have stuffed itself with humidity, first condition for the forming of clouds and rain. They are often stable air masses and bring fewer rains.

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REFERENCES

Bischoff, S.A., P.O. Canziani and A.E. Yuchechen, 2007. The tropopause at southern extratropical latitudes: Argentine operational rawinsonde climatology. Int. J. Climatol., 27: 189-209.

Bjerknes, J. and E. Palmen, 1937. Investigation of Selected European Cyclones by Means of Serial Ascents. American Meteorological Society, Boston, MA., USA., Pages: 62.

Castanheira, J.M. and L. Gimeno, 2011. Association of double tropopause events with baroclinic waves. J. Geophys. Res., Vol. 116. 10.1029/2011JD016163

Fu, Q., C.M. Johanson, J.M. Wallace and T. Reichler, 2006. Enhanced mid-latitude tropospheric warming in satellite measurements. Science, 312: 1179-1179.

Garreaud, R.D., 2000. Cold air incursions over subtropical South America: Mean structure and dynamics. Monthly Weather Rev., 128: 2544-2559.

Keyser, D. and M.A. Shapiro, 1986. A review of the structure and dynamics of upper-level frontal zones. Mon. Wea. Rev., 114: 452-499.

Kochanski, A., 1955. Cross sections of the mean zonal flow and temperature along 80. J. Meteorol., 12: 95-106.

Leroux, M., 1975. Dynamic climatology of Africa. Work Documents Trop. Geogr., 19: 88-112.

Leroux, M., 1980. Climate of tropical Africa. Ph.D. Thesis, University of Burgundy, Dijon.

Leroy, S.S., J.G. Anderson and J.A. Dykema, 2006. Testing climate models using GPS radio occultation: A sensitivity analysis. J. Geophys. Res., Vol. 111.

Nganga, D. and G. Samba, 2011. Atmospheric dynamic and raining mechanisms in the Congo basin. Res. J. Environ. Sci., 5: 850-866.

Noel, V. and M. Haeffelin, 2007. Midlatitude cirrus clouds and multiple tropopauses from a 2002-2006 climatology over the SIRTA observatory. J. Geophys. Res., Vol. 112.

Pan, L.L., W.J. Randel, B.L. Gary, M.J. Mahoney and E.J. Hintsa, 2004. Definitions and sharpness of the extratropical tropopause: A trace gas perspective. J. Geophys. Res., Vol. 109.

Pan, L.L., W.J. Randel, J.C. Gille, W.D. Hall and B. Nardi *et al*., 2009. Tropospheric intrusions associated with the secondary tropopause. J. Geophys. Res., Vol. 114.

Randel, W.J., D.J. Seidel and L.L. Pan, 2007. Observational characteristics of double tropopauses. J. Geophys. Res., Vol. 112.

Samba, G. and D. Nganga, 2012. Rainfall variability in congo-brazzaville: 1932-2007. Int. J. Climatol., 32: 854-873.

Samba, G. and M. Mpounza, 2005. Application of the Markov process for daily precipitation occurrences in Congo-Brazzaville. Comptes Rendus Geosci., 337: 1355-1364.

Satyamurty, P., J.F.B. Fonseca, M.J. Bottino, M.E. Seluchi, M.C.M. Lourenco and L.G.G. de Goncalves, 2002. An early freeze in southern Brazil in April 1999 and its NWP guidance. Meteorol. Appl., 9: 113-128.

Shapiro, M.A., 1978. Further evidence of the mesoscale and turbulent structure of upper level jet stream-frontal zone systems. Mon. Wea. Rev., 106: 1100-1111.

Spenger, M., M.C. Maspoli and H. Wernli, 2003. Tropopause folds and cross-tropopause exchange: A global investigation based upon ECMWF analyses for the time period March 2000 to February 2001. J. Geophys. Res., Vol. 108.

Stohl, A., P. Bonasoni, P. Cristofanelli, W. Collins and J. Feichter *et al*., 2003. Stratosphere-troposphere exchange: A review and what we have learned from STACCATO. J. Geophys. Res., Vol. 108.

Suchel, J.B., 1988. The climate of Cameroon. Ph.D. Thesis, University of Saint-Etienne, France.

Varotsos, C., C. Cartalis, A. Vlamakis, C. Tzanis and I. Keramitsoglou, 2004. The long-term coupling between column ozone and tropopause properties. J. Climate, 17: 3843-3854.

Wang, S. and L.M. Polvani, 2011. Double tropopause formation in idealized baroclinic life cycles: The key role of an initial tropopause inversion layer. J. Geophys. Res., Vol. 116.