AIR POLLUTION EPISODES ASSOCIATED WITH LONG RANGE TRANSPORT OF BIOMASS BURNING PRODUCTS

Cláudia Boian, Volker W. J. H. Kirchhoff INPE - Instituto Nacional de Pesquisas Espaciais, Brazil

Abstract

An experiment was performed in the north-west of the state of Paraná, at Maringá site (23.1^0 S; 51.1^0 W), from August 2001 to November 2002, to determine the impact of large scale transport, over a distant region of the biomass burning area, under the influence of the anticyclonic circulation. This is a typical local transport regime during the dry season (July-September), when intense biomass burning occurs in Central Brazil, and which gives origin to the transport of burning products from the sources to distant regions in the south of the continent. Simultaneous measurements of carbon monoxide and ozone were made in Campo Grande (20S; 54W), a moderate biomass burning region. Campo Grande is a continental site located in the Mato Grosso do Sul state, which was used as a temporary site for the present study. Vertical ozone profiles, surface carbon monoxide and ozone measurements, were compared with backward trajectories, fire pixels seen by the AVHRR satellite and meteorological conditions to determine the influence of the large scale transport at Maringá. An instrumented air-conditioned trailer was installed in a rural area (northeast of Maringá), distant some 15 km from downtown, for continuous and systematic surface ozone measurements. CO measurements were obtained from grab samples, collected weekly. The air samples were then taken to the laboratory where they were analyzed for CO by gas chromatography. Electrochemical concentration cell (ECC) ozonesondes were used to measure the vertical ozone profile. The lowest concentrations were measured in January (carbon monoxide average 110.8 ± 11.8 ppbv and ozone average 13.2 ± 4.0). These values were used as reference background values in our analysis. A clear increase in trace gas concentrations was observed in Maringá during the dry season (from August to October) when intense biomass burning occurs in Central Brazil and the transport term is more significant. An excess of four times the background value of CO was observed in Maringá during this period. Excess ozone was also observed from surface measurements and vertical ozone profiles.

Introduction

In Brazil most of biomass burning (about 85%) occurs in Cerrado regions (where burning products are grass, bushes and small trees) during the dry season. The biomass burning activity is a strong seasonal event. The dry season in central Brazil (Cerrado regions) extends roughly from June to September. In the rainy period, December and January, for example, as much as 300 mm of rain/month are normal, but during the principal dry months July and August, precipitation rates are generally below 10 mm/month (Alvalá and Kirchhoff, 1998). Fig. 1 shows a comparative of fire pixels of some states for 2001 and 2002: Mato Grosso (MT); Pará (PA); Tocantins (TO); Mato Grosso do Sul (MS); Rondônia (RO); Goiás (GO) and Paraná (PR). Note the large contrast of contribution between Mato Grosso and Paraná. Fire pixel activities were obtained by the AVHRR satellite to classify the region as: (a) strong biomass burning (Mato Grosso, Pará, Tocantins); (b) moderate biomass burning (Mato Grosso do Sul, Rondônia, Goiás); (c) weak biomass burning (Paraná).

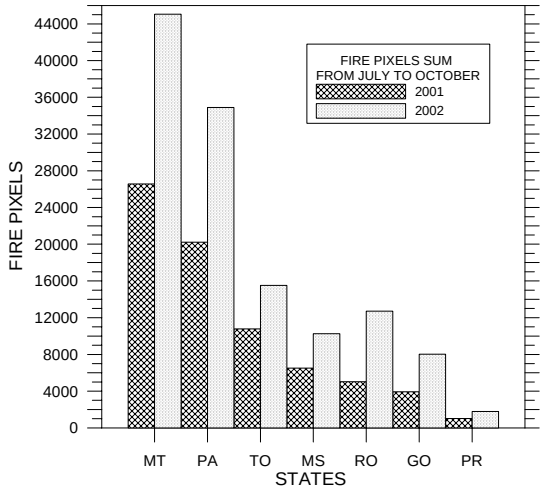

Fig. 1 – Fire pixels for 2001 and 2002 (dry season) for some states: Mato Grosso (MT); Pará (PA); Tocantins (TO); Mato Grosso do Sul (MS); Rondônia (RO); Goiás (GO) and Paraná (PR). Note the large contrast of contributions between Mato Grosso and Paraná.

During the process of biomass burning many trace gases (CO_2, CO, CH_4, NO_x); hydrocarbon and aerosols are injected in the troposphere (Crutzen and Andreae, 1990) and can affect distant areas through long range transport (Kirchhoff and Nobre, 1986; Reichle et al., 1986). Carbon monoxide, CO, has a relatively long lifetime in the atmosphere (between about 2 weeks and 2 month, Novelli et al., 1998) and thus maybe used as important pollution tracer. It is directly produced in the biomass burning process, which can present large variations and has been measured with very good precision and accuracy.

Ozone is not produced directly in the biomass burning process, but indirectly in the atmosphere through photochemical reactions, if there is enough NOx, and UV radiation. Brazilian environmental authority (CONAMA) defines bad air quality as having 80 ppbv ozone for 1 hour, or higher.

Site Description and General Meteorological Conditions

According to the fire pixel results, Maringá (23.1^0 S; 51.1^0 W) is a region of low biomass burning activity located in the north-west of the state of Paraná, south of Brazil. This municipality has nowadays about 303.551 inhabitants. The principal economic activity is agroindustrial.

The climate of the region is subtropical with rainy summer and dry winter. The presence of frontal weather systems is also frequent in the southern regions during the winter.

Fig. 2 shows the average typical monthly precipitation, relative humidity and temperature for the Maringá site. The precipitation at the site (Fig. 1 (a)) has a significant seasonal cycle, and varies between minima of about 60 mm $month^{-1}$ in August, to maxima of 210 mm $month^{-1}$ in January. The seasonal variations of relative humidity (Fig. 1 (b)) is rather small, with minima of about 67% in August-September and maxima of 75% in January. The temperature (Fig. 1 (c)) shows a maximum in December-January of 23^0C and minimum values of about 15^0C in July.

An instrumented air-conditioned trailer was installed in a rural area (northeast of Maringá), distant some 15 km from downtown, for routine and systematic ozone observations. The local wind blows mainly over the rural area before it reaches downtown. The air was fed to the instrument through an orifice at the top of the trailer. A maintenance crew visited the site periodically to calibrate the instruments and make the download of the data.

Method

The technique used to measure CO is based on chromatographic separation followed by mercury vapor detection. The method has been described with additional details by Boian et al., 2004. The technique has excellent chromatographic resolution, is linear in the range of the present measurements, and has precision of about 0.2%. At the sampling point systematic sampling schedules were established from August 2001 to November 2002.

Surface ozone was measured continuously using the UV absorption technique. The measured concentration of ozone is represented in units of parts per billion by volume (ppbv). This technique has been widely used for many years and results of it have been described in considerable detail in the literature (Kirchhoff and Alvalá, 1996).

Eletrochemical concentration cell (ECC) ozonesondes have been used to measure ozone in the troposphere and stratosphere. The ozonesonde is a small ballon-borne device developed at NOAA (Komhyr, 1969). The sensor itself is a small cell with two platinum electrodes immersed in iodide solutions of different concentrations in the cathode and anode chambers. When air containing ozone is circulated through the cathode, an electric current is generated which is telemetered to the ground receiver. The ozonesonde is flown in parallel with a standard radiosonde, wich provides measurements of ambient air pressure, temperature and humidity. The technique to prepare and lauch these ozone sensor has been used regularly in Brazil since 1978, in a NASA-INPE long term collaboration program (Kirchhoff et al., 1991).

Backward trajectories were used to determine the origin of the air masses that arrive at the sampling point. In the determination of the air mass trajectories an isentropic model was used, in which the trajectories are calculated for surfaces with the same potential temperature. Details of this methodology can be seen in Trosniskov, (1998) and, Boian, et al. (2004). The model input parameters were obtained from the National Center for Environmental Prediction (NCEP, 2005).

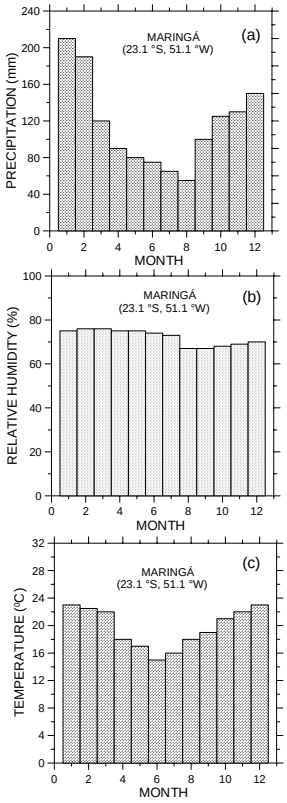

Fig. 2 – Average monthly meteorological parameters at the Maringá site: (a) precipitation (mm $month^{-1}$); (b) relative humidity (%); and (c) temperature (^{0}C).

Results

An experiment was performed in the north-west of the state of Paraná at Maringá site (23.1^0 S; 51.1^0 W), from August 2001 to November, 2002 to determine the impact of large scale transport, over distant region of biomass burning, under the influence of the anticyclonic circulation. Trace gas measurements (surface ozone and carbon monoxide) were made in a rural area (northeast of Maringá). Daily ozone soundings were also performed in

a specific campaign during August 21-25, 2002 to determine the vertical ozone profile.

Fig. 3 shows the daily ozone average concentrations in a typical month of the rainy season (see also Fig. 2). During this period the lowest surface ozone concentrations were measured (ozone average 13.2 ± 4.0). The same effect was observed for carbon monoxide measurements (carbon monoxide average 110.8 ± 11.8 ppbv). During the rainy season a clean atmosphere (pristine air) was observed in Maringá. These values were used as reference background values in our analysis.

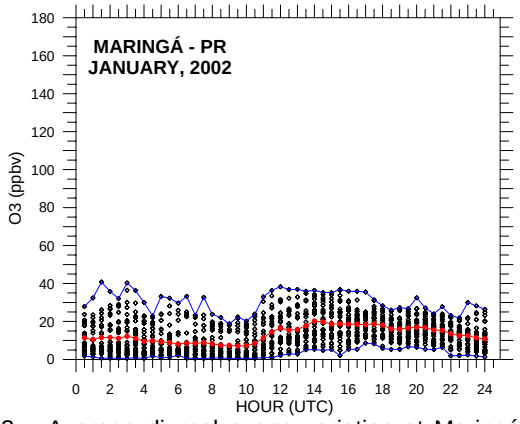

Fig. 3 – Average diurnal ozone variation at Maringá site during the rainy season. The maximum and minimum are also shown.

A clear increase in trace gas concentrations was observed in Maringá during the dry season (from August to October) when intense biomass burning occurs in Central Brazil and the transport term is more significant. An excess of four times the background value of CO could be observed during this period (see Fig. 4).

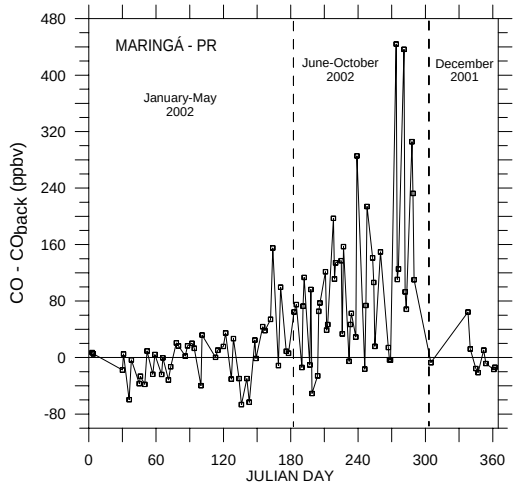

Fig. 4 – Seasonal variations of excess surface CO ($CO_{measurement}$ - $CO_{background}$) at Maringá. For the background value the average CO concentration measured during January (110.8 ppbv).

An interesting case of long range transport was observed for 29 August, 2002. High CO concentrations were measured in Maringá (405.1 and 387.8 ppbv). Simultaneous CO measurements were made in Campo Grande where very high concentrations (915.9 and 923.4 ppbv) were observed. Backward trajectories were used to determine the origin of the air mass reaching each sampling point. Fig. 5 shows the five day backward trajectories to Campo Campo and Maringá (altitudes between 1.0 and 2.5 km) and the fire pixels along the path. A large area of biomass burning activities was seen in Tocantins, Mato Grosso and Goiás states. The anticyclonic circulation was well defined bringing CO from this source to the south region of Brazil. Note that there was practically no fire activity at the sites (Campo Grande and Maringá) on the day of sampling. According to air mass trajectories Campo Grande was receiving contributions from Tocantins and Mato Grosso states and the air masses that were reaching Maringá had contributions from Mato Grosso, Goiás and Mato Grosso do Sul. Campo Grande is nearer to the source regions of biomass burning than Maringá, thus the dilution effects during the long range transport is more efficient for Maringá .

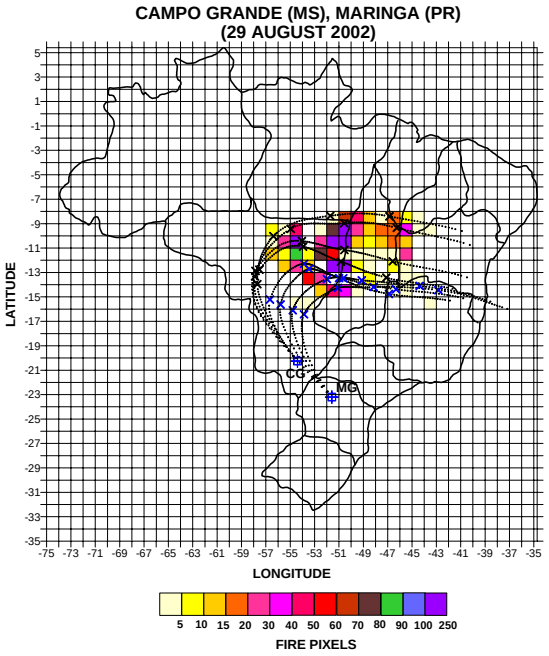

Fig. 5 – Five day backward trajectories from Campo Grande (20S; 54W) and Maringá (23.1^0 S; 53.1^0 W) and the fire pixels along the path. The crosses show one day along the path.

As said previously, evidence of long range transport could be observed also for surface ozone measurements and the vertical ozone profile.

Fig. 6 shows an example of this event (August 25-31), when high surface ozone concentrations were measured (average ozone concentration was 89 ppbv ± 7.4), with maximum values between 93-173 ppbv. Backward trajectories were used to determine the origin of air masses that were reaching Maringá during this period

(Fig. 7). All trajectories were calculated from the geographic coordinate of the Maringá site for five days past and altitudes between 1.0 – 2.5 km. According to these calculations the air masses before reaching Maringá passed through large sources of biomass burning in Pará, Mato Grosso, Mato Grosso do Sul and Tocantins and have been enriched with ozone. From Tocantins (the most distant source) to Maringá the time of travel was around four days.

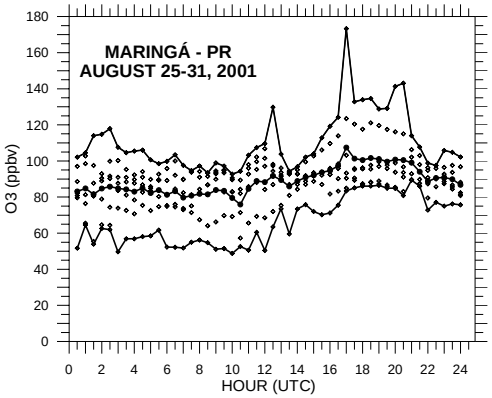

Fig. 6 – Diurnal variations of surface ozone during a typical period of long range transport (August 25-31, 2001). The maximum, minimum and averages are shown.

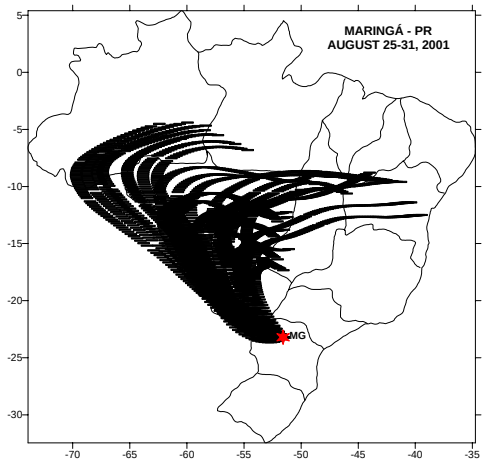

Fig. 7 - Map of Brazil showing five day backward trajectories from Maringá (altitudes between 1.0-2.5 km) during August 25-31.

A specific campaign was performed in Maringá during the dry season (August 21-25, 2002) to determine the vertical ozone profile and their relation with fire pixel activities in Central Brazil. During this period two cases were observed, (see Fig. 8): For the first case, 21 August 2001, low ozone concentrations were measured in the low troposphere; for example, the concentration measured near the surface was 30 nbar (31 ppbv). For the opposite case on 25 August 2001, high ozone concentrations were measured in the low troposphere; for example, the concentration measured near the surface was 75 nbar (79 ppbv).

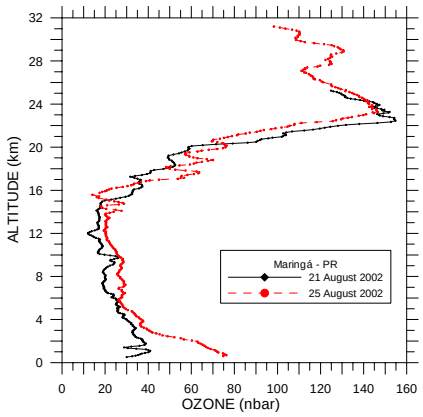

Fig. 8 – Vertical ozone profiles during the dry season at Maringá.

A set of five day backward trajectories were calculated for Maringá (altitudes between 2.5 and 3.0 km) and the fire pixels along the path for both cases (see Fig. 9 and 11). For the first case on 21 August 2002, a frontal system was over the continent. The NOAA 12 infrared satellite image (Fig. 10) shows the NW-SE oriented band of cloudiness over west region of Brazil produced by penetration of a cold frontal sweeping through southaestern Brazil. The passage of this front had been associated with rainfall over west of the Mato Grosso and Mato Grosso do Sul states and with interference in the anticyclonic circulation and biomass burning activities (Fig. 9).

For the other case on 25 August 2002, the anticyclonic circulation was well defined, and was favorable for the transport of biomass burning products. A large area of biomass burning activities was seen in Tocantins, Mato Grosso, Mato Grosso do Sul and Goiás states (Fig. 11) and high ozone concentrations were measured in Maringá.

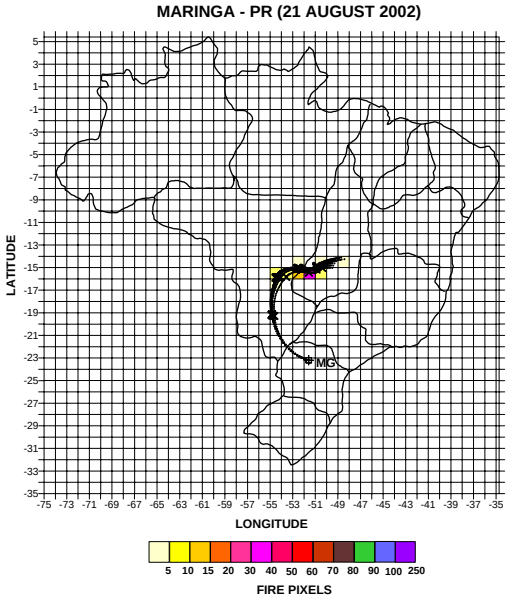

Fig. 9 - Five day backward trajectories for Maringá (21 August, 2002) and the fire pixels along the path. The crosses show one day along the path.

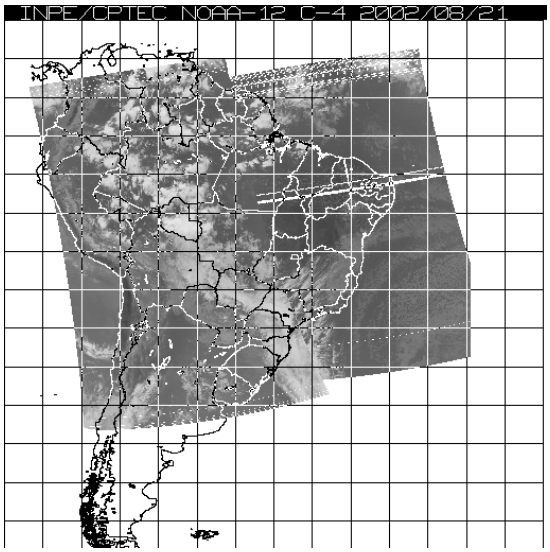

Fig. 10 – The NOAA 12 infrared satellite image on 21 August 2002 showing a frontal system over the continent.

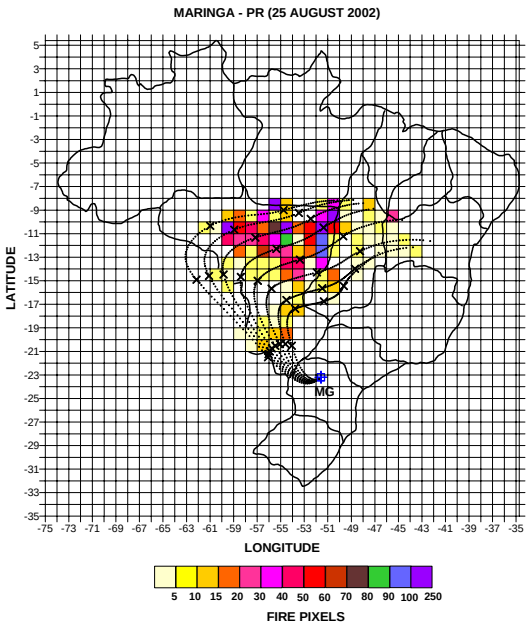

Fig. 11 - Five day backward trajectories for Maringá (25 August, 2002) and the fire pixels along the path. The crosses show one day along the path.

Conclusions

A special experiment was performed in the north-west of the state of Paraná at Maringá site, from August, 2001 to November, 2002 when trace gas concentrations were monitored to determine the impact of large scale transport, over a distant region of biomass burning, under the influence of the anticyclonic circulation.

Significant enhancements in surface ozone concentrations (around 76 ppbv) and carbon monoxide (excess of four times the background value) were observed in Maringá during the period of large scale transport. According to backward trajectories, most of the contributions come from Mato Grosso, Pará, Tocantins, Mato Grosso do Sul and Goiás states. This typical circulation during the dry season is affected due the presence of frontal weather systems in the south region of the brazilian continent when the local convective process stand out over the horizontal transport and lower surface trace gas concentrations are observed. Vertical ozone profiles showed this event. On the other hand during the wet season the absence of local photochemistry at Maringá site modulates the surface trace gas concentrations and much lower values are measured (ozone average around 13.2 ± 4.0 ppbv and carbon monoxide average 110.8 ± 11.8).

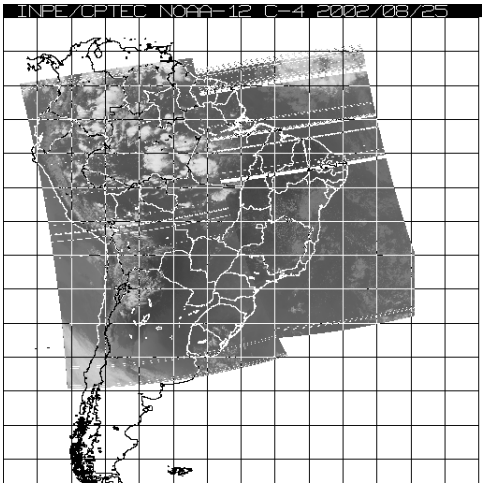

Fig. 12 - The NOAA 12 infrared satellite image on 25 August 2002.

Acknowledgments

The authors are grateful to Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), for the financial support of this project. We thank the infrastructure and logistics provided by INPE and the personnel of the Ozone Lab. Calibration gases were provided by CMDL/NOAA.

References

Alvalá, P.C., Kirchhoff, V.W.J.H. Observations of atmospheric methane and monoxide in Brazil: SCAR B mission. Journal of Geophysical Research, 103, D24, 32,101-32,105, 1998.

Boian, C.; Kirchhoff, V.W.J.H. Measurements of CO in an aircraft experiment and their correlation with biomass burning and air mass origin in South America. Atmos. Environ., 38, 6337-6347, 2004.

Crutzen, P.J.; Andreae, M.O. Biomass burning in the tropics: Impact on atmospheric chemistry and biogeochemical cicles. Science, 250, 1669-1678, 1990.

Kirchhoff, V.W.J.H. and Nobre, C.A. Atmospheric chemistry research in Brazil: Ozone measurements at Natal, manaus and Cuiaba. Revista Brasileira de Geofísica. 24, 95-108, 1986.

Kirchhoff, V.W.J.H.; Barnes, R.A.; Torres, A.L. Ozone climatology at Natal, Brazil, from in situ ozonesonde data. J. Geophys. Res., 96, 10,899-10,909, 1991.

Kirchhoff, V.W.J.H., Alvalá, P.C. Overview of an aircraft expedition into the Brazilian cerrado for the observation of atmospheric trace gases. Journal of Atmospheric Research, 101, D19, 23,973-23,982, 1996.

Komhyr, W.D. Eletrochemical concentration cell for gas analysis, Ann. Geophys, 25, 203-210, 1969.

NCEP (National Center for Environmental Prediction). http://wesley.wwb.noaa.gov//ncep_data/index.html (online), 2005.

Novelli, P.C.; Masarie, K.A. and Lang P.M. Distributions and recent changes of carbon monoxide in the lower troposphere. Journal of Geophysical Research, 103, D15, 19,015 – 19,033, 1998.

Reichle, H. G., Connors, V. S., Holland, J. A., Hypes, W. D., Wallio, H. A., Casas, J.C., Gomsen, B.B., Saylor, M.S. and Hesketh, W.D. Middle and upper tropospheric carbon monoxide mixing rations as measured by a satellite borne remote sensor during November 1981. Journal of Geophysical Research, 91, D10, 10,865-10,888, 1996.

Troniskov, I.; Nobre, C.A. Estimation of aerosol transport from biomass burning areas during SCAR – B experiment. Journal of Geophysical Research 103, D24, 32129-32137, 1998.