

Variability of Aerosol Optical Depth over Cerrado of Mato Grosso, Brazil

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Abstract The optical properties of aerosols have an important meaning in atmospheric research issues. This work proposes a seasonal and inter-annual characterization of the Aerosol Optical Depth (AOD) at 500 nm through a transition region Pantanal, Cerrado (Cerrado characteristics) in the south central region of the State of Mato Grosso. AOD 500 nm data were acquired from the network AERONET 2001 to 2013. The daily values AOD 500 nm have a seasonal pattern, with minimum and maximum in the wet and dry seasons, respectively. The minimum values were mostly around to 0,02 in the wet season while the maximum values close to 5,23 in the dry season. Regarding the inter-annual characterization, it was found that is not a periodic behavior with large variations from year to year. The monthly averages of AOD 500nm were correlated with the monthly records of fire outbreaks in the State of Mato Grosso, however, there was no statistically significant correlation, which shows that this relationship exists, but it is not simple.

Keywords AERONET. Biomass Burning, Depression Cuiabana

1. Introduction

South Central region of Mato Grosso state is a strategic region for analysis of the optical profile of atmospheric aerosols from biomass burning, since this region is affect by numerous outbreaks of fires in the dry season every year [1]. The mid-west region of Brazil can contribute either to analysis of natural aerosols or anthropogenic aerosol analysis emitted by burning biomass [2], since this region is mainly composed of tropical savannas. In Brazil, savanna (locally known as cerrado) covers about 24% of the country and is the dominant vegetation in areas subjected to a prolonged dry season [3].

The Mato Grosso state contains three biomes, Amazon, Cerrado and Pantanal. Our study area lies in a transitional region between Pantanal and Cerrado[3]. The Brazilian Cerrado, in general, is responsible for large emissions of aerosols due to biomass burning. The extent of this biome

covers approximately 2000 km², of which approximately 50% of this territory is considering potentially arable land [4].

Due to pronounced dry season and thus natural and non-natural burning, the Cerrado becomes a potential emitter of particulate material into the atmosphere. The most AOD 550nm critical period begins in July and is consistent from year to year. In general, this period can last just a few weeks, depending on the dry season severity that is related to El Niño Southern Oscillation (ENSO) [5, 14].

The AERONET (Aerosol Robotic Network) is an aerosol monitoring network, a terrestrial network of remote sensing distributed around the globe, among the various information provided by this network are the AOD values, these are provided for specific wavelengths among which is the 500 nm [6]. AOD 500 nm data for the Midwest region of Brazil has allowed a characterization of the optical properties of the local atmosphere, and it has aided for understanding the radiative exchanges in the range of visible light between the atmosphere and the surface [1]. The seasonal variability of AOD 500 nm values for the study area is closely relate to fire outbreaks records [1].

Thus, a quantification of this variable is needed to improve the understanding of the effects of aerosols on the radiative fluxes throughout the year. In this sense the objective of this study is to characterize a seasonal and inter-annual variability of AOD 500nm in the Cerrado region in the state of Mato Grosso from data acquired from AERONET network for a time series extending from 2001 to 2013.

2. Materials and Methods

The study area is in a rural area (Miranda Farm), located approximately 20 km from the urban area of Cuiabá, capital of state of Mato Grosso (Figure 1) whose coordinates are 16° S and 56 ° W to 175 m altitude.

In the site is established the CIMEL photometer controlled by AERONET network. Full details of the instrumentation, measurement protocols, photometric accuracy, calibration, and processing methods can be found in the other work [6].

Figure 2. a) Daily Distribution of AOD 500 nm values from 2001 to 2013, b) distribution of AOD 500nm values over the day of the year.

It can be seen from Figure (2a) a pretty long failure in 2002 due to technical problems in the photometer calibration. However the figures analyzed represent satisfactorily the maximum and minimum each year in the dry and wet seasons. For the year 2001 the daily peaks of AOD 500 nm reached 1,34 in the dry season, in 2003 the maximum record was 0,65 for the same period, in 2004 values exceeded 1,80. All values are considered reliable data since the data acquired from the network AERONET were the level 2.0.

In 2005 and 2006 the maximum AOD 500 nm reached values greater than 4,00 and 2,50 respectively, while for 2007 the maximum value reached 5,23. For 2008 the maximum records occurred in the range of 1,24 to 0,58, diminishing considerably in 2009. For the increasing time of AOD 500 nm values in 2009 there is another failure in the time series that continues until the increasing time in 2010, where the maximum peaks reach values close to 3,52 again. For 2011 and 2012 peak values were around 0,72 and 1,32, as well as for the year 2013.

Records of AOD 500 nm below 0,5 characterizes a virtually clean atmosphere, however [10] stated that under clean air conditions, the values may be less than 0,1. The work of [1] for the years 2010, 2011 and 2012 reports values less than 0,5 for the our study area during the wet season in this region.

The average annuals as well as the standard deviations

each year demonstrate the high variability of AOD in the dry season and low in the wet season. The annual variation showed the highest marks for the years 2005, 2006, 2007 and 2010, these years present historical records of fires on Brazil. Table 1 shows the descriptive statistics for the variations of each season for each year and for the whole study period.

The monthly AOD 500 nm was related to the monthly records of outbreaks of fire for the state of Mato Grosso. Figure 3 shows the distribution of AOD 500 nm monthly values and records of outbreaks of fire.

One can see that the records of fires (Figure 3) are directly related to the increase in AOD 500 nm values, since the increase in fires events launches into the air a large amount of particulate matter, but records of large increases AOD values at 500 nm that are not accompanied by an increase in records of fires. For the years 2010 and 2011 the records of fires were approximately equal, as AOD 500 nm to 2010 figures peaked relatively higher than in 2011.

The Spearman correlation coefficient for the relationship between AOD 500nm and records of outbreaks of fire, was no statistically significant correlation (0, 02), which shows that other variables must be considered in the analysis of AOD 500nm values. The work of [1] found a statistically significant correlation between these variables, however portrayed in his work series addresses a short break in the series.

Table 1. Descriptive statistics for the rainy and dry seasons for each year and throughout the study period

AOD 500 nm						
Years	Wet Season			Dry Season		
	Mean \pm SD	Minimum	Maximum	Mean \pm SD	Minimum	Maximum
2001	0,0616 \pm 0,0218	0,0289	0,1218	0,5099 \pm 0,3481	0,1065	1,3430
2002	--	--	--	--	--	--
2003	0,1743 \pm 0,0244	0,1519	0,2365	0,2632 \pm 0,1160	0,1193	0,6493
2004	0,0925 \pm 0,0231	0,0605	0,1245	0,4926 \pm 0,4225	0,0725	1,8944
2005	0,1954 \pm 0,0323	0,1677	0,2309	0,8026 \pm 0,7154	0,0843	4,4241
2006	0,1350 \pm 0,0327	0,0540	0,2142	0,5026 \pm 0,5404	0,0728	2,5567
2007	0,0991 \pm 0,0269	0,0662	0,1626	0,9457 \pm 0,9275	0,1373	5,2382
2008	0,0992 \pm 0,0185	0,0749	0,1306	0,4037 \pm 0,2515	0,0943	1,2470
2009	0,0999 \pm 0,0443	0,0394	0,2600	0,1778 \pm 0,0952	0,0719	0,5813
2010	--	--	--	0,9977 \pm 0,7622	0,1650	3,5208
2011	0,0695 \pm 0,0210	0,0361	0,1146	0,2886 \pm 0,1775	0,0636	0,9321
2012	0,0831 \pm 0,0273	0,0309	0,1582	0,4122 \pm 0,3111	0,0734	1,3231
2013	0,0921 \pm 0,0322	0,0294	0,1592	0,2845 \pm 0,1789	0,0809	0,7244
All years	0,0965 \pm 0,0408	0,0289	0,2600	0,5389 \pm 0,5607	0,0636	5,2382

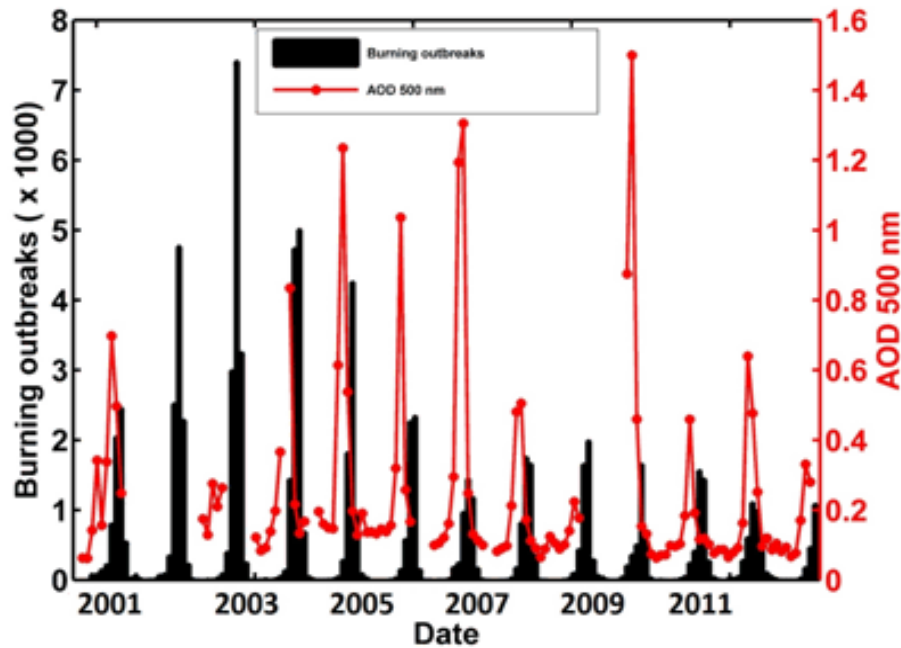


Figure 3. Relationship between the values of AOD 500 nm and burned records in the state of Mato Grosso

In considering that the fire outbreaks data span a state area coverage level, it realizes that the contribution does not necessarily influence the study area. The study area has Cerrado vegetation characteristic, which it would justify in emissions of material suspended dust because of the great length of exposure to dry. Another fact that must be taken into consideration is the actual particulate emissions by vegetation. Thus, a number of variables must still be analyzed in order to understand the seasonal behavior of AOD 500 nm values and optical properties for our study area.

The values found for the AOD 500 nm are daily and monthly in agreement with the vast literature, both the study area studied by [11] and [1] and for areas with the same characteristics as the working [12] developed in the African savanna.

The results obtained clearly observed a seasonal variation of AOD 500 nm data for the study area. Regarding the maximum and minimum values it can be observed that the methodology proposed in this paper takes a quantitative analysis based on variations of AOD 500 nm values, it became possible to accompany the annual variations in the data; however, it was revealed the great influence of foci burned in the variations of optical depth values of aerosols.

To assess the possible contributions of fires from other

locations, Figure 4 shows the trajectories calculated by HYSPLIT model on the study area. The trajectories were calculated for the years whose AOD 500 nm values reached the maximum values (2005, 2006, 2007 and 2010) in the critical period of the dry season. It is noted that air movement in the end of September contributes heavily to the increase of the AOD 500 nm. The case records of outbreaks of fire on the southern region of the Amazon rainforest impacted directly the spatial distribution of AOD 500 nm, thus explaining the higher registers of optical depth on the study area.

For 2006 and 2007 dry seasons, the external contributions came mainly from the eastern and northeastern, which are strongly affected by biomass burning that occurs due to cleaning of arable land [13]. Both 2005 and 2010 there has been a great contribution northern study area (Amazon). Deforestation and biomass burning emit large amounts of particulate matter into the atmosphere which directly impacts the area of study.

In general, east, northeast and northern Brazil are the main contributors sources for the increase AOD in Mato Grosso Cerrado so that the maximum are achieved in the dry season, precisely where the fires registration are high in these regions. The local atmospheric motion contributes to transport the particulate matter that impacts the study area.

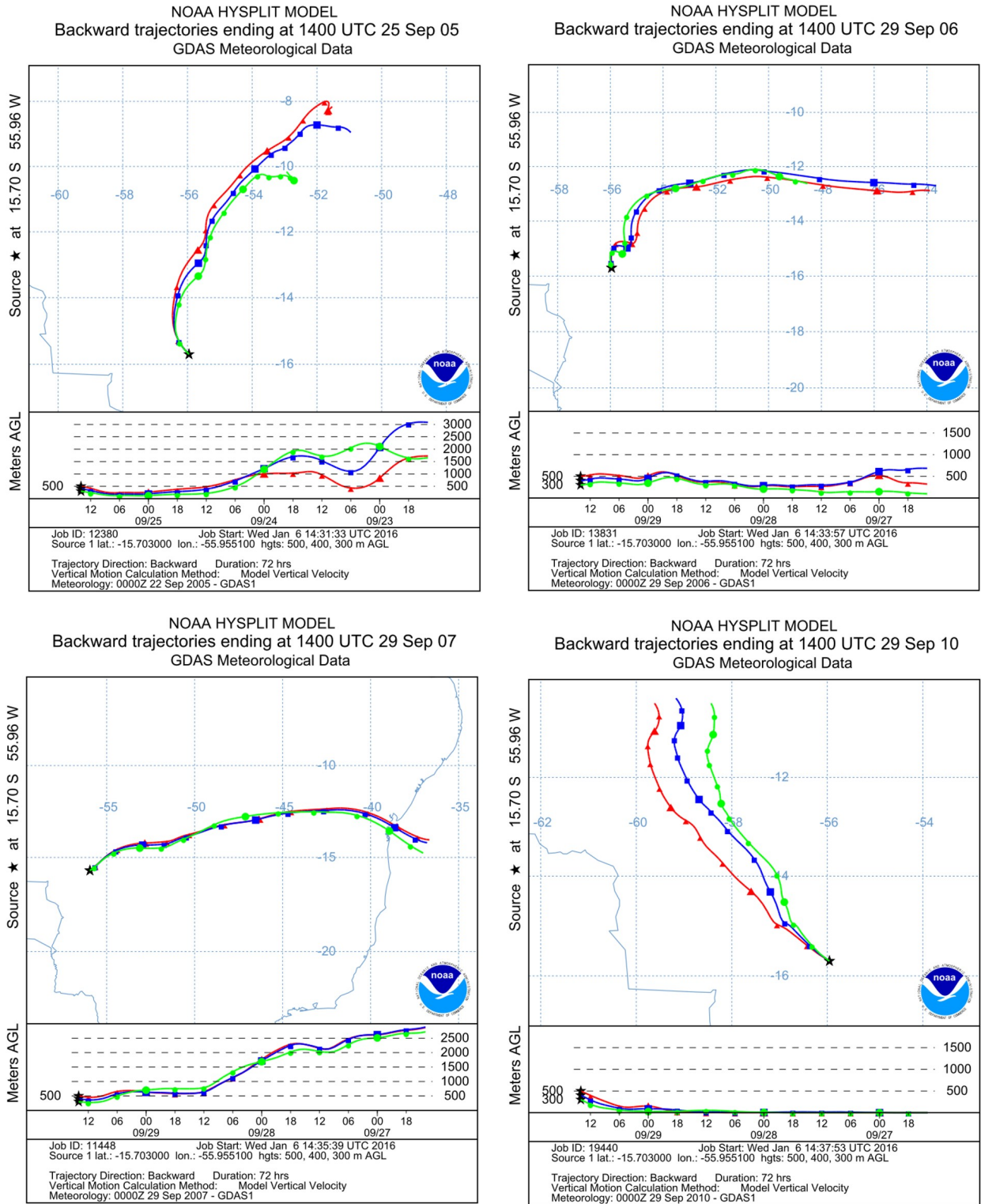


Figure 4. A large figure in one column

4. Conclusions

This study contributes for understanding of the behavior of the optical properties of aerosols in regions with Cerrado characteristics. Daily values of AOD 500 nm clearly show a seasonal pattern with minimum and maximum in the wet and dry season, respectively. The minimum values were concentrated in about 0,02 in the wet season while the maximum values reached 5, 23 in the dry season. Regarding the inter-annual characterization, it was noticed a non-periodic behavior, with large variations from year to year. The monthly averages of AOD 500 nm were correlated with the monthly records of outbreaks of fire for the state of Mato Grosso, however there was no statistically significant correlation, which shows that such a relationship exists, but it is not direct. The relationship between monthly values of AOD 500 nm and fire outbreak records was perceived through the high of AOD values 500 nm when an increase in values in records of outbreaks of fire. Regarding the maximum and minimum values it can be observed that the methodology proposed in this paper takes a quantitative analysis based on variations of AOD 500 nm values, it became possible to accompany the annual variations in the data, however it was revealed the great influence of foci burned in the variations of optical depth values of aerosols. The case records of outbreaks of fire on the southern region of the Amazon rainforest impacted directly the spatial distribution of AOD 500 nm, thus explaining the higher registers of optical depth on the study area.

Acknowledgements

We thank CAPES for the financial support (process n° 01439213127) and the research group of the Graduate Program in Environmental Physics (project of 457824 / 2013-1 approved process in call n° 68/2013 MCTI/CNPq/FNDCT-Cross action/LBA) and the research group of the Institute of Physics of the University of São Paulo (USP) for the availability of the AERONET network data.

REFERENCES

- [1] Palácios, R.S., Sallo, F.S., Do Prado, M.J., De Musis, C.R., Nogueira, J.S. Análise da profundidade ótica de aerossóis e coeficiente de Angstrom no Cerrado Mato-grossense. *Revista Brasileira de Climatologia*, Vol. 14, p. 173-185, 2014.
- [2] Sena, E. T., Artaxo, P., Correia, A. L. Spatial variability of the direct radiative forcing of biomass burning aerosol and the effects of land use change in Amazonia. *Atmospheric Chemistry and Physics*, Vol. 13, p. 1261-1275, 2013.
- [3] Rodrigues, T. R., G. L. Vourlitis, F. D. A. Lobo, R. G. De Oliveira, J. D. S. Nogueira. Seasonal variation in energy balance and canopy conductance for a tropical savanna ecosystem of south central Mato Grosso, Brazil, *J. Geophys. Res. Biogeosci.*, Vol. 119, p. 1-13, 2014.
- [4] Batlle-Bayer, L., Batjes, N.H., Bindraban, P.S. Changes in organic carbon stocks upon land use conversion in the Brazilian Cerrado: A review. *Agriculture, Ecosystems and Environment*, Vol. 137, p. 47-58, 2010.
- [5] Schafer, J.S., Eck, T.F., Holben, B.N., Artaxo, P., Duarte, A. F. Characterization of the optical properties of atmospheric aerosols in Amazônia from long-term AERONET monitoring (1993–1995 and 1999–2006). *Journal of Geophysical Research*, Vol. 113, D04204, p. 1-16, 2008.
- [6] Holben, B. N., Eck, T. F., Slutsker, I., Tanré, D., Buis, J. P., Setzer, A., Vermote, E., Reagan, J.A., Kaufman, Y. J., Nakajima, T., Lavenu, F., Jankowiak, I., Smirnov A. AERONET – a federated instrument network and data archive for aerosol characterization. *Remote Sensing of the Environment*, Vol. 66, n. 1, p. 1-16, 1998.
- [7] Smirnov, A., Holben, B. N., Eck, T. F., Dubovik, O., Slutsker, I. Cloud screening and quality control algorithms for the AERONET data base. *Remote Sensing of the Environment*, Vol.73, p. 337-349, 2000.
- [8] INPE, Instituto Nacional de Pesquisas Espaciais. Portal do Monitoramento de Queimadas e Incêndios. Disponível em <http://www.inpe.br/queimadas>. Acesso em: 29/03/2015.
- [9] Draxler, R.R., Rolph, G.D. HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) Model Access via the NOAA ARL READY Website. NOAA Air Resources Lab., Silver Spring, Md. Available at: <http://www.arl.noaa.gov/ready/hysplit4.html>, 2003.
- [10] Houghton, J. T., MeiraFilho, L. G., Callander, B. A., Harris, N., Kattenberg, A., Maskell, K. (Eds) *Climate Change 1995: The Science of Climate Change*. Cambridge University Press, Cambridge, UK, 1996.
- [11] Procopio, A.S., Artaxo, P., Kaufman, Y. J., Remer, L.A., Schafer, J.S., Holben, B. N. Multiyear analysis of Amazonian biomass burning smoke radiative forcing of climate. *Geophysical Research Letters*, Vol. 31, L03108, p. 1-4, 2004.
- [12] Kumar, K. R., Sivakumar, V., Reddy, R.R., Gopal, K. R., Adesina, A. J. Inferring wavelength dependence of AOD and Ångström exponent over a sub-tropical station in South Africa using AERONET data: Influence of meteorology, long-range transport and curvature effect. *Science of the Total Environment*, Vol. 461-462, p. 397-408, 2013.
- [13] Vieira-Filho, M.S., Pedrotti, J. J., Fornaro, A. Contribution of long and mid-range transport on the sodium and potassium concentrations in Rainwater samples, São Paulo megacity, Brazil. *Atmospheric Environment*, Vol. 79, p. 299-307, 2013.
- [14] ROCHA, V. R., and YAMASOE, M. A. Estudo da variabilidade espacial e temporal da profundidade ótica de aerossol obtida com o MODIS sobre a região amazônica. *Revista Brasileira de Meteorologia*, Vol. 28, n.2, p. 210 - 220, 2013
- [15] *Revista Brasileira de Meteorologia*, Vol.28, n.2, p. 013.