BIOMASS BURNING MEASUREMENTS IN BRAZIL - ANALYSIS FROM NEAR AND FAR SOURCES WITH TWO LIDAR SYSTEMS

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ABSTRACT

Brazil has an important role in the biomass burning aerosol activity. During the Dry Season (June-September) of 2007 at Sao Paulo-SP and during the Dry season of 2009 at Rio Claro-SP, both in Brazil, aerosol profiling campaigns were carried out using a backscattering LIDAR system. The objective of this work is to evaluate the effects of the biomass burning in the southeastern Brazil, over distant (Sao Paulo - SP) (23 33'S, 46 44'W) and near (Rio Claro - SP) (22 23S, 47 32W) regions of the source of burnings mainly through laser remote sensing (LIDAR).

1. INTRODUCTION

Because of the non-homogeneity in the space distribution of burnings, Brazil has great constrast between source and non-source burning regions. In 2008 were detected approximately 135.000 burning spots, according to CPTEC/INPE. Most of these spots occur in the southern part of the Amazon basin during the dry season and these emissions reach the southeast of the country, a highly populated region and with serious urban air pollution problems. With the growing demand on biofuels, sugarcane is considerably expanding in the state of Sao Paulo, being a strong contribution to the bad air quality in the region. In the state of Sao Paulo, the main land use are pasture and sugarcane crop, that covers around 50% and 10% of the total area, respectively. Despite the aerosol from sugarcane burning having reduced atmospheric residence time, from a few days to some weeks, they might be spread over long distances (hundreds to thousands of kilometers)

The biomass burning has effects in several areas: as source of toxic gases, greenhouse gases [1] and aerosols. In South America approximately 34 $Tg.yr^{-1}$ of aerosol particles are emitted to the atmosphere, about one third of the material emitted worldwide [8]. A large part of these aerosols is of black carbon, that heats the atmosphere because of its nature of large solar radiation absorber. This property lead to changes in the atmospheric circulation, as well as an increase in the aerosol optical depth during the burning season in central Brazil, between July and October, with an observed AOD of 4.0 to (440nm) [2].

Extensive elastic lidar observations in troposphere in 532 nm were conducted at Sao Paulo, Brazil (23 33'S, 46 44'W) during the dry season of 2007. The main goal of this campaign was to observe the aerosol load in the lower troposphere (up to 10 km) and its daily behaviour in order to check for air dispersion conditions, planetary boundary and mixed layer daily evolution, mid and long range transport and to correlate with air quality indexing provided by the local environmental agency. Nevertheless, during some days of this campaign, aerosol layers probably from biomass burning were identified. During the period of Dry Season in 2009 a data collection campaign was made in the city of Rio Claro-SP, region surrounded by sugarcane crops. The campaign had an Elastic Lidar, gas (CO, NOx, O3, SO2, CH4) and particulate (PM10, PM2,5) analyzers, as well as a SODAR and a S band Radar (located in Bauru, 160km away from the site).

Therefore, the purpose of this paper is to study the influence of aerosol from biomass burning on the aerosol loading over the city of Sao Paulo-SP (distant from biomass burning regions), during the Brazilian dry season of 2007, and Rio Claro-SP (near to regions of biomass burning), during the dry season of 2009.

2. METHODOLOGY

2.1. Sao Paulo Lidar System Description

The Lidar is located in the Environmental Laser Applications Laboratory at the Centre for Laser and Applications (CLA) at the Instituto de Pesquisas Energeticas e Nucleares - IPEN in Sao Paulo University - USP (figure 1). The system is a single-wavelength backscatter system pointing vertically to the zenith and operating in the coaxial mode. The light source is based on a commercial Nd:YAG laser (Brilliant by Quantel SA) operating at the second harmonic frequency (SHF), namely at 532 nm, with a fixed repetition rate of 20 Hz. The average emitted power can be selected up to values as high as 3.3 W. The emitted laser pulses have a divergence of less than 0.5 mrad. A 30 cm diameter telescope (focal length f = 1.3 m) is used to collect the backscattered laser light. The Lidar is currently used with a fixed field of view (FOV) of the order of 1 mrad, which according to geometrical calculations [7] permits a full overlap between the telescope FOV and the laser beam at heights around 300 m above the Lidar system. This FOV value, in accordance with the detection electronics, permits the probing of the atmosphere up to the free troposphere (7-9 km ASL.).

Data are averaged between 2 and 5 min and then summed up over a period of about 1 h, with a typical spatial resolution of 15 m, which corresponds to a 100 ns temporal resolution. The retrieval of the aerosol optical properties is based on the measurements of the aerosol backscatter coefficient (βaer) at 532 nm, up to an altitude of 5-6 km ASL. The determination of the vertical profile of the aerosol backscatter coefficient relies on the lidar inversion technique following the Klett's algorithm, as proposed in some papers [3; 6], where no multiple scattering corrections are applied, under the assumption of elastic scattering by spherical aerosols.

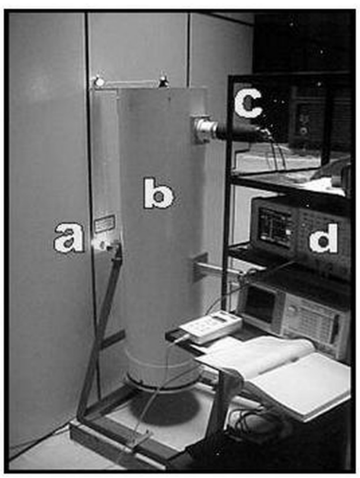

Figure 1: Sao Paulo-SP Lidar system

2.2. Mobile Lidar System Description

The laser source used is a pulsed Nd:YAG laser emitting short pulses at 1064, 532 nm (figure 2). The laser source is factory preset for maximum output energy at 532nm, second (SHG) frequency. The receiving telescope of the lidar system is based on a Cassegrainian design. The primary reflective mirror has a diameter of 200 mm and the secondary reflective mirror has a diameter of 46 mm. The field of view of the telescope is 1 mrads. The signal acquisition unit consists of two sub-units the lidar signals detectors, photomultiplier tubes: PMTs and Avalanche Photodiode module, and the detection electronics working in two modes: the analog detection mode and the photon counting detection mode (only photon counting to 607 nm). The PMTs was operated in 660V (532 nm) and 800 V (607 nm). The optics set-up is such that the maximum overlap is reached at about 180 m above the lidar system and spatial resolution of 7.5 m.

Figure 2: Mobile Lidar System at Rio Claro-SP

2.3. AERONET Sun-tracking photometer

A co-located CIMEL sunphotometer provides aerosol measurements in order to determine the Aerosol Optical Depht values at several wavelengths in the visible spectrum and thus to enable the assessment of the Aerosol Extinction values at the same spectral region at Sao Paulo-SP. The CIMEL 318A spectral radiometer is a solar-powered weather-hardy robotically pointed Sun and sky instrument. This instrument is installed on the roof of the Physics Department at the University of Sao Paulo, distant about 200 meters from the Lidar system. The instrument precision and accuracy follow the standard Langley plot method within the standard employed by the AERONET network [4]. CIMEL data level 2.0 were used in order to eliminate interference from clouds and have data quality assured [4]. The inversion of the solar radiances can be found also in [5]. We also used Angstrom Exponent and Aerosol Size distribution from AERONET data.

2.4. Gases Analyzers Description

In the data campaign at Rio Claro-SP CO, O3, NOx, CH4 and non-methane as well as SO2 analyzers from ECOTECH were used in figure 3. A PM2,5 and PM10 monitoring system was also used, as well as a single wavelength integrating nephelometer Aurora that measures, continuously and in real-time, light scattering in a sample of ambient air due to the presence of particulate matter. The measured values are adjusted automatically and in real-time by on-board temperature and pressure sensors. The wavelength is 520 nm with a light scattering angle between 10 and -170 degrees and 0.25 to 2000 Mm^{-1} measurement range.

Figure 3: Gases/Particulate measurements System

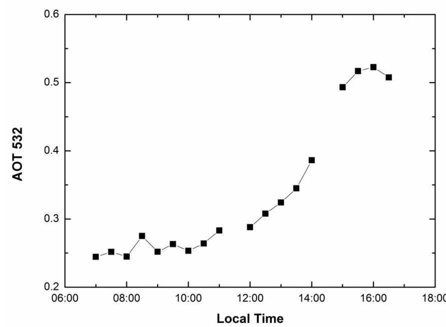

Figure 5: Aerosol Optical Depth (532 nm) for 09/07/2007 at Sao Paulo-SP

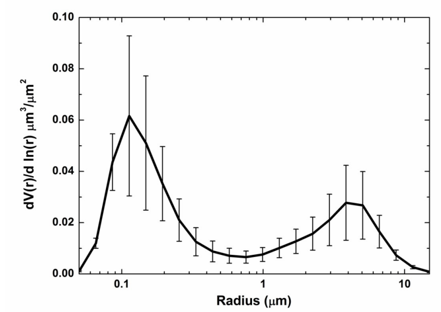

Figure 6: Aerosol Size Distribution for 09/07/2007 at Sao Paulo-SP

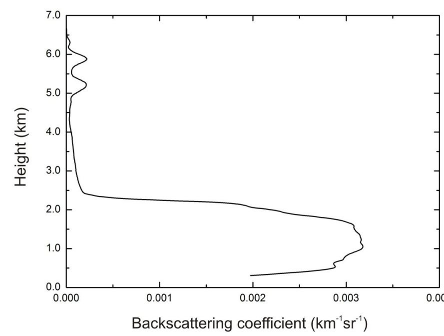

Figure 7: Backscattering coefficient profile for 09/07/2007 at Sao Paulo-SP

3. RESULTS AND DISCUSSIONS

3.1. Sao Paulo - 09/07/2007

It is possible to notice in Figure 4 that the Angstrom exponent calculated for this day was always higher than 1.5, therefore being related to the presence of small particles, potentially coming from biomass burning. Subsequently, active fires (NOAA-15) and backtrajectories (not shown) confirmed. The lidar ratio showed higher values during the morning period, possibly due to the entrance of the burning plume. However, through the analysis of the optical thickness in 532 nm it 5 is not possible to see high values in the morning (smaller than 0.3). The higher values during the evaluated day occurred because of the high aerosol concentration inside the PBL around 16h.

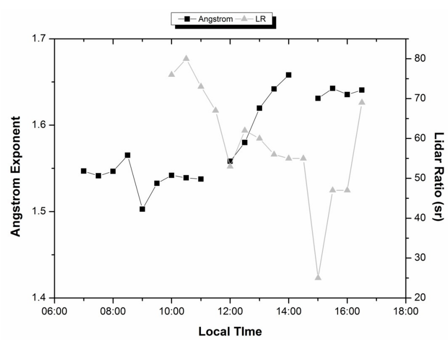

Figure 4: Angstrom Exponent x Lidar Ratio (Sr) for 09/07/2007 at Sao Paulo-SP

Analyzing figure 6 it is possible to see that there were a higher quantity of aerosols of the fine mode, as compared to the coarse mode (approximately double) , possibly due to the entrance of burning plumes at the free atmosphere.

Through Figure 7 it is possible to notice two fine aerosol layers around 5 and 6 km height, which lasted for almost the whole data period measured. The presence of this aerosol layer is easily observed in Figure 8, where the backscattering coefficient in shown along the day. It is shown in red with two layers around 5.2 km and other above, in 5.8 - 6.0 km height.

3.2. Rio Claro - 07/06/2009

Burning plumes can be seen on distinct heights, from surface to 2.2 km. as expected in the case of particulate closer to the surface, after 20:30 there is more backscattered sign, probably due to higher particulate size, as well as interaction with air humidity.

Analysis of the gases/particulate samplers indicated an increase in the concentration, mostly of CO, scattering in 550nm and PM10 during the detection of burning plumes, after 20:30 local time. Due to the fact that some plumes showed by the Lidar do not reach the surface, it is not

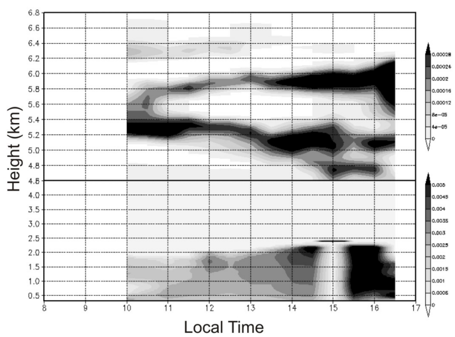

Figure 8: Backscattering Coefficient for 09/07/2007 at Sao Paulo-SP

possible to observe a change at their measurements.

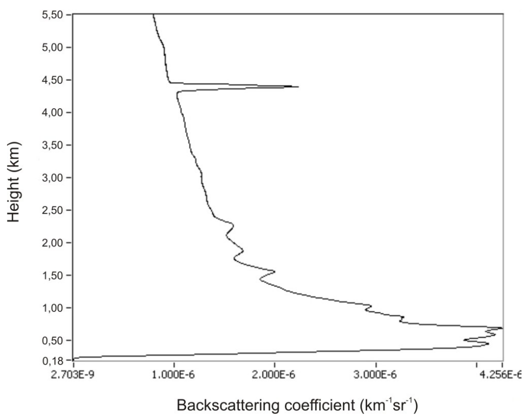

Figure 9: Backscattering coefficient profile for 07/06/2009 at Rio Claro-SP

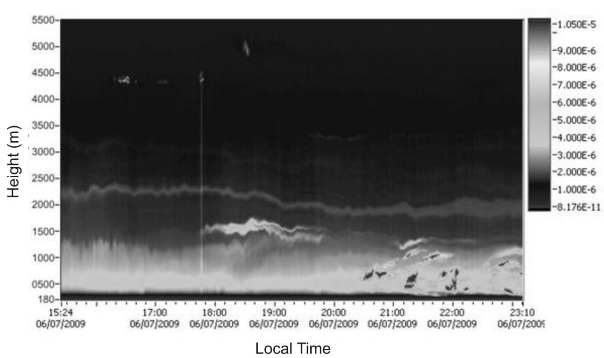

Figure 10: Backscattering Coefficient 07/06/2009 at Rio Claro-SP

4. CONCLUSION

In this work the impact of burnings arriving at the cities of Sao Paulo-SP and Rio Claro-SP in Brazil during the dry period of 2007 and 2009 was analyzed. The confirmation of the origin of the aerosols was made with AERONET data, active fires through NOAA-15 and backtrajectory for the case of the city of Sao Paulo-SP and through impact over several gases and particulate samplers for the city of Sao Paulo.

The burnings of several regions of South America affect the state of Sao Paulo, as it was showed by the studied analysis for the regions closer (Rio Claro-SP) and distant (Sao Paulo-SP) of the sources through elastic Lidar systems. Therefore, mitigating actions should be taken by the government and sugarcane producers concerning these burnings.

5. ACKNOWLEDGEMENTS

The authors would like to thank the supporting agencies Conselho Nacional de Desenvolvimento e Pesquisa (CNPq) and Comissao Nacional de Energia Nuclear (CNEN), Fundacao de Amparo a Pesquisa do Estado de Sao Paulo for financing the research being carried at the Institutes involved in this study. The authors also acknowledge to PETROBRAS to financial support to the project 380/07.

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