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Aerosols monitoring in Rio Claro, Brazil: Using lidar and air pollution analyzers

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ABSTRACT:

Brazil has an important role in the biomass burning aerosol activity. During the Dry Season (June-September) of 2009 an aerosol profiling campaign was carried out using a backscattering and Raman lidar system in Rio Claro-SP, Brazil (22°23'S and 47°32'W). The main goal of this campaign was to observe the biomass burning aerosol load due to sugarcane crops and also study the air dispersion conditions, planetary boundary and mixed layer daily evolution. In this paper we aim to present the preliminary results of the influence of this type of aerosol over the city of Rio Claro-SP, Brazil and one case study to evaluate the aerosol profile in a biomass burning episode that occurred in July, 2009. On July 15 an intense burning was observed about 300 m away from the lidar location. Throughout the measurements it was observed that the plumes reached up to 900 m, and that there was a time gap between the plumes. The gas analyzers showed a strong influence of this burning as it was noticed in the measurements of CO, NO_x and nephelometer, whereas the PM10 did not have due to this burning, possibly because the particulate was deposited further from the emission source, not being detected by the equipment..

Key words: Biomass Burning, Aerosol, Pollution.

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1. Introduction

Because of the non-homogeneity in the space distribution of burnings, Brazil has great constrast between source and non-source burning regions. These contrasts are resulting from climatic (period of dry weather) and regional (prevailing of farming and cattle raising) factors. However, in these regions of few burnings, sometimes high concentrations of trace gases generated by burnings are measured. In other words, the regions with burnings, or source regions, export gases generated in burnings to non-source regions [1].

Brazil has an important role in the biomass burning, with the detection of approximately 135.000 burning spots in 2008, according to CPTEC/INPE. Most of these spots occur in the southern part of the Amazon basin during the dry season (from August to November) 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 São Paulo, being a strong contribution to the bad air quality in the region. In the state of São Paulo, the main land uses are pasture and sugarcane crop, which 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 influence of the sugarcane burning may be seen in the composition of fine and coarse particulate, as well as in the variation of black carbon concentration in Piracicaba-SP (40 *km* from Rio Claro-SP). Beside this study demonstrated that these burnings strongly contribute to the aerosol structure in the studied region, with about 60% of the aerosol mass on PM2.5, 64% of the black carbon mass and 25% of the coarse aerosol mass ($2,5 < d < 10$) [2]. Even with the reduced atmospheric residence time of particulate matter from the sugarcane burning (from days to some weeks, depending on its average size), without the occurrence of wet deposition the particulate matter might be spread over large distances on the Amazon region burnings [3].

In Brazil, there are only two operating lidar system: the first one is devoted to stratospheric studies [4] and the second one, an elastic backscatter lidar system, is devoted to tropospheric aerosol profiling for air pollution applications [5,6].

During the period from 15/06 to 15/10/2009 a data collection campaign was made in the city of Rio Claro-SP (Fig. 1), region surrounded by sugarcane crops.

Fig. 1. Site Location.

The campaign had a Raman Lidar, gas (CO, NO_x, O_3, SO_2, CH_4) and particulate (PM10, PM2,5) analyzers, as well as a SODAR and a S band Radar (located in Bauru, 160km away from the site). This work intends to show some preliminary results of this campaign, with emphasis on the results with the lidar system and gas/particulate analyzers. On 15/07/2009 an intense burning was observed at the UNESP/Rio Claro campus (where the equipment were located) that was advected over the equipment site.

2. Lidar system description

The laser source used is a pulsed Nd:YAG laser emitting short pulses at 1064, 532 nm. The laser source is factory preset for maximum output energy at 532 nm, 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 660 V (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. The principal functional characteristics of the system are:

- Repetition rate: 20 Hz.
- Pulse energy at 532 nm: 120 mJ.
- Pulse duration at 532 nm: 6.7 ns.
- Laser beam diameter: 21 mm.
- Divergence: <0.17 mrad.

3. Gases analyzers description

In the data campaign CO, O_3, NO_x, CH_4 and non-methane as well as SO_2 analyzers from ECOTECH were used. A PM2.5 and PM10 monitoring system was also used, as well as a single wavelength integrating nephelometer Aurora that will measure, continuously and in real-time, light scattering in a sample of ambient air due to 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 10º and -170º and <0.25 to 2000 Mm^{-1} measurement range. The main functional characteristics of the gas analyzers are given in Table I.

Table I
Functional characteristics of the gas analyzers

	O_3	CO
Method	UV absorption	Gas filter correlation
Ranges	0-20ppm	0-200ppm
Noise	<0.25ppb	<0.20ppb
Response time	30 seconds to 95%	60 seconds to 95%

	NO_x	SO_2
Method	Gas phase chemi-luminescence	UV fluorescence
Ranges	0-20ppm	0-20 ppm
Noise	<0.2ppb	<0.15 ppb
Response time	15 seconds to 95%	60 seconds to 95%

4. Results and discussions

Table II is a summary of the data campaign until 20/09, but only for the days on which both systems (lidar and analyzers) were working perfectly. It is also important to stress that the gases values shown on the table and from the nephelometer are the maximum values measured during the data collection period, indicated on the table.

It can be seen that 25% of the days were contaminated by low and medium clouds at the site, about 39% had cirrus clouds and in more than half of the days the systems observed burnings. On the table, it is also possible to notice that in the cases where evidence of burnings were detected, there are high values of measured gases and the nephelometer (only the maximum shown in the measured period).

The height of the detected burnings varied between 0.18 km (minimum height detected by the used Lidar) to 3.00 km, but, as expected, in the cases where the burning plume was situated in higher altitudes the measured gases did not have a good correlation with the data measured by lidar.

Table II
Campaign summary

Date	Start time	Raman	Final Time	Lower/ Medium Clouds	Cirrus Cloud	Biomass burning	Range (km)	CO (ppb)	NO (ppb)	NO_2 (ppb)	NO_x (ppb)	SO_2 (ppb)	PM10 (ppb)	Backscattering Sr^{-1}
06-jul	15:25	17:59	23:10	No	Yes	Yes	0,18-2,20	2930,2	13,39	22,81	34,35	8,79	0,21	112,52
07-jul	15:11	18:08	23:10	No	No	Yes	0,40-1,60	3605,4	25,79	24,75	44,94	8,25	0,26	158,5
08-jul	15:36	18:01	18:07	Yes	No	No		2808,1	6,66	15,51	22,17	7,9	0,19	104,12
09-jul	16:14	-	23:01	Yes	Yes	Yes	0,18-2,60	2991,5	9,04	28,2	33,7	9,04	0,32	353,18
13-jul	16:05	18:02	0:08	No	Yes	Yes	0,18-1,50	3465,8	8,6	38,32	45,11	8,66	0,16	140,25
14-jul	16:02	18:04	23:52	No	Yes	Yes	0,15-1,60	3064,7	14,16	35,81	46,13	12,82	0,41	162,05
15-jul	15:22	17:48	0:05	No	No	Yes	0,15-1,60	4083,4	13,25	55,48	62,79	13,86	0,48	1199,9
16-jul	16:03	17:47	0:17	No	Yes	Yes	0,15-1,60	3039,2	7,16	18,34	22,31	8,3	0,61	356,33
17-jul	10:27	-	17:52	Yes	Yes	No		3125,7	13,07	20,74	29,15	8,17	0,38	85,87
20-jul	7:37	17:49	23:13	Yes	No	Yes	0,13-0,60	2990,7	17,09	43,27	53,67	12,74	0,16	103,62
21-jul	16:15	17:50	0:37	No	Yes	Yes	0,13-1,70	4316,4	10,45	35,51	43,24	8,45	0,28	666,63
22-jul	15:07	17:46	23:35	No	Yes	Yes	0,15-2,80	3386,2	5,23	39,96	45,12	9,22	0,37	192,18
29-jul	17:01	18:20	21:46	Yes	Yes	Yes	0,22-1,50	3494	46,93	19,95	58,07	9,26	0,17	156,56
31-jul	17:21	18:11	22:22	Yes	Yes	Yes	0,25-0,85	3845,4	14,22	29,51	34,81	9,88	0,22	105,67
03-ago	17:46	18:17	22:21	Yes	No	Yes	0,15-1,60	3989,1	49,71	36,72	68,66	8,68	0,4	337,23
04-ago	15:20	18:17	22:22	No	No	Yes	0,15-3,00	3532,8	15,41	36,12	47,13	10,34	0,46	219,33
09-ago	15:57	17:59	20:36	Yes	Yes	Yes	0,15-2,60	4952	9,41	20,8	25,13	10,08	0,4	113,78
02-sep	16:37	18:31	23:01	No	No	Yes	0,15-0,90	3259,3	13,65	31,48	40,63	8,95	0,44	152,42
07-sep	18:18	18:18	22:18	No	Yes	Yes	0,15-3,00	3359,4	3,39	31,68	34,43	13,49	0	126,13
14-sep	16:39		17:54	Yes	No	No		3495,4	13,77	38,71	48,8	13,27	0	144,86
15-sep	8:44	17:56	7:05	No	No	Yes	0,15-1,00	3251,4	8,91	38,56	46,19	10,53	0	160,91
16-sep	16:54	18:24	0:32	No	Yes	Yes	0,20-0,60	3391,6	13,82	42,41	48,33	10,45	0	255,03
17-sep	17:12	18:15	0:39	No	Yes	Yes	0,20-0,55	3622,3	51,87	532,17	532,78	11	0	251,67

On Fig. 2 there is an example of burning detected by the lidar for 06/07. 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.

The gases measured for the day showed above can be seen on Fig. 3. It is possible to see the measurements of CO, NO, NO_2 and NO_x, SO_2, scattering in 550 nm and the concentration of PM10. The grey vertical bars shown on each figure refers to the time on which the lidar system was operating for the day. It can be seen that in most graphs an increase in the concentration is showed after 20:30, period in which the lidar system possibly detected material coming from burnings close to the surface. As already said, due to the fact that some plumes showed by the lidar do not reach the surface, it is not possible to observe a change at them in the graphs below.

Figure 4 shows the lidar range corrected signal obtained by the lidar system at 532 nm for 07/15/2009 until 3 km between 15:22 and 17:40 (left) and between 17:48 and 00:05 (right). It is possible to observe, mostly in the left figure, aerosol plumes close to the surface (until about 1 km) between 15:22 and 16:40 (local time). A remarkable characteristic is that the plumes were emitted and the lidar system detected gaps between them. In the right figure it is possible to see from 20 h the detection of material probably coming from the burnings of the surrounding area.

Figure 5 shows the backscattering coefficient calculated for the data showed in the previous figure. It is possible to observe high values of these coefficients in the region and in the period of plume entrance over the system. Similar characteristic was also observed for the entrance of burning material from 20:00 local time, as shown in the previous figure. It can be seen a decrease in the plume maximum height along time; this happened due to the intervention of teams trying to control the fire, causing a decrease in the burning and consequently in the emitted plume.

The gas analyzers, nephelometer and particulate matter 10 μm is shown on Fig. 6. The grey bars on each graph refer to the period that the lidar system was operating. The high values in the beginning of the lidar system operation are easily noticed in practically all the graphs. It can be pointed out especially the scattering in 550 nm measured by the nephelometer. It is possible to notice very high values in the beginning of the lidar system measurements; however, when the plume entrance occur at 20:00 measured by the lidar system, it is not possible to notice a significant change in the values.

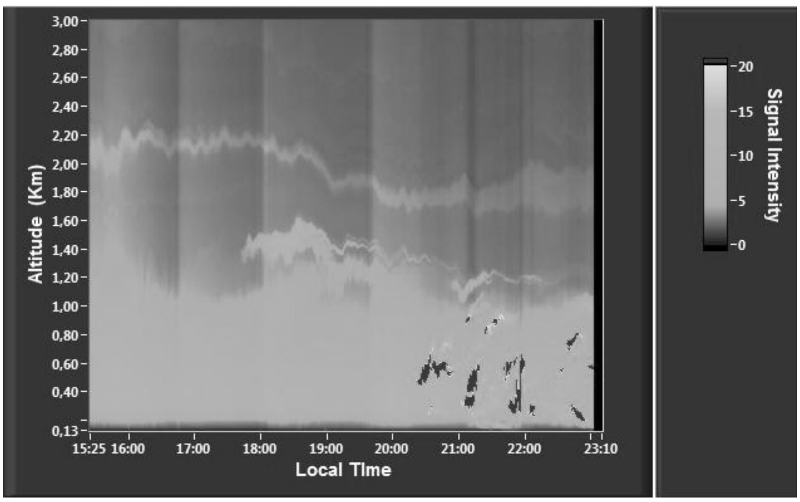

Fig. 2. The lidar range corrected signal from MSP-Lidar system for 07/06/2009.

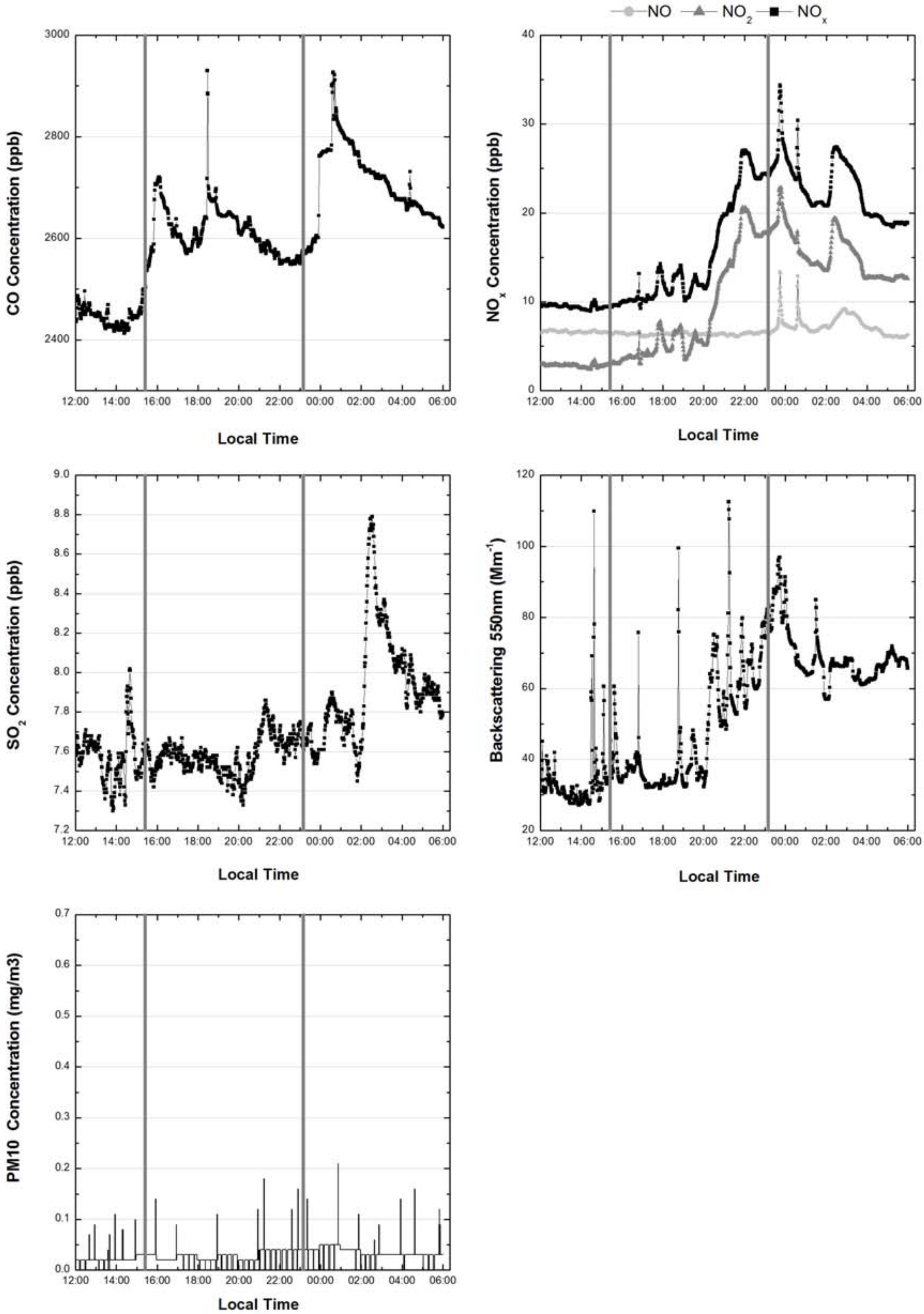

Fig. 3. Gases and backscattering by nephelometer measurements for 07/06/2009.

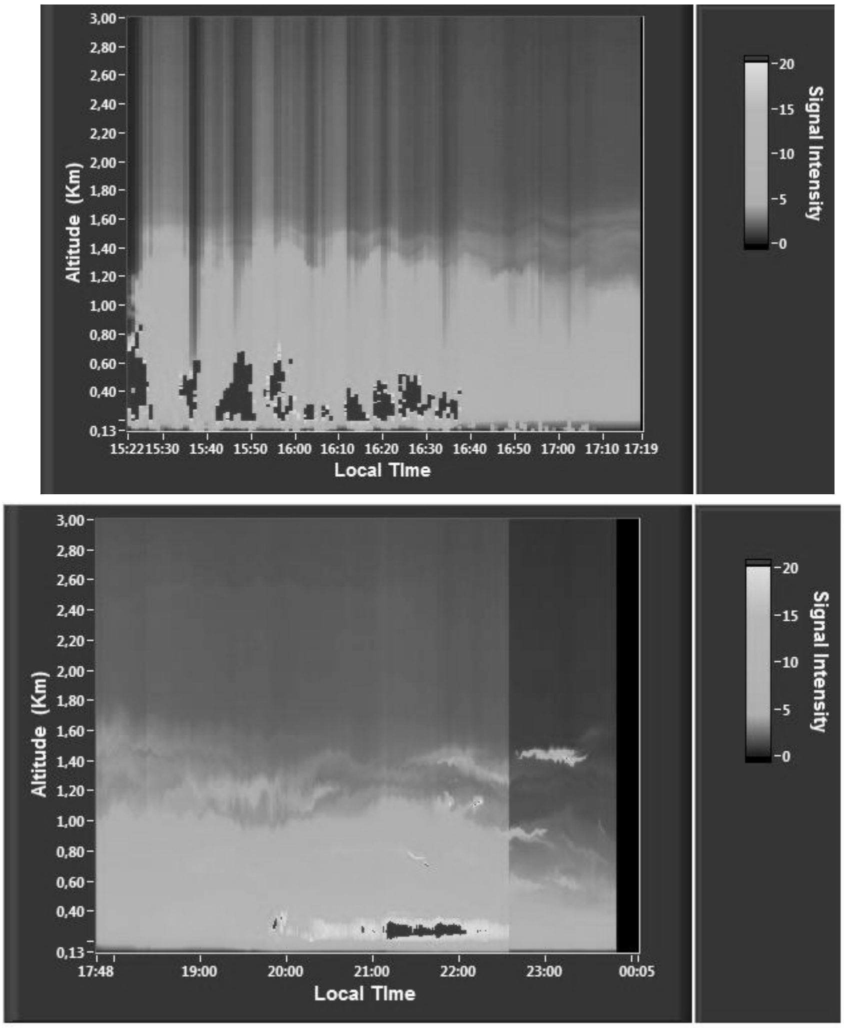

Fig. 4. The lidar range corrected signal from lidar system for 07/15/2009.

5. Conclusions

In this paper we presented the first preliminary results from the data collected in Rio Claro – SP, with the purpose of studying the impacts of burnings in the surroundings of the city. It is possible to observe a great amount of burning material advected over the region.

The burnings detected by the Lidar system varied from 0.18 km (minimum height detected by the system) and 3 km. Possibly the entrance of burning plumes detected in smaller heights was due to the burnings that occurred over regions closer to the measurement site, whereas the opposite occurred for the burnings detected in higher heights.

The gas analyzers, nephelometer and particulate matter samplers showed in most of the cases good correlation with the data presented by the lidar, mostly when, through the lidar system, burnings were observed close to the surface. In general, the best correlations were noticed for CO, NO_x and scattering, whereas the worst were for SO_2 and PM10. For particulate matter, the reason for this low correlation is because of the material resulting from the burnings not being deposited over the region in most of the detected cases.

On July, 15th, 2009, an intense burning was observed inside the UNESP/Rio Claro campus, approximately 300 m away from the equipment set used in the project.

Through lidar, the maximum height reached by the burning plume observed was 900 m, and the plumes had gaps between them. The duration of the event was of about 01:10 h. The reason for the decreasing of the burning plume throughout the period was the action of teams in the attempt to extinguish the burning. The plumes showed high values of backscattering coefficients measured by the lidar, and affected several gases (CO, NO_x) and the scattering measured by the nephelometer in 550 nm However, an increase in the values of PM10 was expected, which was not observed. Possibly, this increase in the values of PM10 occurred due to the proximity of the burning, so that the particulate matter was deposited in further regions.

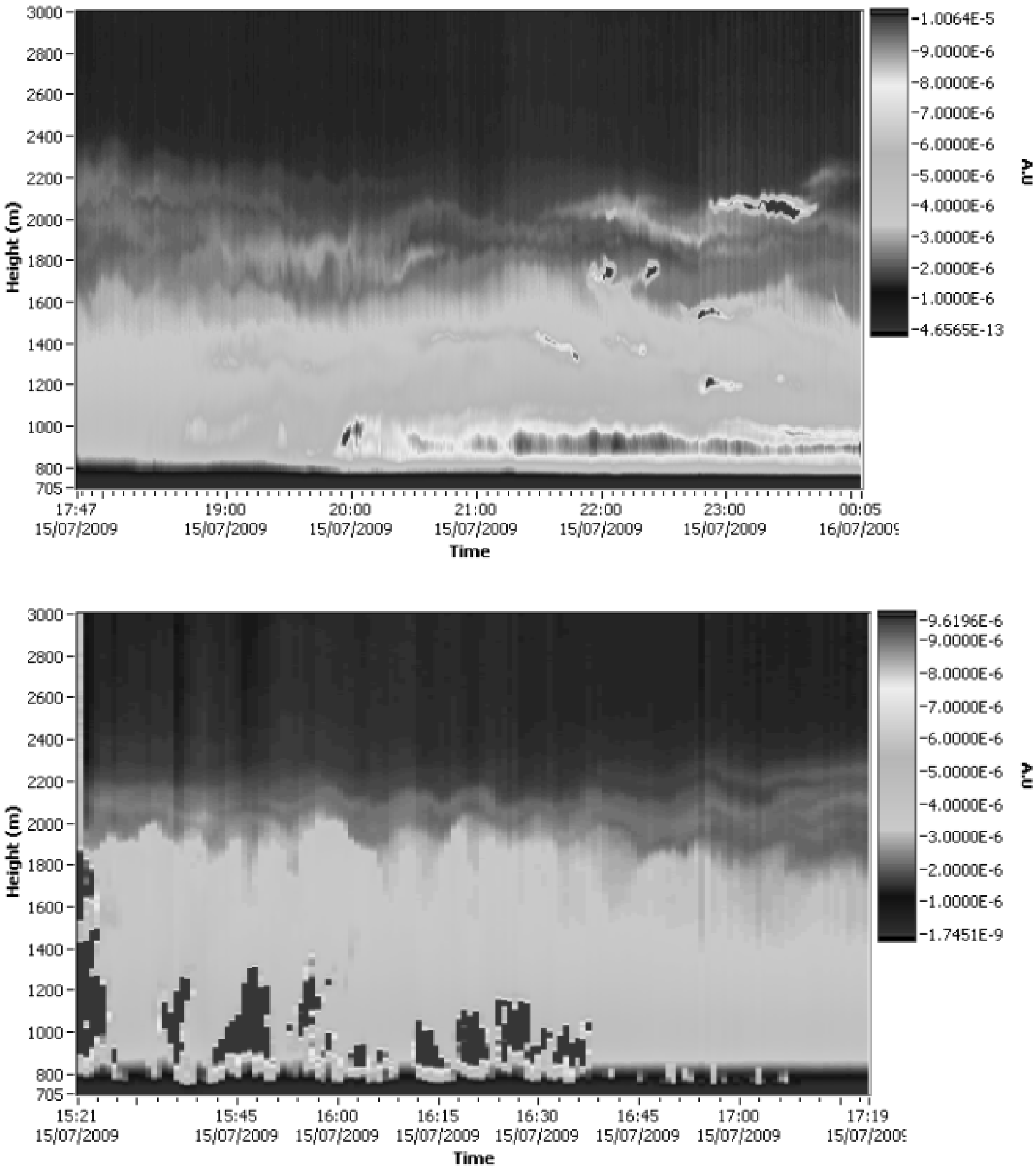

Fig. 5. The backscattering coefficient from lidar system for 07/15/2009.

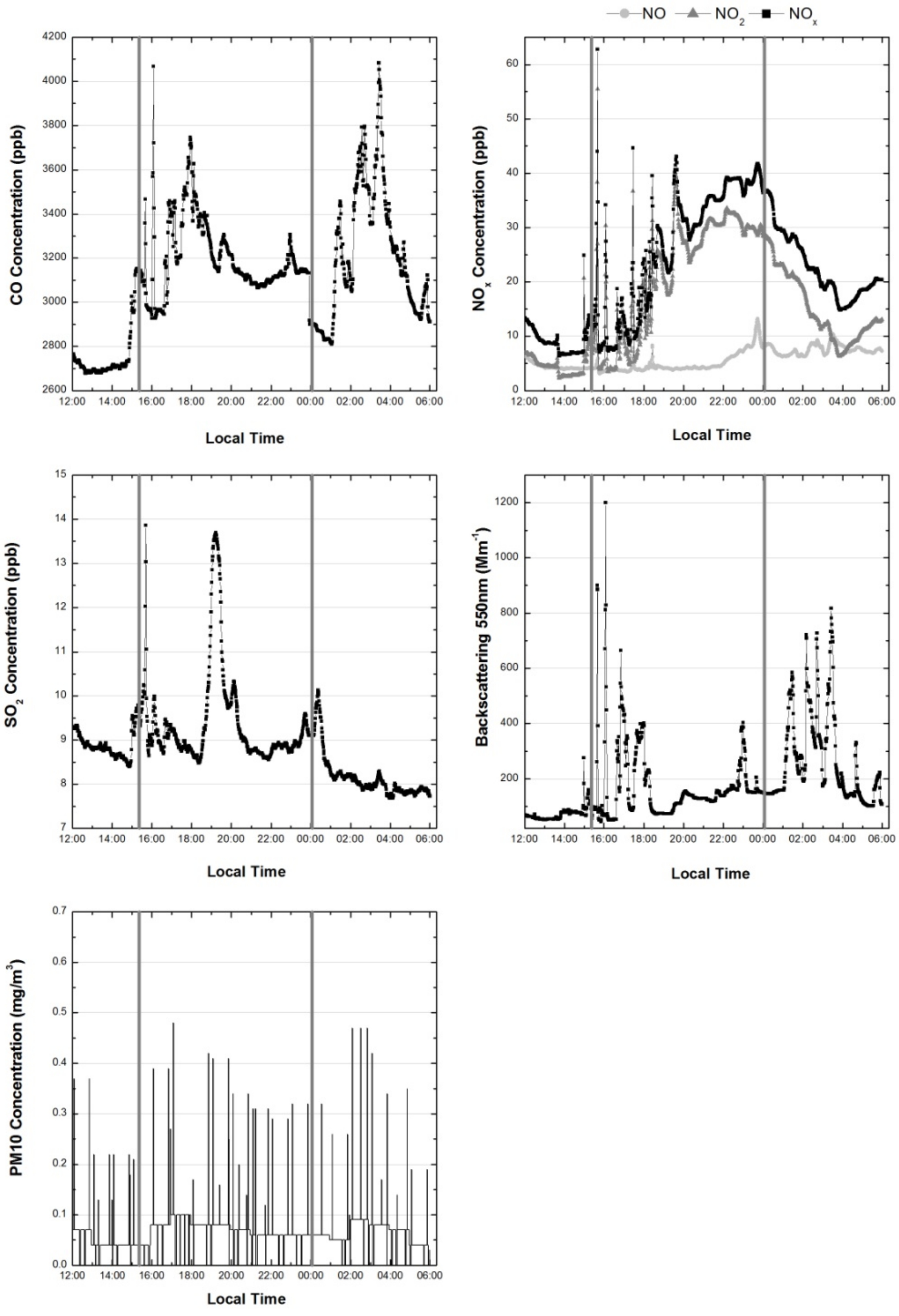

Fig. 6. Gases and backscattering by nephelometer measurements for 07/15/2009.

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