Evaluating the capabilities of the CEILAP tropospheric lidar, for stratospheric aerosols measurements.

René Estevan[(1)] , Juan Carlos Antuña[(2)] and Mario B. Lavorato[(3)]

[(1)] *Camagüey Lidar Station, Meteorlogical Center of Camagüey, INSMET, Carretera Nuevitas Km 7½ PO Box 134, Camagüey 70100, rene@met.cmw.inf.cu.*
[(2)] *Camagüey Lidar Station, Meteorlogical Center of Camagüey, INSMET, Carretera Nuevitas Km 7½ PO Box 134, Camagüey 70100, anadelia@caonao.cu.*
[(3)] *División Radar Laser, CEILAP (CITEFA-CONICET), Juan B. de La Salle 4397, B1603ALO Villa Martelli, Argentina, mlavorato@citefa.gov.ar*

ABSTRACT

The lidar located at CEILAP (34.6 ºS and 58.5 ºW), Buenos Aires, Argentina, was designed for atmospheric boundary layer, tropospheric aerosols and cirrus cloud measurements. In the present paper we evaluate the potentiality of such lidar for lower stratospheric aerosols measurements. We processed two lidar profiles using the appropriated software, developed at Camagüey Lidar Station. The results show clear evidence of the presence of stratospheric aerosols in the backscattering profiles above the tropopause level. We conducted a comparison of one of the profiles with coincident in space and time SAGE II extinction profiles. Comparison results corroborate the lidar possibilities for such measurements, as well as the effectiveness of the processing algorithm. Also we document the advantage to use aerological sounding, to derive the molecular backscattering profile, over the use of statistical density models, based on means sounding or standard atmosphere.

1. INTRODUCTION

The CEILAP lidar (34.6 °S and 58.5 °W), Buenos Aires, Argentina, has been carrying out measurements of atmospheric boundary layer (ABL), tropospheric aerosols (TA) and cirrus clouds (CC). Table 1 shows the lidar characteristics [1]. The goal of the present work is to determine the CEILAP lidar capabilities to retrieve information from stratospheric aerosols. Two measurements were employed for such purpose, achieved one November 16, 2000 at 02:20:55 and the other on June 22, 2001 at 02:04:00 (both in local time).

The measurements processing was conducted with the "BackScatter Process Application" (BSPA) software, designed by the Camagüey Lidar Station (CLS) team [2]. For processing procedure, the density model obtained for this station was employed [3], as such as aerological sounding carried out in Buenos Aires, the same day of the lidar measurements or near to this. In the aerological sounding case, it was employed until the heights were aerological sounding data are available. From this height to the lidar profile maximum height, was employed the density model from CLS. The aerological sounding corresponds to November 17, 2000 at 00:00 GMT and June 22, 2001 at the 12:00 GMT.

Table 1. Principal characteristic of CEILAP lidar.

Parameters	Magnitude
Laser, wavelength	Nd:YAG, 532 nm
Energy	300 mJ (max)
Frequency	10 Hz
Mirrors diameter	50 cm – Newtonian 8 cm – Cassegrain
Field of view	<1.5 mrad
Detector	Photomultipliers
Signal processing	Analogical (photocurrent)

2. RESULTS

2.1. Evaluating the processing capabilities with BSPA and the impact in sounding use.

The Fig. 1 shows the aerosols backscatter coefficient profiles for 532 nm wavelength, corresponding to both measurement days.

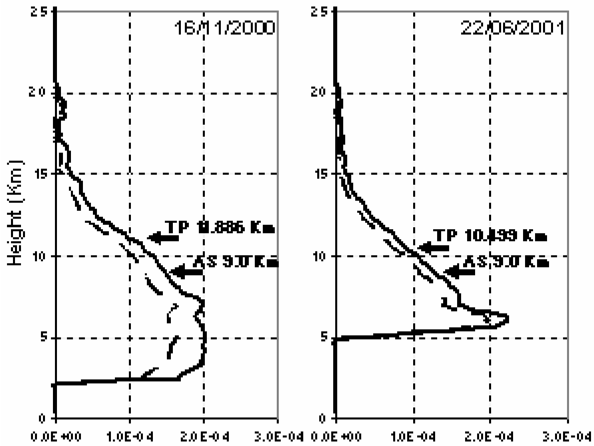

Fig. 1. Backscatter Aerosols Coefficient, calculated with aerological sounding and density model.

In both profiles the height that the aerological sounding (AS) reach and the tropopause (TP) height are marked with arrows. With dashed line it is shown the calculated profile with density model, and with continuous line it is represented the achieve process employing aerological sounding.

Differences between both results using different data for deriving the molecular density are clearly showed. It is evident the overestimation on density values for the case when density model is used for both measurements dates. Is evident too, despite of the aerological sounding reach only 9 Km of height, that the calculated density values using aerological sounding, influence the rest profile calculus.

From above mentioned facts it is clear the necessity to use, whenever it is possible, of the aerological sounding form same measurement day or near to this. In Fig 1, can be appreciate too the presence of stratospheric aerosols, which corroborate the CEILAP lidar potentiality for detecting this particles, as such as, the possibility of BSPA software for the measurement processing at this lidar site. Although, in the case of measurement process with density model, it must be preferably, employing a density model calculated for the CEILAP lidar site.

Table 2 shows the density values calculated from aerological sounding data and values belonging to density model, employed for the measurements processing with BSPA software. The error magnitudes can be appreciate, expressed in percent and calculated from Eq. 1. They have significant values in most of the cases.

Table 2. Error percent between density values, calculated from both sounding and model.

	Z (m)	Density (kg/m^3)		Error (%)
		Sounding	Model	
16/11/2000	0	1.202	1.1873	1.24
	3000	8.79E-01	8.80E-01	-0.13
	6000	6.57E-01	6.46E-01	1.77
	9000	4.80E-01	4.69E-01	2.49
22/06/2001	0	1.2975	1.1745	10.47
	3000	9.09E-01	8.78E-01	3.60
	6000	6.63E-01	6.47E-01	2.52
	9000	4.86E-01	4.68E-01	3.81

$$\delta = \frac{\rho_{SOUNDING} - \rho_{MODEL}}{\rho_{MODEL}} \cdot 100 \qquad (1)$$

2.2. SAGE II comparison

To compare obtained results with other instruments, in this case the SAGE II satellite, were searched for coincident measurements between SAGE II and the CEILAP lidar. As temporal coincident criteria was establish ± 72 hours and as spatial coincident criteria ± 6 degrees in latitude. In longitude case the criteria was relaxed to all the longitudes around the CEILAP latitude. For measurement on November 16, 2000, no coincident measurement was found. However, for June 22, 2001, 6 coincident measurements were found according to established coincident criteria. The Fig. 2 shows the coincident measurements points, as such as the CEILAP lidar location.

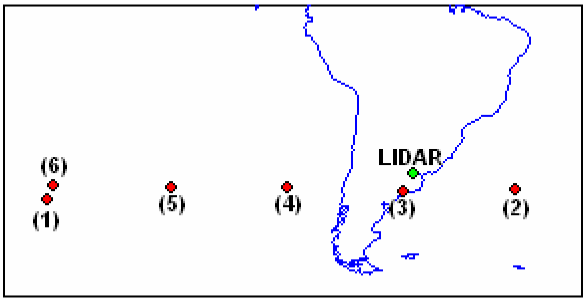

Fig. 2. SAGE II coincident measurements locations and CEILAP lidar location.

In Table 3 appears the SAGE II coincident profiles information. For this comparison was employed the version 6.20 of SAGE II data set, available at the instrument web site [4,5].

Table 3. SAGE II coincident profiles, belonging to June 2001.

No.	Day	Time	Lat. (S)	Lon. (W)	TP (Km)
1	24	01:39:37	40.43	134.71	9.91
2	24	19:17:16	38.44	37.55	10.32
3	24	20:53:25	38.23	61.37	11.79
4	24	22:29:35	38.02	85.23	12.98
5	25	00:00:54	37.87	109.28	10.83
6	25	01:45:53	37.63	133.08	10.14

To compare both instrument profiles, it was necessary integrate the backscatter profile to a resolution of 500 meters, and then, convert the integrated backscattering profile to extinction profile [6]. For this, the Jaeger method was employed but, upon not having the Jaeger coefficient values neither Angstron exponents for measurement dates, a mean values was calculated for the 1980 – 1998 period [7,8]. Table 4 shows the values for each height range.

Table 4. Jaeger Coefficient mean values and Anstrong Exponents, for 1980-1998 period.

	TP-15	15-20	20-25	25-30
Jaeger Coeficient	38.8	41.8	49.7	48.4
Ángstrom Exp. 694nm	-0.7	-0.8	-1.3	-1.8
Ángstrom Exp. 1024nm	-1.1	-1.3	-1.8	-2.1

Then the extinction profiles for 532 and 1024nm wavelength respectively were calculated, from lidar backscatter aerosols coefficient. The resulting aerosol extinction profile was compared with SAGE II coincident profiles.

Fig. 3 show both, SAGE II (—o—) and CEILAP lidar (——) profiles, at 532nm wavelength. In the upper – right corner of each graphic profile, appear additionally, a number corresponding to the SAGE II profile number on Table 3. Also appear for each one, the tropopause height contained in SAGE II data set for each profile.

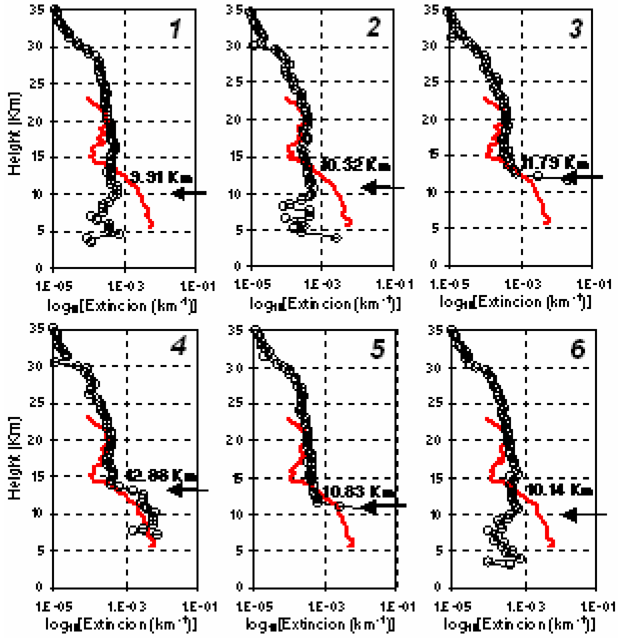

Fig. 3. SAGE II and CEILAP lidar coincident profiles, corresponding to June 2001 at 532nm.

In Fig. 3 can be appreciated the good agreement between SAGE II and lidar profiles, mainly for 24 day at 19:17:16, 20:53:25 and 22:29:35 GMT, almost two day after of lidar measurement. In the case of the last hour, the agreement is better than the rest, these results prove the capability of CEILAP lidar for aerosol measurements, both upper troposphere and lower stratosphere.

The Fig. 4 show the same profiles that Fig. 3 but for 1064nm wavelength. As in 532nm case, the nearest profiles have better agreement than the rest. In particular for 1064 nm, the better agreements correspond to 20:53:25 and 22:29:35 hour of June 24, 2001.

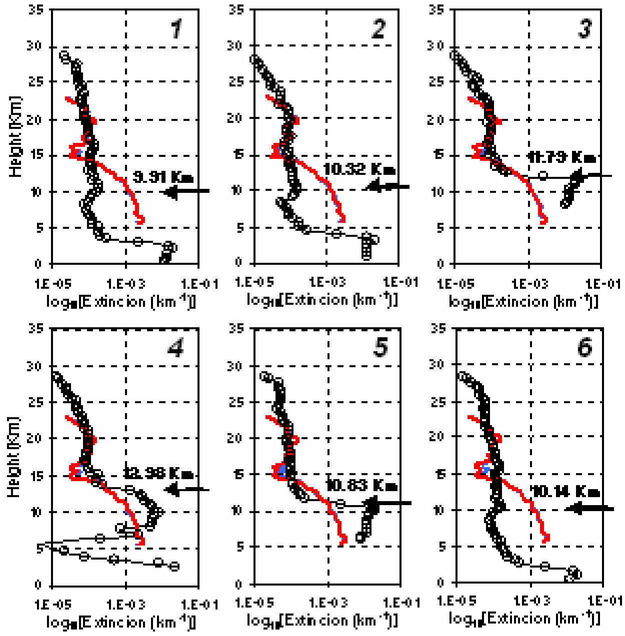

Fig. 4. SAGE II and CEILAP lidar coincident profiles, corresponding to June 2001 at 1064nm.

The absolute mean differences (in percent), between better SAGE II and lidar coincident profiles are presented in Fig. 4, for both wavelength 532nm (a) and 1064nm (b). All profiles corresponding to June 24, 2001. In case of 532nm wavelength (a), the differences percent are under 50% in height range between 17 and 22Km, as average. For 1064nm wavelength case, these behaviors occur starting from 16km.

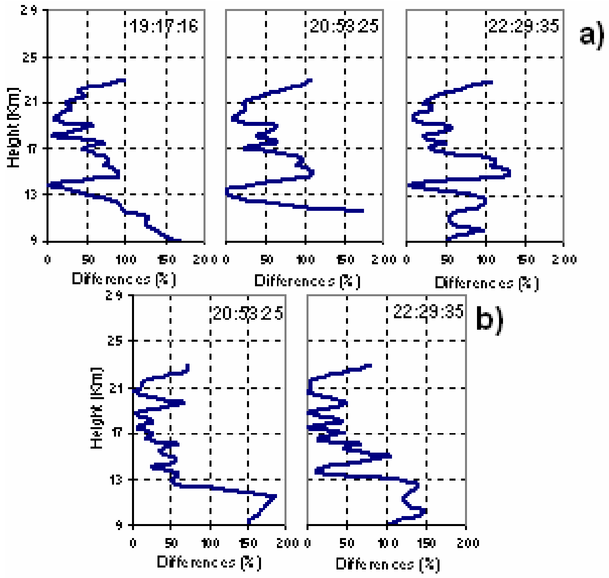

Fig. 5. Percent of absolute mean differences, between extinction profiles of SAGE II and lidar. a) For 532nm wavelength and b) For 1064nm wavelength.

2.3. Comparison with CEILAP radiometer.

The Aerosol Optical Depth (AOD) was calculated from lidar measurement and compared with the CEILAP radiometer AOD [9]. The radiometer is a CIMEL model belonging to AERONET network. Table 5 shows the calculated values for both instruments. In general sense, exist a good agreement between both results, taken into account the differences between wavelengths. Also it is important the fact that lidar derived AOD belongs only from the middle troposphere to the lower stratosphere. The radiometer measured AOD is representative of the whole column from surface to atmosphere top.

Table 5. AOD calculated for both instruments.

	λ	16/11/2000	22/06/2001
Lidar	532nm	2.44×10^{-2}	1.63×10^{-2}
	1064nm	1.26×10^{-2}	7.63×10^{-2}
Radiometer	500nm	3.81×10^{-2}	8.49×10^{-3}
	1020nm	6.61×10^{-2}	4.85×10^{-2}

3. FUTURE WORKS

In the near future (during 2006) a 1064 nm detection system will be mounted and tested for improve tropospheric and stratospheric aerosols data analysis. A new time series lidar acquisitions will be programmed in nighttime for improve signal to noise ratio in aerosols detection

4. CONCLUSIONS

Has been demonstrated the CEILAP lidar potentially for stratospheric aerosols measurements. The BSPA software has demonstrated its capability for processing diverse lidars datasets. It was corroborated the importance of using, whenever it is possible, of aerological sounding due to the influence in atmospheric density calculus, even when profile do not reach all height range.

REFERENCES

1. Lavorato M., et. al. Dual Backscatter Lidar is Operated in Buenos Aires (34.6 S / 58.5 W) for Determine the Atmospheric Parameters in Cirrus Clouds, Tropospheric Aerosols and ABL, *Proceeding 21 Lidar Remote Sensing in Atmospheric and Earth Sciences*, 75-78, Jul (2002).
2. Antuña J.C., Estevan R. y Barja B., ICT: Caracterización de los aerosoles en la estratosfera y la troposfera alta en la región del Gran Caribe, bajo condiciones de fondo. Informe Científico Técnico, Programa: Los Cambios Globales y la Evolución del Medio Ambiente Cubano, Subprograma: Variabilidad Climática, 63 pag, Sep. (2004).
3. Antuña J. C. y R. Aroche, Modelo Estadístico de algunos parámetros, *Revista Cubana Meteorología*, (1991).
4. http://www-sage2.larc.nasa.gov/data/v6_data
5. ftp://ftp-rab.larc.nasa.gov/pub/sage2/v6.20
6. Estevan R., J. C. Antuña, "Updated Camagüey lidar dataset: validation with SAGE II", submitted to *Revista de la Sociedad Española de Optica*.
7. H. Jäger and T. Deshler, Lidar backscatter to extinction, mass and area conversions for stratospheric aerosols based on midlatitude balloonborne size distribution measurements, *Geophysical Research Letters* 29, No. 19 (2002).
8. H. Jäger and T. Deshler, Correction to: Lidar backscatter to extinction, mass and area conversions for stratospheric aerosols based on midlatitude balloonborne size distribution measurements, *Geophysical Research Letters* 30, No. 7, (2003).
9. AERONET – Aerosol Robotic Network – gsfc NASA – CEILAP-BA Station. http://aeronet.gsfc.nasa.gov/

Acknowledgments

This work has been supported by the Cuban National Climate Change Research Program grant 01303177 and by the grant CU/PA04-UXIII/014 from the Scientific and Technology Cooperation Program between SECYT (Argentina) and CITMA (Cuba). Authors thank the NASA Langley Research Center and the NASA Langley Radiation and Aerosols Branch for providing the SAGE II dataset.