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The LITE correlative measurements campaign in southern Italy: preliminary results

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Abstract. In conjunction with the LITE mission an intensive LIDAR measurement campaign was carried out in Napoli ($40°50'N - 14°10'E$, at sea level) and Potenza ($40°36'N - 15°44'E$, 820 m a.s.l.). The LITE experiment, flying on board the Space Shuttle in the period September 10–19, 1994, represents the first attempt to perform global coverage LIDAR measurements from space. The LITE experiment was planned to provide measurements of clouds, tropospheric and stratospheric aerosols, stratospheric temperature and density, characteristics of the planetary boundary level as well as surface albedo. Because of the relative distance between LITE ground tracks and the two southern Italy validation stations for all passes, measurements carried out in Napoli and Potenza were primarily aimed at validation of LITE stratospheric measurements. In the present preliminary analysis Potenza LIDAR measurements in coincidence with the orbit 128 LITE overpass, are reported and discussed. Potenza LIDAR data show a good agreement with LITE data in terms of aerosol scattering ratio both at 355 nm and 532 nm ($R_{A,355}$ and $R_{A,532}$); the two data sets appearing to be highly correlated. LITE vs. Potenza LIDAR measurements of $R_{A,355}$ and $R_{A,532}$ display a correlation coefficient of 0.72 and 0.86, respectively. Stratospheric aerosol dimensional characteristics are determined starting from the measured values of the Ångstrom coefficient.

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The LIDAR In-Space Technology Experiment (LITE) was developed by the NASA Langley Research Center to fly on the Space Shuttle and demonstrate the utility of LIDAR systems in space. The LITE experiment is based on two identical flashlamp-pumped, Q-switched Nd:YAG lasers and a 1 meter Cassegrain receiving telescope. The two-laser design provides redundancy in case of a failure in one of the lasers. By incorporating doubling and tripling crystals, part of the energy at the fundamental wavelength of 1064 nm is converted to the second (at 532 nm) and third (at 355 nm) harmonics. A full, engineering description of the system is given by McCormick et al. in [1]. LITE flew its first 11-day mission on STS-64 in September 1994, collecting more than 50 hours of data.

The LITE experiment, which represents the first attempt to operate a LIDAR system from space, aimed at two major objectives. The first, a technological demonstration, was to test the system operational performances and demonstrate its effectiveness in the space environment. The second was to perform various scientific investigations (see [2] for example), to show the utility of spaceborne LIDARs to the study of the Earth's atmosphere and environment. Primary atmospheric parameters measured by LITE are clouds, tropospheric and stratospheric aerosols, characteristics of the planetary boundary layer, surface albedo, and stratospheric temperature and density with much greater resolution than is available from current orbiting sensors. These studies are of unique importance to produce a global data set that will be exceedingly useful to the development of global chemistry and climate model parameterizations.

Given the importance of the LITE measurements to scientific studies and to the development of future space-based LIDAR sensors, the validation of the measurements was an essential and crucial part of the experiment. In order to be satisfactorily carried out, a validation effort requires an extensive correlative measurements program in which LITE

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measurements can be compared with coincident measurements occurred over a variety of geographical regions. Further, the comparisons should be made with all the interesting atmospheric features observed by LITE, namely latitudinal distribution of stratospheric aerosols, continental and marine aerosols, desert aerosols, various cloud types, and various surface features.

Instrumentation employed in the validation effort included: i) ground-based and airborne LIDAR systems; ii) solar spectral radiometers for optical depth measurements; iii) "in situ" aerosol samplers for computation of aerosol optical properties; iiii) multispectral visible and infrared satellite imagers.

In particular, about fifty ground-based LIDAR systems carried out comparative measurements all over the world (see [2] for a detailed, although not complete, list). Ideal sensors for comparison with LITE measurements are backscatter LIDARs measuring the same physical quantities, and preferably operating at the same wavelengths as LITE. However, LIDAR measurements at other wavelengths can also provide very useful correlative data for LITE, since they can be modelled to match the LITE measurements if sufficient data on the optical properties of the scattering medium are available.

Five correlative LIDAR systems were operated in Italy during the LITE mission (Firenze, Frascati, L'Aquila, Napoli and Potenza). In particular, our group performed measurements in Napoli ($40°50'N, 14°10'E$, sea level) and in Potenza ($40°36'N, 15°44'E$, 820 m above sea level).

The two LIDAR Systems of Napoli and Potenza meet the characteristics required by the correlative measurements plan. Napoli LIDAR is based on an excimer laser source working at 351 nm (XeF), while the Potenza LIDAR is based on a Nd:YAG laser operating both at 532 nm (second harmonic of the fundamental) and 355 nm (third harmonic). Thus, the LIDAR wavelengths are coincident or very near by the same as LITE.

LITE accomplished 6 overpasses within 2000 km of Napoli and Potenza, 5 of which were night-time. None of the night-time orbits was really close to our validation stations, with the distances ranging between 600 and 1400 km, while the day-time orbit was expected to be closer. Because of these considerable distances, comparisons between LITE and southern Italy LIDAR data were performed in terms of stratospheric parameters only, since little change is expected in them over these distances. However, the LIDAR system in Napoli was optimized to perform tropospheric measurements. Comparisons between LITE and Napoli LIDAR data are then expected to be possible for the day time orbit only (LITE data for this orbit are not available yet). Although the six passes over the two sites were planned between the 11th and 18th September 1994, the ground-based measurements were run from September 10th to September 19th in order to have a more complete statistical sample.

Both Potenza and Napoli LIDARs provided elastic scattering measurements in coincidence with LITE overpasses, in order to provide vertical profiles of the aerosol scattering ratio at 351 nm (Napoli), 355 and 532 nm (Potenza). At other times with respect to LITE passes, the receivers of both systems were tuned to the Raman shifted wavelengths of molecular nitrogen and water vapour, in order to retrieve the vertical profile of temperature (5–40 km) and humidity (0–8 km).

The retrieval of temperature profiles from LITE measurements is still in progress. As a consequence, in this paper we focus on the validation of LITE stratospheric measurements in terms of aerosol backscatter data.

Preliminary results of the data comparison between LITE and Potenza LIDAR in terms of stratospheric aerosol data are discussed for orbit 128 (17 September 1994). Simultaneous elastic measurements at 355 and 532 nm also allowed us to determine the vertical profile of the Ångstrom coefficient, for both LITE and Potenza LIDAR data, thus providing information on aerosol dimensional characteristics.

Fourteen radiosonde launches were also performed in Potenza during the correlative measurement campaign in coincidence with LIDAR operations, as well as solar irradiance measurements during day-time by means of a grating spectrometer. These latter measurements were performed in order to have a characterization of the atmospheric optical properties during the period of the field campaign. LIDAR measurements of water vapour and temperature have been compared with radiosonde measurements. Preliminary comparisons between LIDAR and radiosonde measurements of temperature and water vapour show a satisfactory agreement.

1 Experimental

The LIDAR system located in Napoli (Italy, $40°50'N - 14°10'E$) has been operational since July 1991. It is based on a XeF laser emitting 100 mJ, 10 ns pulses at 351 nm at a repetition rate of up to 200 Hz. The receiver consists of a vertically pointing cassegrainian telescope with a 500 mm diameter primary mirror (combined focal length of 5 m). The resulting field of view is approximately 0.5 mrad.

A quartz beamsplitter deflected about 90% of the collected radiation toward either an interference filter centered on the H_2O Raman shifted wavelength (402 nm) or a second interference filter centered on the N_2 Raman shifted wavelength (382 nm). The remainder of the radiation (10%) reached the third interference filter centered at the elastic backscatter wavelength (351 nm). Such a configuration provided continuous elastic backscatter measurements at 351 nm. In coincidence with LITE overpasses, the N_2 Raman signal was detected, while at other times the H_2O Raman signal was detected. In order to prevent elastic backscatter contamination of the Raman signals, interference filters used for the selection of the Raman bands provided high out of band rejection at 351 nm (10^9 for the 382 nm filter, and 10^{10} for the 402 nm filter).

Detection was accomplished in both channels by means of photomultipliers cooled down to –30 °C in order to reduce dark current. The photomultiplier signals were amplified and sampled by means of both analog-to-digital (A/D) conversion and photon counting. The counting unit was located inside a personal computer acting both as a control unit and a storage device. The main characteristics of the LIDAR in Napoli are summarised in Table 1.

The LIDAR system in Potenza (Italy, $40°36'N - 15°44'E$, 820 m above sea level) has been operational since July 1993. It is based on second (532 nm) and third (355 nm) harmonic beams of a Nd:YAG laser source. The receiver consists of two cassegrainian telescopes of the same type as the Napoli LIDAR. The telescopes are located 10 m apart in order to

Table 1. Characteristics of the LIDAR system in Napoli

Transmitter	
Laser	XeF (Lambda Physics, LPX 100 I)
Wavelength and pulse energy	351 nm, 100 mJ
Pulse duration	15 ns approx.
Pulse rep. rate	up to 200 Hz
Beam divergence	0.5 mrad approx.
Receiver	Cassegrainian telescope
Size	0.5 m diameter primary
Field of view	0.5 mrad
Interference filters	Barr Associates
Wavelength, bandwidth,	351 nm, 1 nm, 10^{-6}
rejection factor	382 nm, 1 nm, 10^{-9} @ 351 nm, 10^{-6} to 1.2 µm
	402 nm, 1 nm, 10^{-10} @ 351 nm, 10^{-6} to 1.2 µm
Photomultipliers	Thorn EMI
Model	9202QB & 9558QB
Signal processing	A/D conversion and photon counting

accomplish both short and long range signal detection simultaneously. The telescope devoted to long range signals has one detection channel, while the radiation collected by the other telescope is split into two channels by means of a 90% beamsplitter. Spectral selection is performed by means of double-grating monochromators, placed at the focus of each telescope. The selected radiation is detected by cooled photomultipliers, the signals of which are finally amplified and sampled by both A/D conversion and photon counting. Because of the non negligible distance between the LIDAR transmitter and the receivers, raw data are corrected through a height dependent geometrical factor.

In coincidence with LITE overpasses, from one hour before to one hour after the passes, the Potenza LIDAR system was devoted to elastic scattering measurements only, with the long and short range telescopes detecting backscattering signals at 523 and 355 nm, respectively. Within ±2 hours of the LITE overpasses, the two monochromators in the short range telescope were used to detect H_2O (407.5 nm) and N_2 (386.6 nm) Raman shifted wavelengths, in order to accomplish water vapour and temperature measurements.

The main characteristics of the LIDAR system of Potenza are summarized in Table 2. Figures 1a and 1b illustrate the block diagrams of Napoli and Potenza LIDARs, respectively.

Data were integrated over 1 minute, corresponding to 90 000 laser shots, in Napoli, and over 3 minutes, corresponding to 12 000 laser shots, in Potenza. The vertical resolution for both was 300 m. According to weather conditions, aerosol backscattering profiles are based on 1–2 hour data averaging.

In Potenza fourteen radiosonde launches were also performed to carry out cross-correlated measurements of temperature, density and water vapour. Solar irradiance spectra at ground level were measured by an optical spectrum analyser in the spectral range 0.40–1.10 µm, with a resolution of about 0.5 nm. The light collecting system consisted of a variable aperture viewing telescope with an eye piece and a precision graticule scale used in conjunction with an adjustable field-of-view selector, allowed focusing of sun light with high accuracy. In the actual measurements, the angle of view was set to 1°. The telescope was coupled to the monochromator via an optical fiber. Finally, the telescope was mounted on a solar tracker, which is basically an equatorial system driven by a stepping-motor, permitting sun tracking

Table 2. Characteristics of the LIDAR system in Potenza

Transmitter	
Laser	ND:YAG (Continuum, NY 60)
Wavelength and pulse energy	1064 nm, 600 mJ
	532 nm, 300 mJ
	355 nm, 170 mJ
Pulse duration	6 ns approx.
Pulse rep. rate	up to 20 Hz
Beam divergence	0.5 mrad approx.
Receiver	two Cassegrainian telescopes (10 m apart)
Size	0.5 m diameter primary
Field of view	0.2–1.0 mrad
Monochromator	Jobin Yvon
Type	double grating
Wavelength, bandwidth, rejection factor	150–900 nm, 1 nm, 10^{-8}
Photomultipliers	Thorn EMI (9202QB & 9558QB), Hamamatsu (R 1826-01)
Signal processing	A/D conversion and photon counting

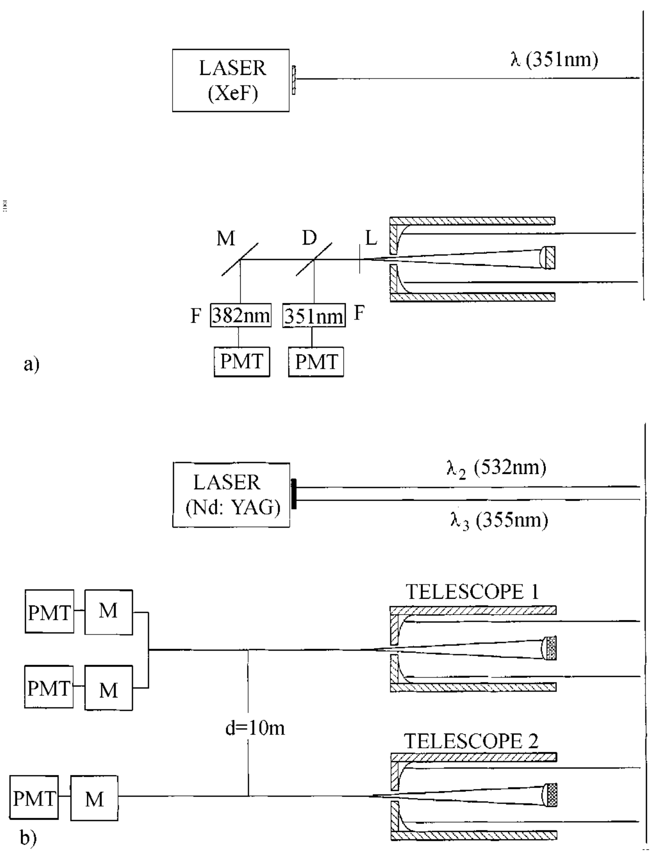

Fig. 1a,b. Block diagrams of the LIDAR Systems in (**a**) Napoli and (**b**) Potenza. L = lens, M = monochromator, PMT = photomultiplier tube, F = filter, D = dichroic mirror, M = mirror

Table 3. LITE overpasses over Napoli ($40°50'N$, $14°10'E$, sea level) and Potenza ($40°36'N$, $15°44'E$, 820 m a.s.l.)

NIGHT TIME			
Orbit	Date	Time (sub-satellite point)	Distance from Napoli and Potenza
Orbit #33	11 September 1994	22:37 GMT ($40.30°N$,$30.2°E$)	1200 and 1300 km eastward
Orbit #34	12 September 1994	00:10 GMT ($40.30°N$,$7.4°E$)	650 and 750km westward
Orbit #128	17 September 1994	20:23 GMT ($40.30°N$,$29.9°E$)	1200 and 1300km eastward
Orbit #129	17 September 1994	21:56 GMT ($40.30°N$,$7.2°E$)	650 and 750 km westward
Orbit #145	18 September 1994	21:45 GMT ($40.30°N$,$4.4°E$)	900 and 1000 km westward
DAY TIME			
Orbit #60	13 September 1994	14:39 GMT ($40.30°N$,$?°E$)	Not available yet.

within a tolerance of 1/10 of a degree. For further details see [3].

For the sake of completeness, we report in Table 3, a summary of the LITE shuttle overpasses over Napoli and Potenza.

2 Data analysis

In what follows we shall devote to stratospheric aerosol data, these being the only presently available from LITE of interest for us.

A brief review of the main principles of LIDAR data analysis is given below.

When monochromatic laser pulses are vertically sent into the atmosphere, a temporal analysis of the backscattered light provides information on the vertical structure and composition of the atmosphere. In the troposphere and lower stratosphere at wavelengths where there is no gaseous absorption, the LIDAR elastic backscattered signal $S(z)$ is determined by two effects: Mie scattering by particles (aerosol) and Rayleigh scattering by atmospheric molecules. $S(z)$ can thus be written as:

$$S(z) = KP_o \frac{\beta_M(z)+\beta_A(z)}{z^2} T^2_{\lambda o}(z) \qquad (1)$$

where z is the altitude above station level, K is a constant term depending on the LIDAR system characteristics, P_o is the output power of the laser at the LIDAR wavelength λ_o, $\beta_M(z)$ is the molecular backscattering coefficient, $\beta_A(z)$ is the aerosol backscattering coefficient and $T_{\lambda o}(z)$ is the atmospheric transmission coefficient at the LIDAR wavelength.

The aerosol backscattering coefficient $\beta_A(Z)$ is defined as:

$$\beta_A(z) = [R(z)-1] \cdot n(z) \cdot \sigma_{Ray} \qquad (2)$$

where $n(z)$, σ_{Ray} and $R(z)$ are the atmospheric number density profile, the Rayleigh backscattering cross-section, and the backscattering ratio, respectively. Data presented in this paper are expressed in terms of the aerosol scattering ratio $R_A(z) = R(z)-1$. $R(z)$ is related to the elastic LIDAR signal $S(z)$ through the expression:

$$R(z) = \frac{S(z)}{S_m(z)} \qquad (3)$$

$S_m(Z)$ represents the molecular contribution to $S(z)$ and takes the form:

$$S_m(z) = C \cdot \varrho(z) z^2 \cdot \exp\{-2\tau_m(z)\} , \qquad (4)$$

where $\tau_m(z)$ is the molecular contribution to the optical thickness and c a calibration factor which can be determined by normalizing the LIDAR signal $S(z)$ to $S_m(z)$ in any aerosol free region above the stratospheric aerosol layer. The mass density profile $\varrho(z)$ is obtained either from radiosonde data or from a standard density profile. Radiosonde launches became available in Potenza in September 1994, just before the LITE campaign. For the present analysis $\varrho(z)$ was determined from standard pressure and temperature profiles. We used the seasonal standard upper air data tabulated by Houghton et al. [4] for September at $40°N$.

The aerosol cloud bottom and top heights, z_b and z_t respectively, can be found through a procedure defined by Di Girolamo et al. [5], with a typical uncertainty of 1–2 data points (300–600 m in the present measurements).

Within the aerosol cloud a height-dependent correction factor has to be introduced in (4) in order to account for aerosol extinction. In the case of large stratospheric aerosol optical thickness (> 0.02), this factor can be estimated through an iterative procedure illustrated in detail by Di Girolamo et al. [5]. In the case of reduced stratospheric aerosol optical thickness (< 0.02), as in the present measurements, the height-dependent correction factor is estimated through a Klett type modified procedure [6]. This procedure is based on the assumption of a constant value within the stratospheric aerosol layer of the extinction-to-backscattering ratio, k_λ. The value of k_λ depends on the laser wavelength and aerosol dimensional characteristics. For background aerosol, k_λ has been found to have values in the range 35–63 sr at 532 nm and in the range 23–41 sr at 355 nm [7].

3 Results

Solar extinction spectra were recorded in Potenza by a grating spectrometer during the whole LITE experiment in order to have at least the gross features of the tropospheric aerosol population near the measuring site for this period.

During this time, the climate at the Potenza LIDAR station could be described as having fair weather with mostly clear skies. There were slight winds from various directions which was a consequence of the uneven heating of the land. Due to the intense solar radiation, the surface air temperature changed

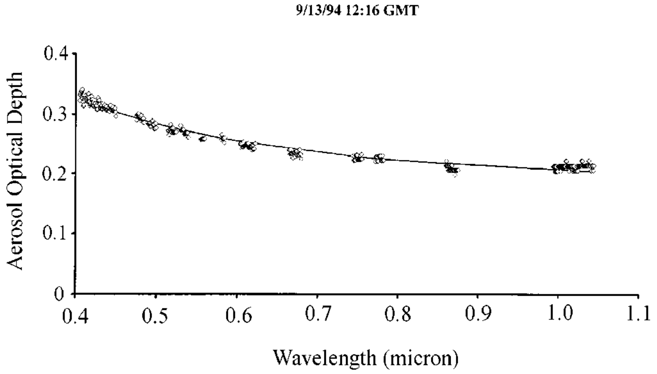

Fig. 2. Spectral aerosol optical depth during the diurnal LITE overpass. The gaps in the curve correspond to non-window regions for which the optical density was not computed

from approximately 20 °C in the morning to above 25 °C in the early afternoon. Consequently, relative humidity dropped during the first part of the day and increased again towards the evening.

Because of such conditions, day-time aerosol optical characteristics were quite constant during the measuring period. Figure 2 shows the aerosol optical depth for September 13, 1994, during the diurnal LITE overpass as derived from the grating spectrometer. The aerosol optical depth at 550 nm is slightly higher than 0.2, which is expected for average conditions.

Figure 3 shows the Shuttle ground track for orbit 128 (September 17, 1994). The closest distance to the Potenza ground LIDAR station is approximately 1300 km eastward (40.3°N,29.8°E) at 20:23:53 GMT.

Figure 4 shows the corresponding measurements performed in Potenza of the aerosol scattering ratio vertical profile, $R_A(z)$, both at 355 nm ($R_{A,355}(z)$, continuous line) and 532 nm ($R_{A,532}(z)$, broken line). The presence of the stratospheric aerosol layer is evident. The two curves have been plotted with different amplitude scales to show their similarities. The signal amplitude difference is due to the dependence of $R_A(z)$ on wavelength. According to the data, the stratospheric aerosol layer base is located between 12 and 14 km, while the top is at 26 to 28 km. Minor structures can be observed at 14.5, 18 and 22 km on both profiles. The good agreement between the data taken at two laser wavelengths highlights the internal consistency of the data. Features above 30 000 m are the result of statistical noise and have no physical relevance.

In the data retrieval, different values of the *extinction-to-backscattering ratio*, k_λ, were considered. This introduced slight changes in the aerosol layer characteristics. Based on a

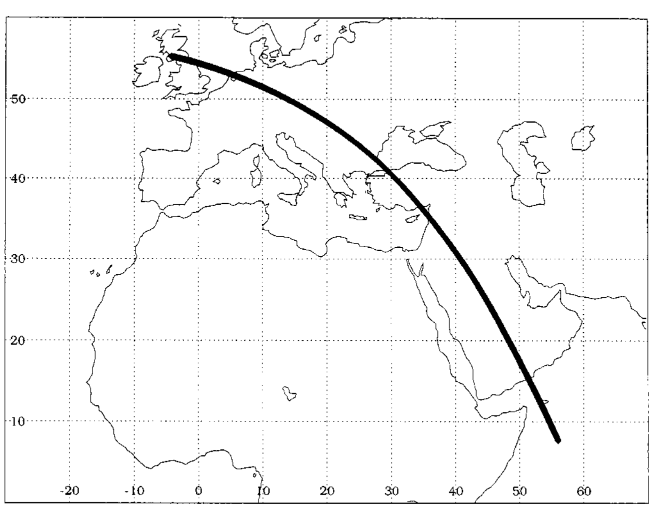

Fig. 3. Shuttle ground track for orbit 128 (September 17, 1994); the closest point to Potenza is approximately 1300 km eastward (40.3°N,29.8°E) at 20 : 23 : 53 GMT

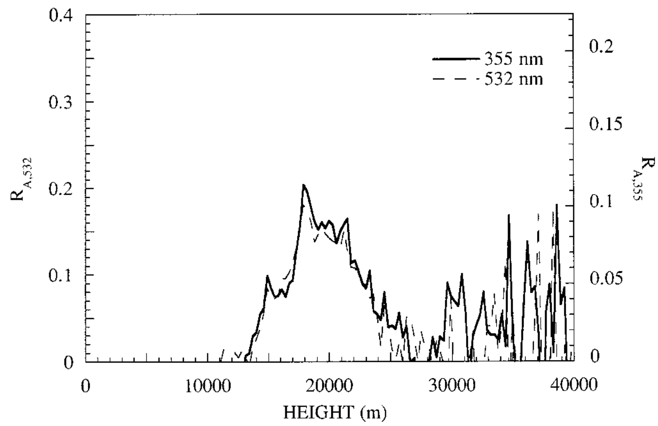

Fig. 4. Potenza LIDAR measurement of the aerosol backscattering ratio as a function of altitude at 355 (*solid line*) and 532 nm (*broken line*). $R_{A,355}(z)$ and $R_{A,532}(z)$ are displayed on the left and right vertical scales in order to verify an internal consistency in the data

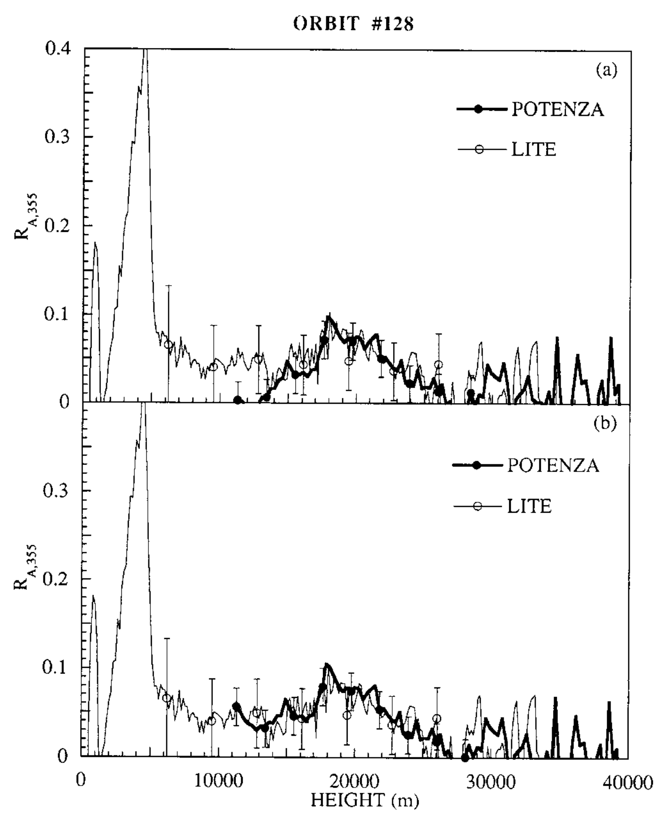

Fig. 5a,b. Simultaneous LITE (*thin line*) and Potenza (*solid line*) LIDAR measurements of $R_{A,355}(z)$, in coincidence with orbit 128; **a** $k_{355} = 30$ sr was used in the retrieval of $R_{A,355}(z)$; **b** $k_{355} = 20$ sr was used number of cases of statistical relevance, Del Guasta et al. [7] found $k_{355} = 32 \pm 9$ sr and $k_{532} = 49 \pm 14$ sr. We report in Figs. 5a and 5b the comparison between simultaneous LITE and Potenza LIDAR measurements of $R_{A,355}(z)$ during orbit 128 overpass for different k_{355} values. In particular, in Figs. 5a and 5b we have used $k_{355} = 30$ sr and $k_{355} = 20$ sr, respectively, i.e. the average and lower values of k_λ proposed in [7] for $\lambda = 355$ nm. The use of $k_{335} = 20$ sr, produces a value of $R_{A,355}(z)$ at the aerosol lower bound ($R^b_{A,355}(z)$) of approximately 0.05, while $k_{355} = 30$ sr leads to $R^b_{A,355} \approx 0$. Accounting for the measurement uncertainty, both proposed profiles of $R_{A,355}(z)$ are in accordance with simultaneous LITE data.

A similar behaviour can be observed for $R_{A,532}(z)$. Figs. 6a and 6b show simultaneous LITE and Potenza LIDAR measurements of $R_{532}(z)$ for orbit 128, obtained by using $k_{532} = 50$ sr and $k_{532} = 35$ sr, respectively (once again the average and lower values of k_λ proposed in [7] for $\lambda = 532$ nm). Similarly to the case at 355 nm, the use of $k_{532} = 35$ produces a value of $R^b_{A,532}$ different from zero (0.04), while $k_{532} = 50$ leads to $R^b_{A,532} \approx 0$. Both $R_{A,532}(z)$ profiles are in agreement with simultaneous LITE data within experimental uncertainty.

In Fig. 7, the LITE measurements of $R_{A,355}(z)$ ($R^{LITE}_{A,355}(z)$) have been plotted as a function of corresponding values measured at Potenza ($R^{Pz}_{A,355}(z)$) for $k_{355} = 30$ sr. That is, for any given z within the stratospheric aerosol layer, points of coordinates ($R^{Pz}_{A,355}(z)$, $R^{LITE}_{A,355}(z)$) have been reported. These points have been least square fitted with a linear function of the form:

$$R^{LITE}_{A,355}(z) = mR^{Pz}_{A,355}(z) + c \tag{5}$$

In this manner $m = 0.57 \pm 0.06$ and $c = 0.017 \pm 0.004$, with a resulting correlation coefficient equal to 0.72. We have also carried out the same fitting procedure at $\lambda = 532$ nm (values of $R^{Pz}_{A,355}(z)$ are those corresponding to $k_{355} = 50$ sr) and the results are reported in Fig. 8. The straight line corresponds to $m = 1.03 \pm 0.06$ and $c = 0.004 \pm 0.005$, with a correlation coefficient of 0.86.

The simultaneous measurements of $R_A(z)$ at two different wavelength also allows one to infer the value of the Ångstrom coefficient, thus obtaining relevant information on the aerosol dimensional characteristics. The vertical profile of the Ångstrom coefficient within the stratospheric aerosol layer can be obtained as:

$$\delta(z) = 4 - \frac{\ln \frac{R_{A,355}(z)}{R_{A,532}(z)}}{\ln\left(\frac{355}{532}\right)} \tag{6}$$

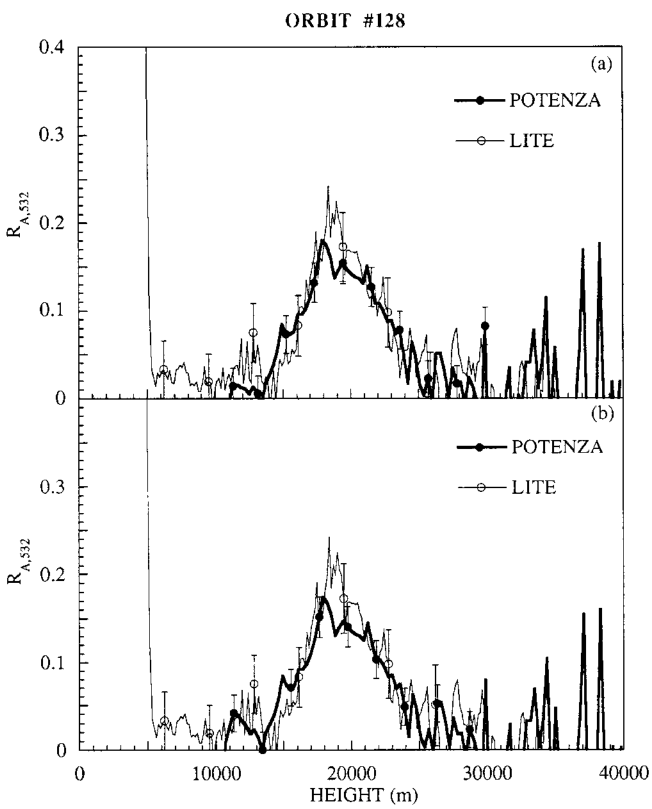

Fig. 6a,b. Simultaneous LITE (*thin line*) and Potenza (*solid line*) LIDAR measurements of $R_{A,532}(z)$ in coincidence with orbit 128. **a** $k_{532} = 50$ sr was used in the retrieval of $R^{Pz}_{A,532}(z)$; **b** $k_{532} = 30$ sr was used

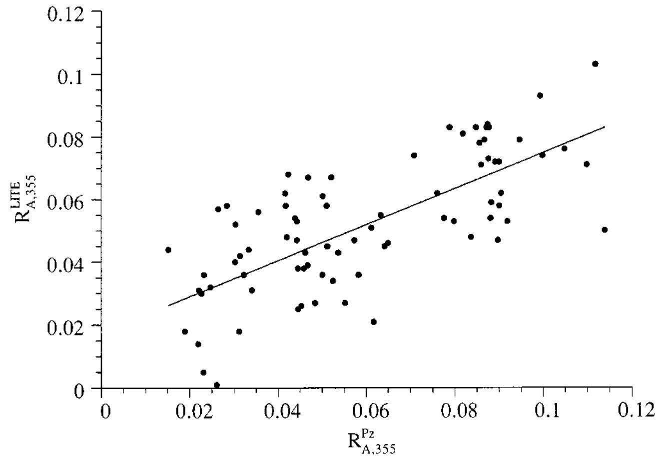

Fig. 7. $R^{LITE}_{A,355}(z)$ versus $R^{Pz}_{A,355}(z)$ for all data points within the stratospheric aerosol layer. The *solid line* corresponds to a linear fit ($mx+c$), where $m = 0.57 \pm 0.06$ and $c = 0.017 \pm 0.004$

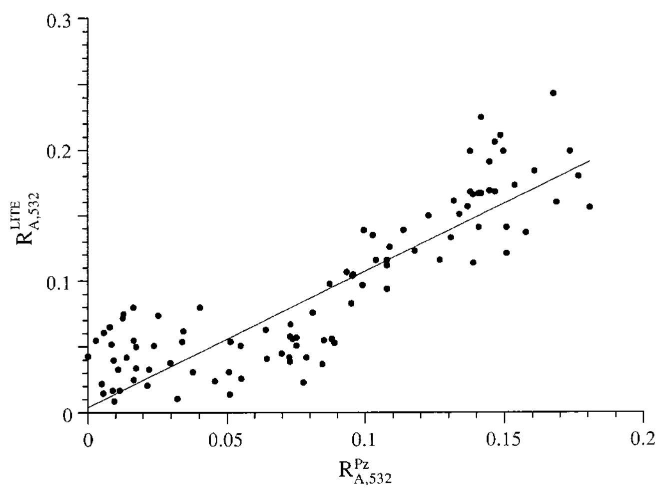

Fig. 8. $R^{LITE}_{A,532}(z)$ versus $R^{Pz}_{A,532}(z)$ for all data points within the stratospheric aerosol layer. The *solid line* corresponds to a linear fit ($mx+c$), where $m = 1.03 \pm 0.06$ and $c = 0.004 \pm 0.005$

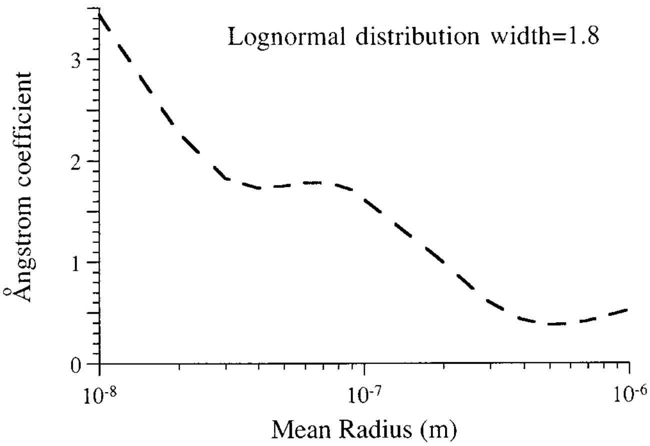

Fig. 9. Theoretical dependence of the Ångstrom coefficient, $\delta(z)$, on aerosol mean radius *r*, for a single mode log-normal aerosol distribution (width = 1.8) and an aerosol refractive index of 1.43-0i and l.45-0i at 532 and 355 nm, respectively

Figure 9 illustrates the theoretical dependence of $\delta(z)$ on the particle mean radius, for a single mode log-normal aerosol distribution (width $= 1.8$); the real part of the refractive index has been taken equal to 1.43 and 1.45 at 532 nm and 355 nm, respectively. These values for the index of refraction were obtained from Palmer and Williams [8] considering an aerosol composed of 75% H_2S0_4 water solution. The imaginary part of the reflecting index has been considered equal to zero [5]. Vertical profiles of $\delta(z)$ obtained from simultaneous LITE and Potenza LIDAR measurements by using (6) are reported in Fig. 10. The uncertainty affecting values of $\delta(z)$ is approximately 50% for both data sets. Accounting for the theoretical data of Fig. 9, the experimental values of $\delta(z)$ are consistent with sub-micrometer aerosol particles. LITE and Potenza LIDAR measurements of $\delta(z)$ are in agreement with measurements performed by other groups in the same latitude region. In particular Gross et al. [9] report a vertically averaged value of 1.5 in the period August 1993–January 1994 in Greenbelt (Maryland, 40°N). The same authors show a variability in the range 1.46–2.18 in the period 1992–1994. D'Altorio et al. [10] report a vertically averaged value of $\delta(z)$ of 1.32 in L'Aquila (Italy, 42°N) for 6 May 1992, while Ferrare et al. [11] find a value of 1.7 in Southeastern Kansas (37°N) for December 1991.

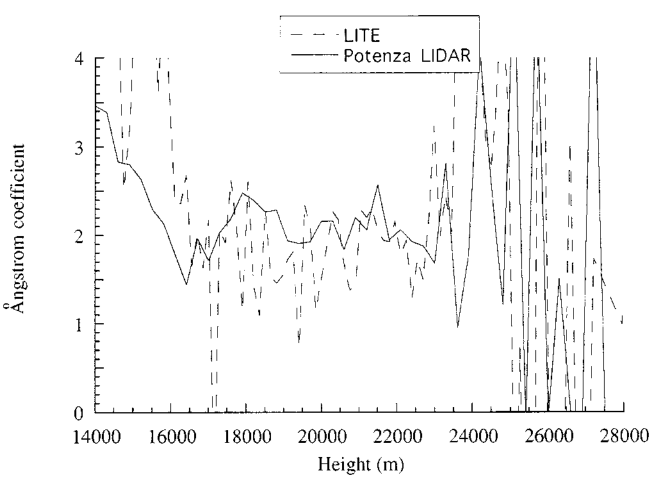

Fig. 10. Simultaneous vertical profiles of the Ångstrom coefficient, $\delta(z)$, as obtained from LITE and Potenza LIDAR data

4 Conclusion

In the present paper we reported and discussed Potenza LIDAR measurements of the aerosol backscattering ratio at 355 and 532 nm ($R_{A,355}$ and $R_{A,532}$), in coincidence with orbit 128 LITE overpass. Potenza LIDAR data show a very good agreement with LITE data both at 355 and 532 nm, the two data sets appearing to be highly correlated LITE vs. Potenza LIDAR measurements of $R_{A,355}$ and $R_{A,532}$ display a correlation coefficient of 0.72 and 0.86, respectively.

Different values of k_λ were considered in the data retrieval procedure, based on a Klett type modified method, which introduces slight changes in the aerosol layer characteristics. Accounting for the measurement uncertainty, proposed values of k_λ produce profiles of $R_{A,355}$ and $R_{A,532}$ in accordance with simultaneous LITE data. Lower values of k_λ lead to the presence of a residual aerosol loading in the upper troposphere.

Stratospheric aerosol mean-size characteristics have also been determined starting from the measured value of the Ångstrom coefficient $\delta(z)$. Measured values of $\delta(z)$ are consistent with sub-micrometer aerosol particles and are in agreement with results performed by other groups.

In conclusion, we can now safely observe that, although both LITE and our ground-based LIDAR results are still preliminary and have to be further analyzed, the validation effort of LITE measurements can be considered satisfactorily carried out, at least as far as the LIDAR systems operating in Southern Italy are concerned.

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