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RAMAN LIDAR AND SUN PHOTOMETRIC MEASUREMENTS OF AEROSOL OPTICAL PROPERTIES DURING A BIOMASS BURNING EPISODE OVER THESSALONIKI, GREECE

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ABSTRACT

In this poster, we discuss one selected case (09 Aug 2001) where an aerosol layer originated from forest fires in Eastern Europe was present in the free troposphere over Thessaloniki, Greece. The four-day back-trajectories on that day indicate that air masses were advected from Bulgaria and the northern coast of the Black Sea, where strong forest fires occurred in early August 2001. This case was of special interest because a rare transboundary aerosol transport from fires could be studied over Greece. In order to investigate the optical parameters of biomass burning aerosols we used a 2-wavelength lidar that combines Raman and elastic backscatter observations in addition with a Brewer spectrophotometer and a multi-filter rotating shadowband radiometer. A second multi-filter rotating shadowband radiometer of the same type as well as a three wavelength integrating nephelometer was also continuously operating at Ouranoupolis, a rural area in the Chalkidiki peninsula, 100 km east of Thessaloniki. High values of aerosol optical depth was found from all instruments and the lidar ratio and Angstrom exponent optical parameters were calculated for this case study. Estimates of aerosol single scattering albedo (ω_0) were made from matching of the measured irradiance values to a model computed irradiances by varying ω_0.

INSTRUMENTATION

At the Laboratory of Atmospheric Physics (LAP) (40.5°N, 22.9 E) a combined Raman elastic-backscatter lidar is used to perform continuous measurements of suspended aerosols particles in the Planetary Boundary Layer and the lower free troposphere. A multi-filter rotating shadowband radiometer (MFR-7 Yankee Env System Inc) is operating at Thessaloniki and at Ouranoupolis (40°23΄N 23 57E, 170 m asl), a rural area in the Chalkidiki peninsula, 100 km east of Thessaloniki. These filter radiometers provided us with 1-min average aerosol optical depths (AOD) at five wavelengths (415, 501, 615, 675 and 867 nm). A three wavelength (450, 550 and 700 nm) integrating nephelometer (TSI 3563, TSI Inc) is also continuously operating at Ouranoupolis provided us measurements of aerosol scattering and backscattering coefficients, additionally. At the Thessaloniki station two Brewer UV spectrophotometers (one single and one double monochromator) operate continuously and monitor the whole UV solar spectrum with a 0.5 nm spectral resolution. In addition, measurements of global total, UV-A and UV-B radiation, direct and diffuse erythemal irradiance are being performed.

METHODS

The measurement of the elastic-backscatter signal at 355 nm and of the nitrogen inelastic backscatter signal at 387 nm permits the determination of the extinction and backscatter coefficients independently of each other and, thus, of the extinction-to-backscatter ratio according the Raman method (Ansmann et al., 1992). The aerosol backscatter coefficient at 532 nm is determined from the elastic backscattered signal profile with the well-known Klett inversion method (Klett 1985). Measurements of the aerosol backscatter and extinction are performed routinely in the frame of the EARLINET project while lidar system of LAP and the algorithms implemented were successfully intercompared with the other EARLINET groups (Matthias et al., 2002).

A range of single-scattering albedo values was used to investigate its impact on surface UV irradiance, through comparison of measurements with model calculations. The tropospheric Ultraviolet and Visible model (TUV) (Madronich, 1993) version 4.0 using the radiation transfer solver pseudospherical DISORT (Stamnes et al., 1988) was run using 16 streams. Irradiance spectra were calculated in 0.015 nm steps and then they were convoluted with the slit function of the Brewer and sampled at intervals of 0.5 nm to match the measurements. By comparing the modeled spectra with the measured ones the effective single scattering albedo was determined using an iterative methodology proposed by Bais et al., (2002).

RESULTS AND DISCUSSION

The synoptic situation during the case study (9 Aug 2001) was characterized by stagnant conditions with light winds over the Balkan Peninsula associated with an anticyclonic system extending from western Mediterranean to Balkans and north eastern Europe. This stagnant anticyclonic situation over Balkans was dominating for several days from 3 to 10 August. The four-day back-trajectories on 9 August at 19:00 UTC (when lidar measurements were available over Thessaloniki) indicate that at 975, 850 and 700 hPa air masses were advected slowly from Eastern Europe and especially from Bulgaria and the northern coast of the Black Sea. The positions of fires superimposed on Figure 1 (source: ATSR World Fire Atlas, http://shark1.esrin.esa.it/FIRE/AF/ATSR/) imply the influence by biomass burning on the advected air masses from Bulgaria and the northern coast of the Black Sea.

The radiosonde launched at Macedonia Airport at the coast of Thessaloniki at 18 UTC indicated relatively dry conditions with the RH being lower than 50% up to 5000 m.

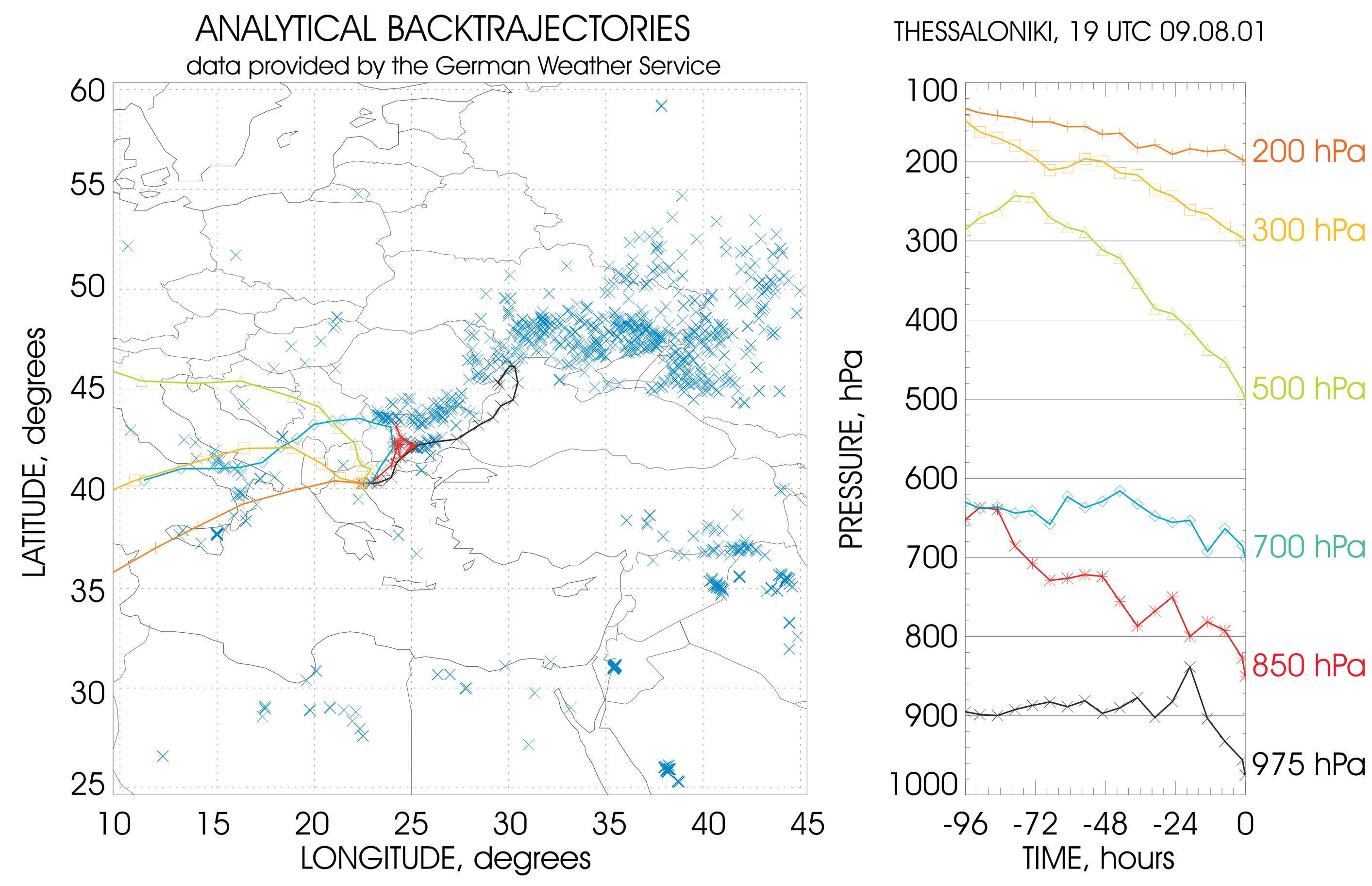

Figure 1. Four-day backward trajectories with arrival at Thessaloniki on 9 August 2001, 19:00 UTC. Blue crosses indicate the locations of forest fires in Bulgaria and the northern coast of the Black Sea around 5-9 August 2001.

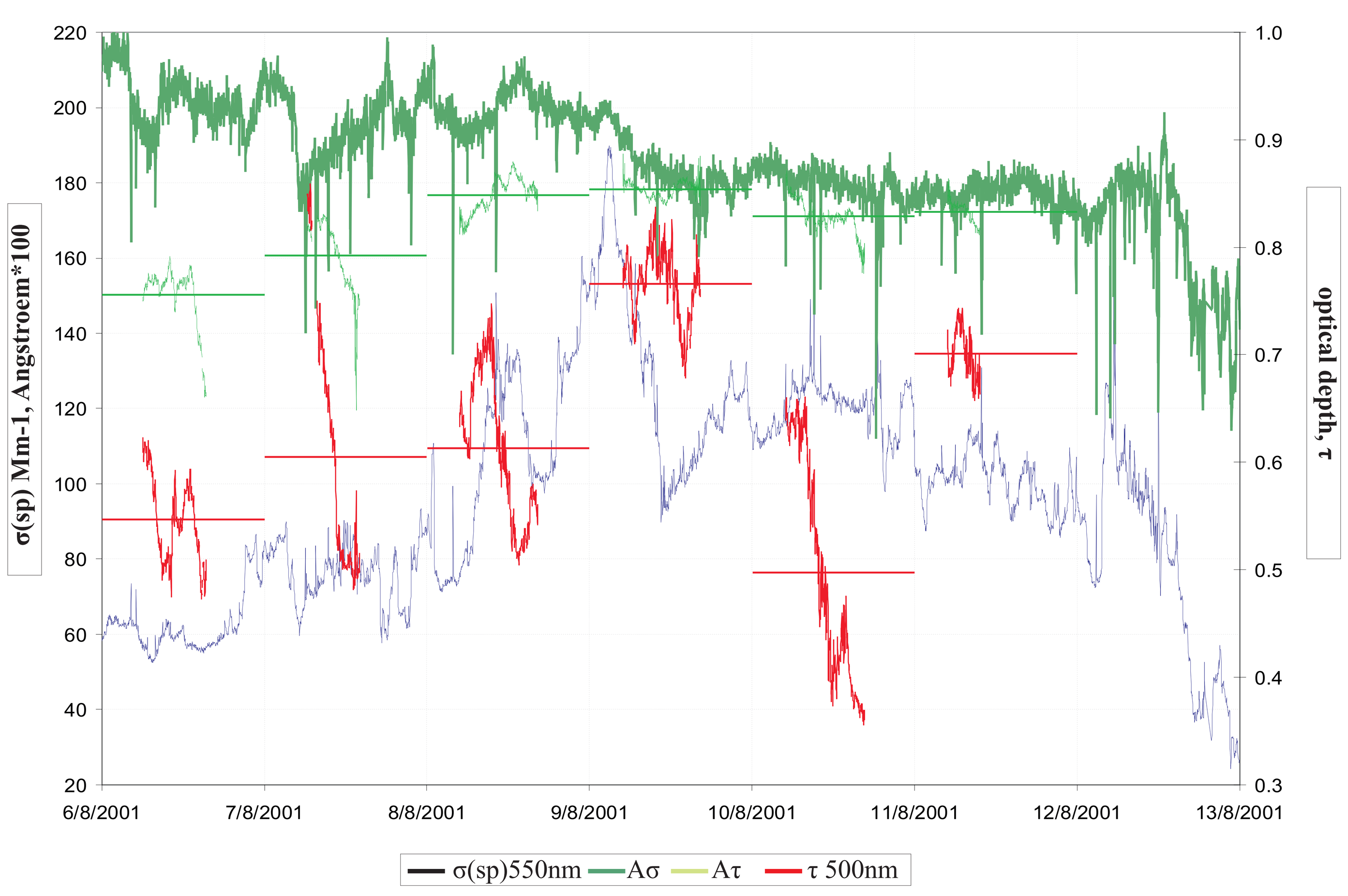

Figure 2. Optical depth (500 nm) and scattering coefficient (550 nm) during the period influenced by biomass burning aerosol derived by an MFR and a nephelometer respectively. Angström exponents calculated from both aerosol optical depths and scattering coefficients are also presented

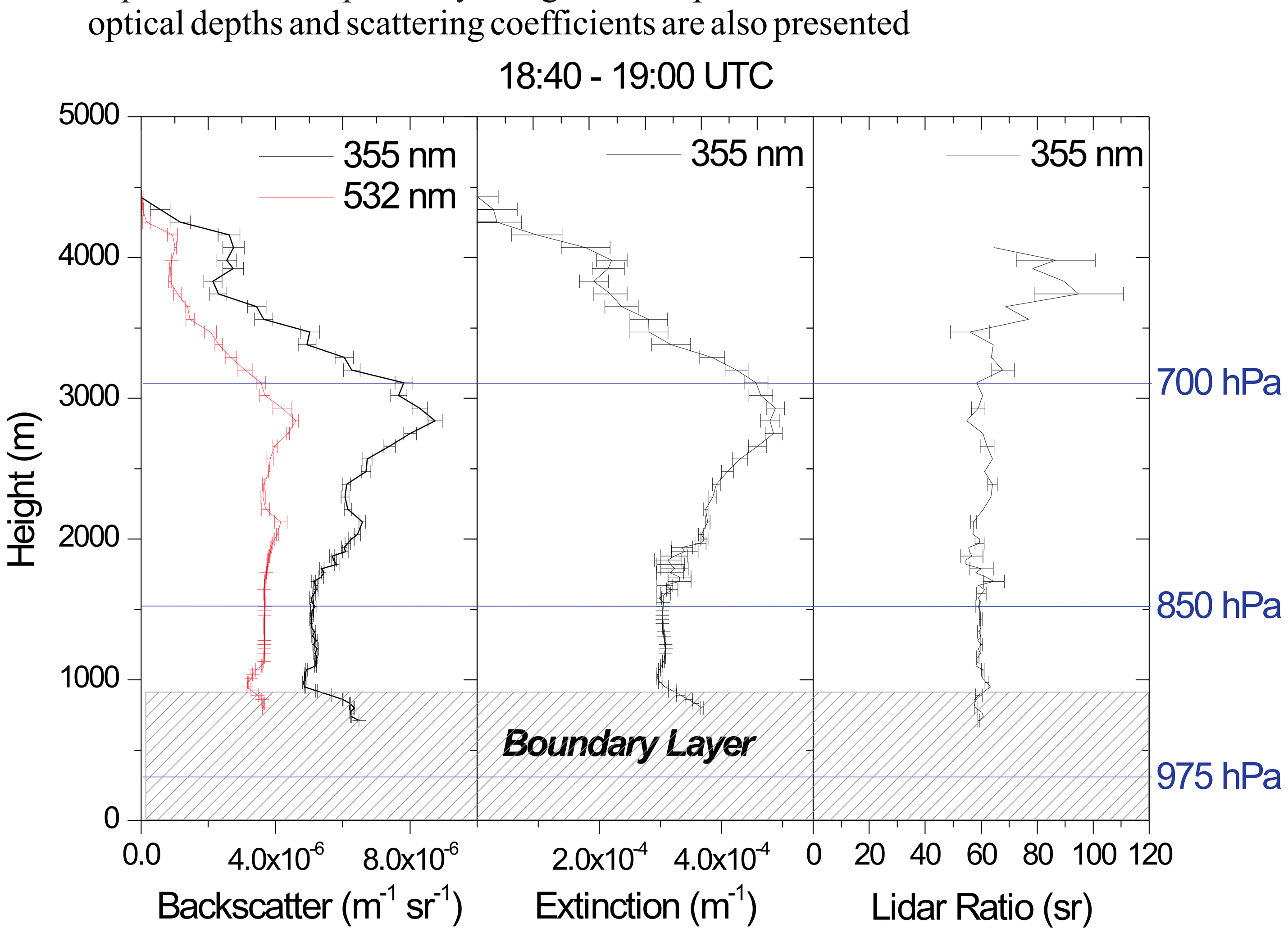

Figure 3. Backscatter coefficients at 355 and 532 nm along with extinction and lidar ratio profiles measured in the biomass-burning free-troposphere aerosol layer at Thessaloniki on 9 August 2001, between 08:40 and 19:00 UTC. The height resolution is 30 m below 2 km and 90 m above.

ACKNOWLEDGEMENTS

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REFERENCES

1. Wandinger U, D. Muller, C. Boeckmann, D. Althausen, V. Matthias, J. Boesenberg et al., Optical and microphysical characterization of biomass burning and industrial pollution aerosols from multiwavelength lidar and aircraft measurements, J. Geophys. Res., 107, 2002

2. Matthias et al., Lidar intercomparison on algorithm and system level in the frame of EARLINET, Max Planck Institut for Meteorology, Hamburg, Report no. 37, 2002

3. Bais A.F., A. Kazantzidis, S. Kazadzis, D. Balis, C.S. Zerefos and C. Meleti, Effects of aerosol optical depth and single scattering albedo on surface UV irradiance, in Ultraviolet Ground- and Space-based Measurements, Models, and Effects, proceedings of SPIE, San Diego 30 July 1 August 2001, Vol. 4482, 15-22, 2002.

4. Ansmann A, U. Wandinger, M. Riebesell, C. Weitkamp and W. Michaelis, Independent measurement of extinction and backscatter profiles in cirrus clouds using a combined Raman elastic-backscatter lidar, Appl. Opt. 31, 7113, 1992

The signature of the biomass burning influence over the extended area of Thessaloniki is captured by the radical change of aerosol optical properties, namely scattering coefficient and optical depth (AOD). A time series of AOD and scattering coefficients as well as of the Angström exponent calculated from both aerosol optical depths and scattering coefficients for the period around the 9th of August (6/8/01-13/8/01) is presented in Figure 2.

In Figure 3 the backscatter coefficients at 355 and 532 nm along with the extinction and lidar ratio profiles at 355 nm are shown. The error bars indicate statistical errors. The optical depth value calculated from the integrated extinction profile at 355 nm is 1.15 in the height region from 800-4500 m, where laser beam overlaps completely with telescope's field of view.

The lidar ratio profile obtained with Raman technique contains information on the aerosol type, since it depends on the index of refraction and on the size of the particles [Ackermann, 1998]. The optical quantity was almost constant with height at 355 nm indicating a stable layer of the same aerosol type. The high optical depth value of the aerosol layer makes the Klett solution for the 532 nm very sensitive to the lidar ratio estimate. Since the vertical variability of the lidar ratio was not found to be significant, we estimated a columnar-averaged value of lidar ratio for 532 nm by using a combination of the backscatter measurements and multifilter aerosol optical depth measurements. According to the findings, the mean lidar ratios were reduced from 60 to 50 sr from shorter (355 nm) to longer (532 nm) wavelengths.

To derive estimates of the effective SSA we compared measured spectral irradiances and aerosol optical depth with model calculations, which were based on the actually measured total ozone column and aerosol optical depth. The vertical profiles of the aerosol extinction coefficient at 355 nm derived from LIDAR measurements were also used as inputs to the model. The SSA value we estimated with the above technique was 0.91. *Radke et al., 1991* measured the ω_0 to be under 0.7 for the flaming phase of the fires compared to a value of 0.90 of the smoldering phase.

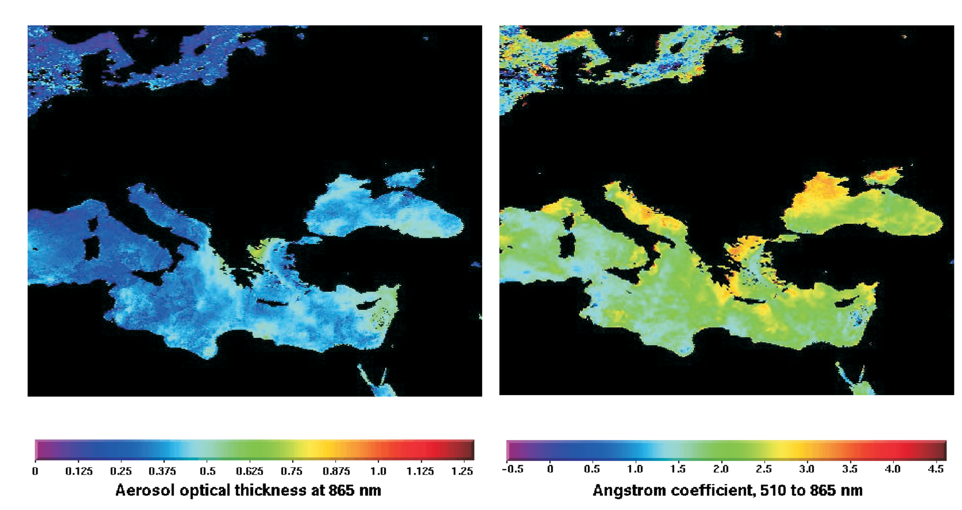

Figure 4. Aerosol optical depths at 865 nm and Angstom exponent (510-865 nm) for the time period between 5-12 August 2001. Satellite images provided by the SeaWiFS Project, (NASA/Goddard Space Flight Center and ORBIMAGE)

CONCLUSIONS

- **For the specific day, August, 9th 2001, the aerosol optical depth at 355 nm was calculated 1.29 using the direct sun Brewer spectroradiometer measurements and 1.35 using a multifilter radiometer. The integral of the extinction coefficient in the height region from 800-4500 m, measured with the Raman lidar at 355 nm was equal to 1.15.** Considering that the day was free from clouds, the aerosol load can be considered as extremely high, taking into account that average aerosol optical depth values for Thessaloniki area are 0.5 0.6 at 355 nm.
- **Values of the single scattering albedo of the order of 0.9 estimated with the method pre-described are comparably large and indicate a small influence of absorption of the particles.** Processes like absorption of water by the aerosols, gas to particle conversion and coagulation of aerosols into larger particles possibly modifying the aerosol size distribution and their absorption properties with aging. The values of ω_0 which we estimated may be due to such aging processes.
- **The value of the Angstrom wavelength exponent computed from 415 and 868 nm exhibited high values (1.78), similar to those reported for biomass burning aerosols in the fire season in Brazil.** This suggests size distributions dominated by accumulation mode particles.
- **Mean lidar ratios were reduced from 60 to 50 sr from shorter (355 nm) to longer (532 nm) wavelengths.** This result is similar to the one reported by *Wandinger et al., 2002,* for a large-scale aerosol layer in the free troposphere which originated from forest fires in northern Canada. Low optical depths of the order of 0.1 at 532 nm and quite dry conditions were found for the smoke layer in this study. The similarity in lidar ratio calculations between these 2 cases is a nice indication of the independence of the lidar ratio parameter from the particle concentration and aerosol optical depth.