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CHARACTERIZATION OF ATMOSPHERIC AEROSOLS FOR A LONG-RANGE TRANSPORT OF BIOMASS-BURNING FROM NORTH AMERICA OVER THE IBERIAN PENINSULA

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ABSTRACT

This work presents the characterization of atmospheric aerosols performed over the Iberian Peninsula in the framework of EARLINET for a special episode on 20th August 2007. The assessment of aerosol radiative impact requires an accurate determination of their optical and microphysical properties, which are presented here for a variety of instrumentation including passive remote sensors, as sun-photometers, and active systems both ground-based and on board CALIPSO satellite. Measurements highlight the presence of a multilayered structure with a well-defined planetary boundary layer and biomass-particles in elevated layers, extending up to 7 km asl over the central Iberian Peninsula, and even higher, up to 9 km asl, at the south-eastern part of the peninsula. Lidar computations reveal a contribution to the aerosol optical depth around 10-40% for these biomass-burning particles, with backscatter-related Angström exponents around 2-3 for different spectral ranges.

1. INTRODUCTION

The optical properties of biomass burning (BB) aerosols are an important element in the complex system of atmospheric radiative transfer because of their influence on the radiation budget of the atmosphere by both absorbing and scattering shortwave radiation. The studies of the properties of BB particles have usually focused on tropical regions because approximately 80% of global biomass burning emissions are in the tropics [1]. The body of work on emissions by fires in non-tropical locations is somewhat smaller [2]. In Europe few studies reported lidar observations of biomass burning long-range transport in the troposphere (i.e. [3, 4]). In particular, there is a lack of systematic studies of long-range transported biomass burning aerosols by a continental scale lidar network. To our knowledge this is the first time that BB aerosols transported from North

America have been characterized by lidar over the Iberian Peninsula.

Routine lidar measurements of backscatter and extinction coefficients are performed in the framework of EARLINET (European Aerosol Research Lidar Network) [5]. The scientific aims of EARLINET are to build a statistical database of the horizontal, vertical and temporal distribution of aerosol properties on a continental scale. Several Raman lidar stations over the Iberian Peninsula, which integrate the so-called western Mediterranean cluster of the network for the CALIPSO validation program, detected an intrusion of BB particles from North America on 20th August 2007. Thus, for the first time, the high resolved vertical distribution of BB aerosols can be studied in the free troposphere over the Iberian Peninsula.

Besides the BB episode reported here, in summer 2007 the Iberian Peninsula was also affected by Saharan dust events (i.e. [6]), episodes of local/regional anthropogenic pollution transport and biomass burning events (i.e. [7]). In summer, as a consequence of the complexity of aerosols over the Iberian Peninsula, the BB long-range transport becomes more complex and difficult to follow. Backward trajectory analysis has been used to characterize the aerosol source area and the plume transport. The properties derived by lidar allow for distinguishing the aerosol type.

2. EXPERIMENTAL SETUP

Two multiwavelength Raman lidars were used for vertically resolved measurements of the particle optical properties to characterize the BB plume discussed in this contribution. One system is operated at the Andalusian Center for Environmental Research (CEAMA) located in Granada (Spain, 37.16°N, 3.6°W, 680 m above sea level (a.s.l)), and the other one is operated at the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT) located in

Madrid (Spain, 40.46°N, 3.73°W, 669 m asl). Backscatter profiles at 532 nm are provided by both systems, while the system at Granada provides also those at 355 and 1064 nm, both day and night time, using the Klett method [8]. Extinction, backscatter and lidar ratio profiles are also computed by both systems at 532 nm, during the night using the Raman method [9], when an acceptable signal to noise ratio can be achieved. The details of the experimental setups of the lidar systems involved are shown in [10]. The stations included in SPALINET (Spanish and Portuguese Aerosol Lidar NETwork), where both systems are also members, have successfully followed an intercomparison exercise for both instruments and algorithms [10]. The errors associated to the overlap function do not affect the results of this work, because the present study focus on layers above 2 km.

The aerosol optical depth in the range 340 to 1020 nm has been obtained by a Cimel sun-photometer included in AERONET [11] and a star-photometer [12].

3. RESULTS AND DISCUSSION

In summer 2007, several heavy load episodes with large loads (in terms of optical depth) of aerosol particles occurred over the Iberian Peninsula. In particular, on 20th August 2007 an unexpected plume of particles was detected in the free troposphere. The backward trajectories analysis based on HYSPLIT [13] and FLEXTRA [14, 15] models reveal as main source region the East coast of North-America, where many forest fires were active during the first part of August 2007, as MODIS sensor indicates (<http://firefly.geog.umd.edu/firemap/>). Over southern Iberian Peninsula, sun-photometers register aerosol optical depth (440 nm) up to 0.37 and Angström exponents (440-870 nm) around 1.45 during this episode (not shown here).

Figure 1 shows the evolution of the BB plume by means of some vertical profiles of backscatter coefficients obtained in Madrid (a-c) at night, noon and evening and in Granada (d-e) at noon and evening on 20th August 2007. The profiles reported have been computed from the signals averaged over 30 min. The corresponding lidar ratio values are included in the plots. For Madrid lidar, the lidar ratios were selected to match the Raman profile obtained at night (02:10-02:40 UTC), as presented in Figure 2, whereas for Granada station, the lidar ratios were selected minimizing the differences between the aerosol optical depth derived from the integration of extinction lidar profiles and the aerosol optical depth derived from a sun- and a star-photometer during day and night time, respectively. The BB plume is detected over central (Madrid) and southeastern (Granada) Iberian Peninsula simultaneously at noon and evening above the planetary boundary layer (PBL)

(around 2.5-3.0 km asl depending on time and station) (Figure 1). During the previous night no measurements were available from the Granada lidar station. The comparative analysis between the Madrid and Granada stations suggests horizontal and vertical in-homogeneity of the extensive properties for the BB plume (Figure 1). Thus the largest backscatter coefficients are detected over the southern Iberian Peninsula during the evening of 20 August (when the photometer registers maximum aerosol optical depths) with two differentiated layers. This is the first time that particles have been registered up to more than 9 km asl over this station. This BB plume contributed between 10 and 40 % (depending on time and station) to the aerosol optical depth. Measurements of the backscatter coefficient at different wavelengths allow evaluating the backscatter-related Angström exponent, related to the size and chemical composition of the aerosol type. Thus the multispectral capabilities of the Granada lidar reveal the presence of small particles in the free troposphere with backscatter-related Angström exponents (355-532 nm) around 2.3 ± 0.3 and 2.7 ± 0.2 in the BB layer at noon and evening, respectively.

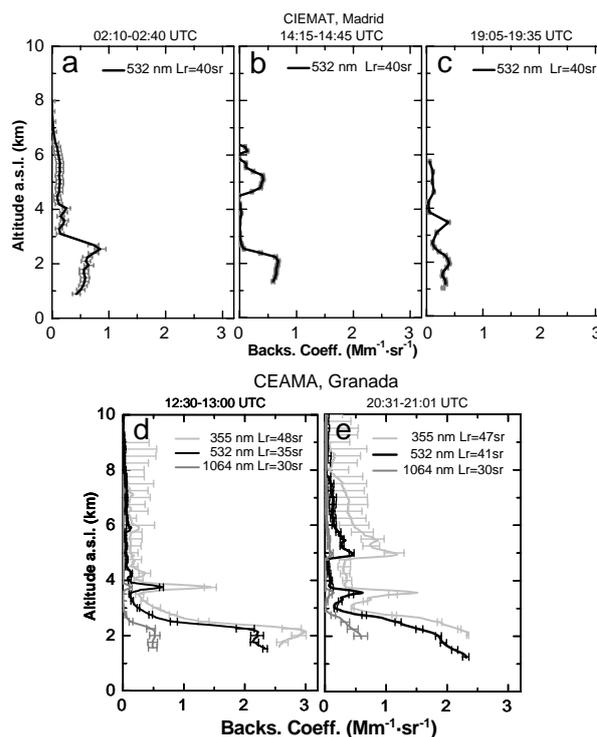


Figure 1. Aerosol backscatter profiles observed by some EARLINET lidar stations on 20th August 2007.

The aerosol backscatter and extinction profiles obtained independently from simultaneous measurements of elastic and nitrogen Raman signals allow computing an altitude-variable lidar ratio. Figure 2 shows the Raman retrieval over the Madrid station (a) at night (02:10-

02:40 UTC) and over the Granada station (b) in the evening (20:31-21:01 UTC). The backscatter-weighted lidar ratio computed over the profiles shown in this figure is an approximation of the lidar ratio representative for the whole atmospheric column. Hence, the backscatter-weighted lidar ratios of 38.0 and 46.7 sr were obtained for Madrid and Granada, respectively, in agreement with the values used for the retrievals of vertical profiles with Klett's method (40 and 41 sr, respectively). In addition, the Granada lidar ratio profile indicates the presence of particles with different features inside the BB plume (Figure 2 b).

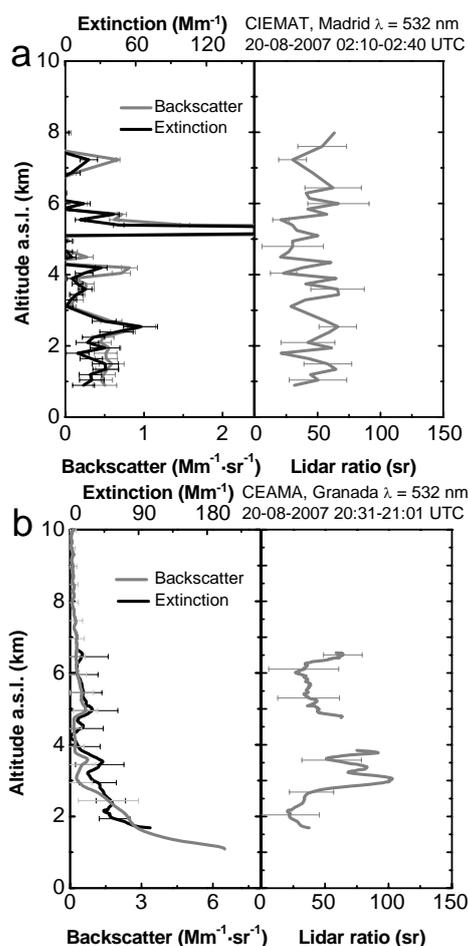


Figure 2. Extinction, backscatter and lidar ratio of aerosol layer observed by some EARLINET lidar stations on 20th August 2007. Data from EARLINET Madrid station were acquired at 02:10-02:40 UTC during a CALIPSO satellite overpass (a). Data from EARLINET Granada station were acquired at 20:31-21:01 (b).

The CALIPSO satellite carries the first satellite-borne lidar instrument CALIOP (Cloud- Aerosol Lidar with Orthogonal Polarization) which provides vertically resolved aerosol and clouds profiles on the global scale.

The total and perpendicular attenuated backscatter at 532 and total attenuated backscatter at 1064 nm have been presented as the first products (level-1 products) of the CALIPSO mission. Figure 3 shows the comparison of level-1 CALIPSO data with ground-based lidar data in terms of the vertical profiles of attenuated backscatter coefficient obtained at 532 nm during the overpasses over Madrid and Granada on 20th August 2007. Taking into account the spatial and temporal in-homogeneity of the BB plume and the typical distances between the CALIPSO ground track and the EARLINET stations (up to 80 km), a good agreement between the aerosol profiles is generally found. The plots include the minimum distances for these overpasses.

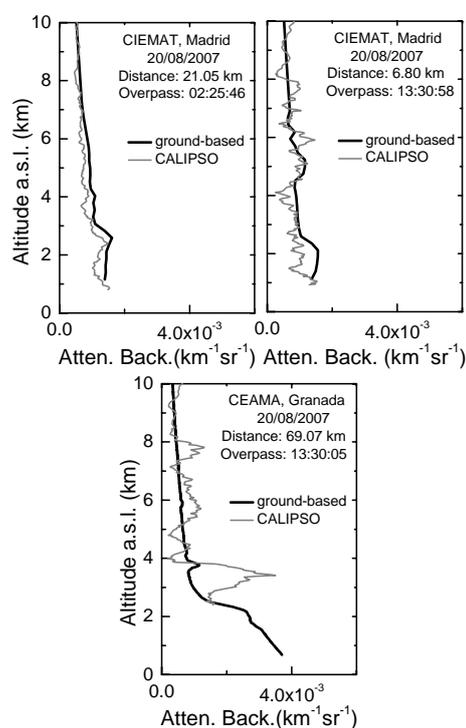


Figure 3. Comparison of CALIPSO and EARLINET attenuated backscatter profiles at 532 nm.

4. CONCLUSION

This work reveals that the unexpected aerosol load detected in the free troposphere over the Iberian Peninsula in the middle of August 2007 corresponds to an episode of long-range transport of biomass-burning particles from North America. Our preliminary results for the Iberian Peninsula indicate the importance of synergetic analyses, assisted by transport models, to clarify the overall transport to regional scale. The contribution of the BB plume to the aerosol optical depth varied between 10 and 40 %. The radiative impact of these particles (in terms of radiative forcing and heating rate) will be analyzed in a future work.

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REFERENCES

- [1] Hao W. M., M. H. Liu, 1994: Spatial and temporal distribution of tropical biomass burning, *Global Biogeochem. Cycles*, **8**, pp. 495–503.
- [2] McMeeking G. R., S. M. Kreidenweis, C. M. Carrico, T. Lee, J. L. Collett Jr., W. C. Malm, 2005: Observations of smoke-influenced aerosol during the Yosemite Aerosol Characterization Study: Size distributions and chemical composition, *J. Geophys. Res.*, **110**, D09206, doi:10.1029/2004JD005389.
- [3] Mattis I., A. Ansmann, U. Wandinger, D. Müller, 2003: Unexpectedly high aerosol load in the free troposphere over central Europe in spring/summer 2003, *Geophys. Res. Lett.*, **30**(22), 2178, doi:10.1029/2003GL018442.
- [4] Müller D., I. Mattis, U. Wandinger, A. Ansmann, D. Althausen, A. Stohl, 2005: Raman lidar observations of aged Siberian and Canadian forest fire smoke in the free troposphere over Germany in 2003: Microphysical particle characterization, *J. Geophys. Res.*, **110**, D17201, doi:10.1029/2004JD005756.
- [5] Boesenberg J., A. Ansmann, J. M. Baldasano, D. Balis, C. Böckmann, B. Calpini, A. Chaikovsky, P. Flamant, A. Hagard, V. Mitev, A. Papayannis, J. Pelon, D. Resendes, J. Schneider, N. Spinelli, T. Trickl, G. Vaughan, G. Visconti, M. Wiegner, 2001: EARLINET: a European aerosol research lidar network, laser remote sensing of the atmosphere, in: Selected Papers of the 20th International Laser Radar Conference, 2001, edited by Dabas, A., Loth, C., and Pelon, J., Edition Ecole Polytechnique, Palaiseau, France, pp. 155–158.
- [6] Guerrero-Rascado J. L., F. J. Olmo, I. Avilés-Rodríguez, F. Navas-Guzmán, D. Pérez-Ramírez, H. Lyamani, L. Alados-Arboledas, 2009: Extreme Saharan dust event over the Southern Iberian Peninsula in September 2007: Active and passive remote sensing from surface and satellite, *Atmos. Chem. Phys.*, **9**, pp. 8453–8469.
- [7] Alados-Arboledas L., D. Müller, J. L. Guerrero-Rascado, F. Navas-Guzmán, D. Pérez-Ramírez, F. J. Olmo: Optical and microphysical properties of fresh biomass burning aerosol retrieved by Raman lidar, and star- and sun-photometry, *Geophys. Res. Lett.*, submitted.
- [8] Klett, J. D., 1985: Lidar inversion with variable backscatter/extinction ratios, *Appl. Optics*, **24**, pp. 1638–1643.
- [9] Ansmann A., U. Wandinger, M. Riebesell, C. Weitkamp, W. Michaelis, 1992: Independent measurement of extinction and backscatter profiles in cirrus clouds by using a combined Raman elastic-backscatter lidar, *Appl. Opt.*, **31**, pp. 7113-7131.
- [10] Sicard M., F. Molero, J. L. Guerrero-Rascado, R. Pedrós, F. J. Expósito, C. Córdoba-Jabonero, F. Rocadenbosch, A. Comerón, M. Pujadas, L. Alados-Arboledas, J. A. Martínez-Lozano, J. P. Díaz, F. Navas-Guzmán, M. Gil, 2009: Aerosol Lidar intercomparison in the framework of SPALINET – the SPANish Lidar NETwork: methodology and results, *IEEE Trans. Geosci. Remote Sens.*, doi: 10.1109/TGRS.2009.2021525.
- [11] Holben B. N., T. F. Eck, I. Slutsker, D. tanré, J. P. Buis, A. Setzer, E. Vermote, J. A. Reagan, Y. J. Kaufman, T. Nakajima, F. Lavenu, I. Jankowiak, and A. Sirmonov, 1998: Aeronet—a federated instrument network and data archived for aerosol characterization, *Rem. Sens. Environ.*, **66**, pp. 1–19.
- [12] Pérez-Ramírez D., J. Aceituno, B. Ruiz, F. J. Olmo, L. Alados-Arboledas, 2008: Development and calibration of a star photometer to measure the aerosol optical depth: Smoke observations at a high mountain site, *Atmos. Environ.*, **42**, pp. 2733-2738.
- [13] Draxler R. R., and G. D. Rolph, 2003: HYSPLIT (HYbrid Single- Particle Lagrangian Integrated Trajectory) Model access via NOAA ARL READY Website (<http://www.arl.noaa.gov/ready/hysplit4.html>), NOAA Air Resources Lab., Silver Spring, MD.
- [14] Stohl A., M. Hittenberger, G. Wotawa, 1998: Validation of the Lagrangian particle dispersion model FLEXPART against large scale tracer experiments, *Atmos. Environ.* **32**, pp. 4245–4264.
- [15] Stohl A., C. Forster, A. Frank, P. Seibert, G. Wotawa, 2005: Technical note: the Lagrangian particle dispersion model FLEXPART version 6.2. Atmospheric Chemistry and Physics, **5**, pp. 2461–2474.