Retrieval of particle microphysical properties for different aerosol types with LIRIC algorithm

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ABSTRACT: This work presents a characterization of three different aerosol types in terms of their microphysical properties, for several events registered at the EARLINET [1] Granada station (37.16° N, 3.61° W, 680 m asl) during July 2013. A preliminary analysis of the aerosol optical properties, presented in a previous work [2], has been used to make a classification of the aerosol types forming the detected plumes. Backward trajectories analysis with HYSPLIT [3] model to identify the origin of the air masses arriving at our station and modeling tools as NAAPS [4] and BSC-DREAM8b [5] have been used as ancillary information. According to those data, the presented cases correspond to mineral dust particles coming from Sahara Desert, biomass burning particles transported from Canadian forest fires, and mixed layers containing anthropogenic pollution. The study has involved lidar data processing for both Raman and elastic lidar signals and also combined analysis of sun-photometer AERONET [6] data and elastic lidar signal using LIRIC [7] algorithm. The results evidence a large concentration of fine mode particles in the biomass-burning aerosol layers, whereas for Saharan dust layers, the largest concentration values were obtained for the coarse mode, in particular for the non-spherical fraction. Layers with anthropogenic or with mixed aerosol layers were found to exhibit a hybrid behavior.

PROCEDURE

Lidar Raman LR331D400
-Monostatic biaxial alignment
-Emission: 355, 532, 1064 nm (Pulsed Nd:YAG laser)
-Detection: 355, 532 (both polarizations), 1064, 387, 408 and 607 nm (Cassegrainian telescope)
-Spatial resolution: 7.5 m; temporal resolution: 1 min
-Incorporated to EARLINET [1] and SPALINET [8]

Sun-Photometer CIMEL CE-138
-Direct Sun measurements every 15 min
-Sky radiance: Almucantar and Principal plane
-1.2° full field of view
-Interference filters: 340, 380, 440, 500, 675, 870, 940 and 1020 nm
-Incorporated to AERONET [5]

Measured signals:
-3 backscattered signals (355, 532 and1064 nm)
-Parallel and cross-polarized backscattered signal (532 nm)

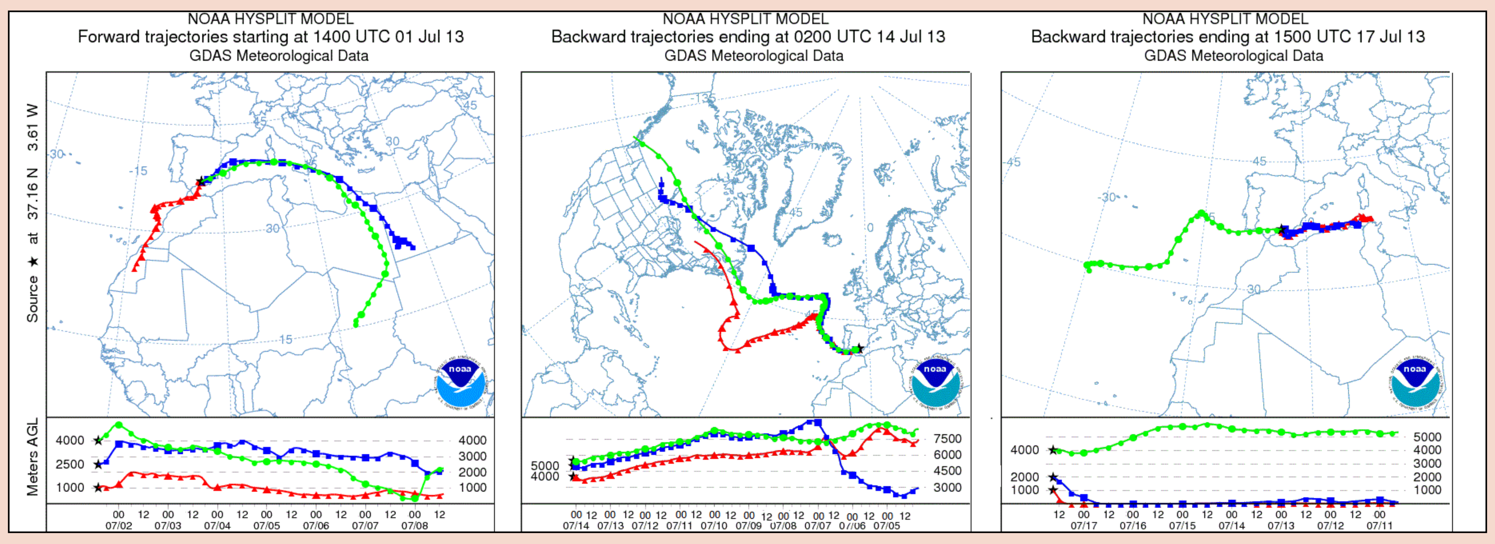
LIRIC
(Lidar-Radiometer Inversion Code)
[7]

Retrieved properties (by AERONET):
-Columnar particle size distribution
-Volume concentrations
-Refractive index
-Radiative properties

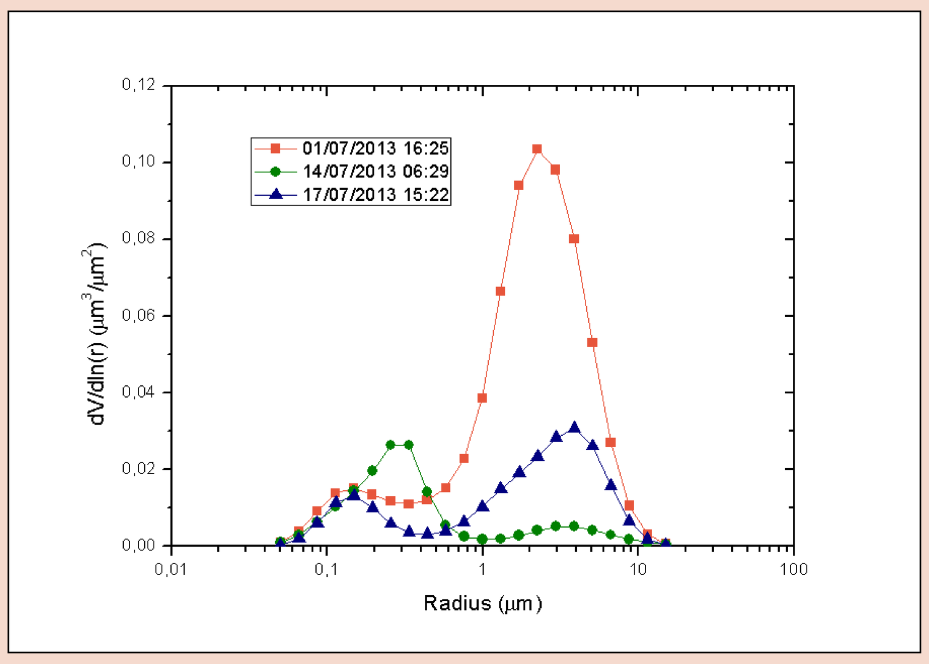
Products:
-Fine mode (<0.5 μm) concentration profile
-Coarse mode (>0.5 μm) concentration profile
Spherical coarse mode
Non-Spherical Coarse mode
- Column aerosol modes concentrations
- Integrated backscatter

RESULTS

Three different situations are presented here to illustrate distinct aerosol scenarios. According to a preliminary classification using backward trajectories and forecast models, we expected to find mineral dust particles on July, 1st; biomass burning particles transported from North American forest fires on July, 14th, and mixed layers containing anthropogenic regional pollution on July, 17th.

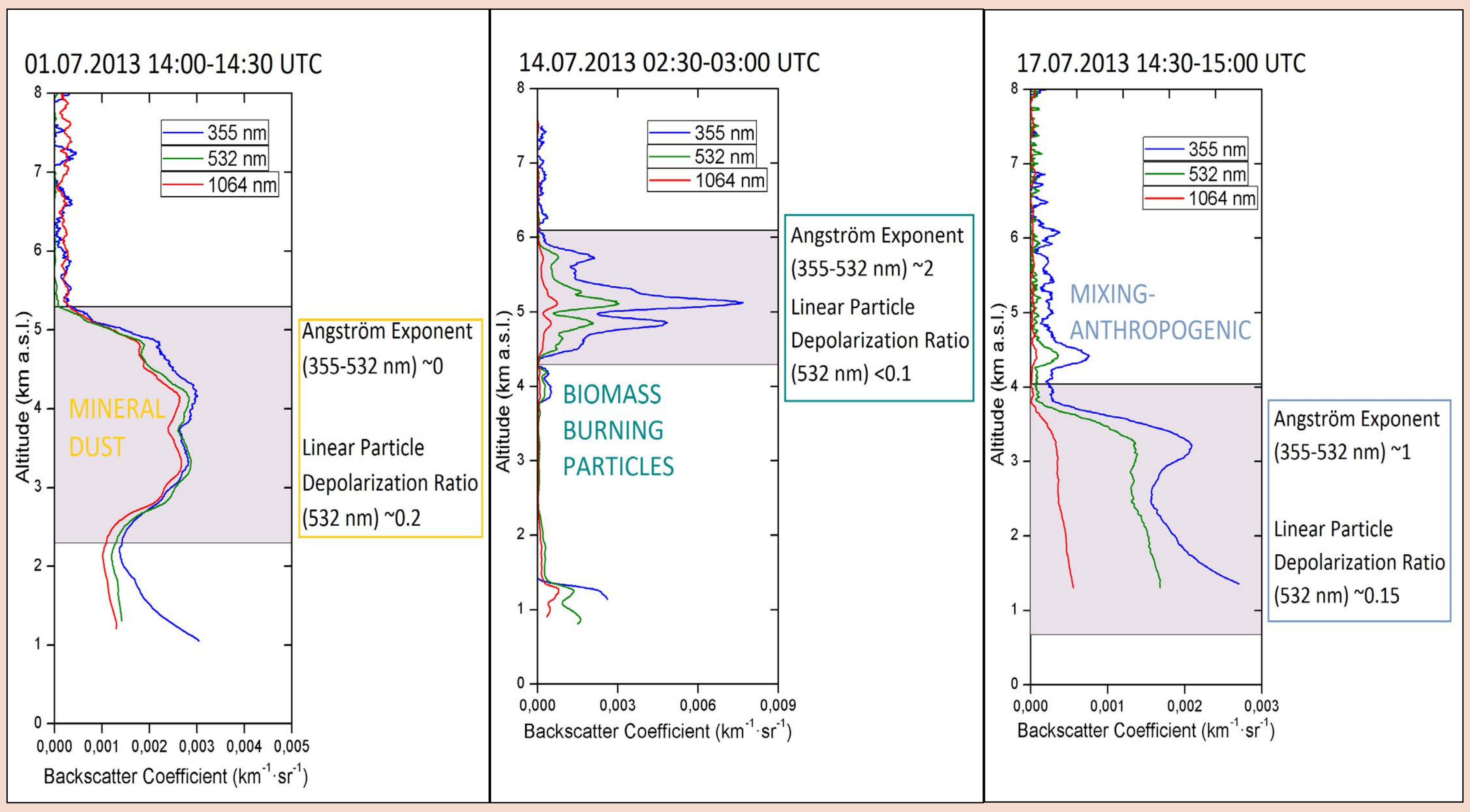


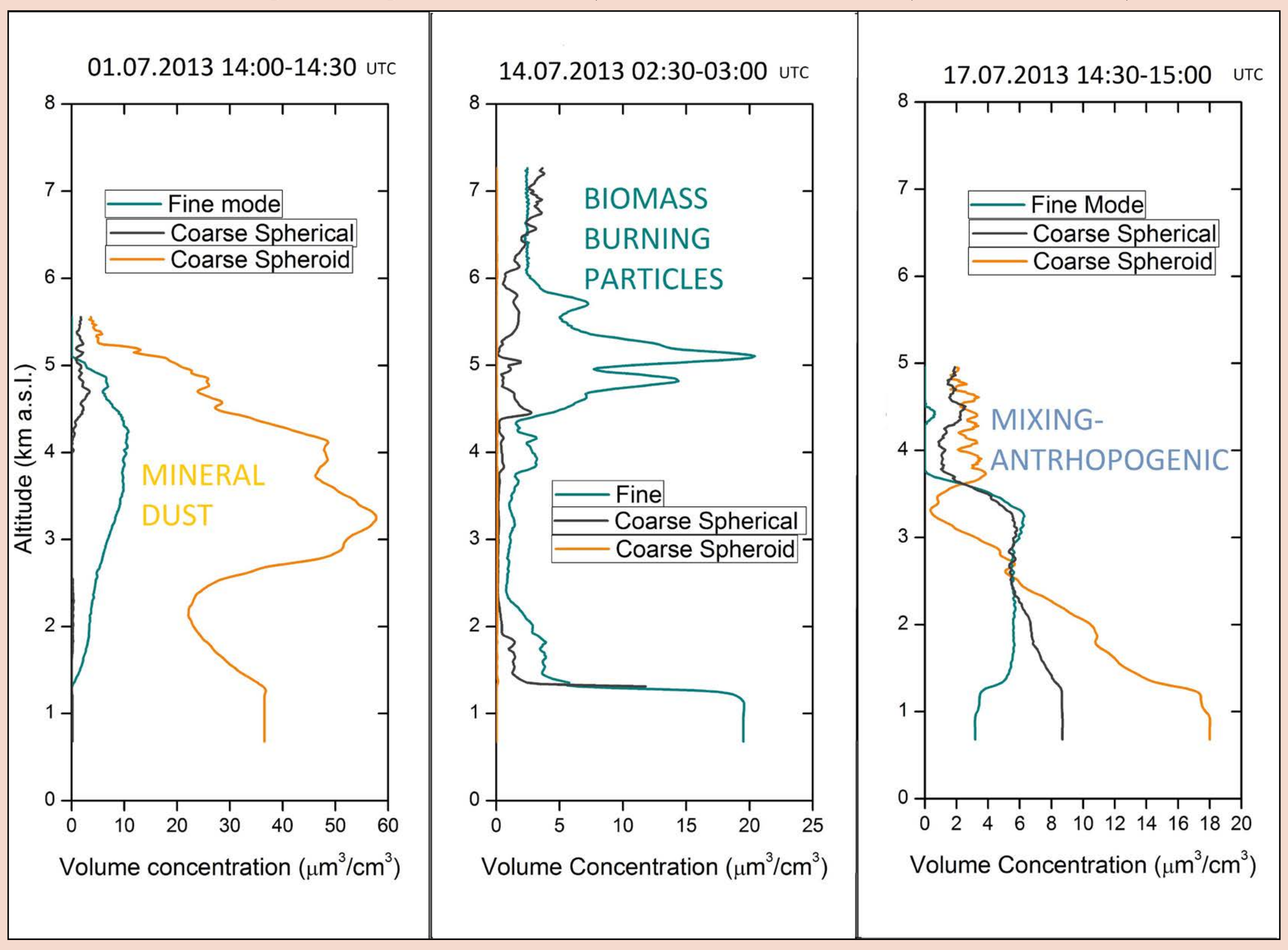
Columnar size distributions were retrieved from the sun-photometer using AERONET code. Coarse mode dominated on July 1st, when total AOD was 0.40 (at 500 nm) with 68% associated to coarse particles. On July 14th, total AOD barely exceeded 0.1, but the size distribution exhibits a clear tendency towards fine mode. For July 17th, the contribution of both modes to the total AOD was around 50%.



Elastic and Raman lidar signals were analyzed in order to retrieve vertically resolved particle optical properties.

Combination of lidar and sun-photometer data used to calculate particle microphysical properties with LIRIC algorithm [7]. Volume concentration profiles were obtained for the fine and the coarse mode, distinguishing between spherical and non-spherical (or spheroidal) particles.





Same layering as optical profiles

July 1st:
· Coarse non-spherical particles
· Vol. conc. up to 58 μm³/cm³

July 14th:
· Fine particles
· Vol. conc. more than 20 μm³/cm³

July 17th:
· Mixture of 3 modes
· Upper layer (2.5-4 km asl): predominance of fine mode; lower layer (below 2.5 km asl): coarse particles

CONCLUSIONS

- Sinergy between multiwavelength vertically-resolved optical profiles retrieved from lidar data and column integrated microphysical properties from sun-photometer measurements provides the input for the retrieval of vertically-resolved particle microphysical properties with LIRIC [7] algorithm.
- Coarse spheroid mode volume concentration values up to 58 μm³/cm³ (~ 87% of the total particle volume concentration) were found coinciding with the highest backscatter and extinction coefficients values for the mineral dust layer. This is in agreement with Angström exponents (AE) around 0 and linear particle dep. ratios (LPDR) around 0.2.
-Fine mode with volume concentration values more than 20 μm³/cm³ (corresponding to 98%) were attributed to the peaks of optical properties for the burning biomass case, whose AE were around 2 and LPDR less than 0.1.
-The layer with local and regional anthropogenic pollution, which is coupled with the planetary boundary layer, shows volume concentration values around 6 μm³/cm³ for the three size modes, higlighting the hybrid behavior of the layer. These results are in agreement with the backward trajectories analysis and the particle optical properties: AE around 1 and LPDR around 0.15.
- In the future, more cases of similar aerosol type events will be analyzed with LIRIC, what will allow for inferring statistical behavior of the aerosol plumes over Granada.

REFERENCES.
[1] Pappalardo, G. et al., "EARLINET: towards an advanced sustainable European aerosol lidar network", Atmos. Meas. Tech. 7, 7, 2389-2409, doi: 10.5194/amt-7-2389-(2014)
[2] Ortiz-Amezcua, P., et al., "Characterization of atmospheric aerosols for a long range transport of biomass burning particles from Canadian forest fires over the southern Iberian Peninsula in July 2013", Applied Optics 47, 43-49 (2014)
[3] Draxler R. R., and G. D. Rolph, "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, 2003
[4] http://www.nrlmry.navy.mil/aerosol.html/
[5] Basart, S., et al., "Development and evaluation of the BSC-DREAM8b dust regional modelo ver Northern Africa, the Mediterranean and the Middle East", Tellus Series B- Chemical and Physical Meteorology 64, 1-23 (2012)
[6] Holben, B. N., et al., "AERONET -A federated instrument network and data archive for aerosol characterization", Remote Sens. Environ. 66 (1), 1-16 (1998)
[7] Chaikovsky A., et al., "Algorithm and software for the retrieval of vertical aerosol properties using combined lidar/radiometer data: dissemination in EARLINET", Volume 1 pp. 399-402, Reviewed and Revised Papers of the 26th International Laser Radar Conference, Porto Heli, Greece (2012)
[8] Sicard, M., et al., "Aerosol lidar intercomparison in the framework of SPALINET -the SPAnish Lidar NETwork: mothodology and results", IEEE Trans. Geosci. Remote Sens . (2008)

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