Sección Especial: 37th AMASON / Special Section: 37th AMASON
Aerosols in the Atmosphere

Aerosol radiative properties retrieved during Saharan dust events in Southeastern Spain from 2005 to 2008

Propiedades radiativas del aerosol obtenidas durante los eventos de polvo sahariano en el Sureste Español desde 2005 a 2008

A. Valenzuela[1,2,*], F. J. Olmo[1,2], H. Lyamani[1,2], A. Quirantes[1], L. Alados-Arboledas[1,2]

1. Departamento de Física Aplicada. Universidad de Granada. Fuentenueva s/n. 18071-Granada. Spain.
2. Centro Andaluz de Medio Ambiente (CEAMA). Avd. del Mediterráneo s/n. 18006-Granada. Spain.

(*) Email: avalenzuela@ugr.es S: miembro de SEDOPTICA / SEDOPTICA member

Recibido / Received: 30/01/2011. Aceptado / Accepted: 30/08/2011.

ABSTRACT:

A large set of aerosol radiative properties using sun-photometric measurements during dust events over Granada from 2005 to 2008 has been obtained. During these desert dust intrusions high values of AOD (440 nm) (0.32±0.17) and low α values (0.51±0.21) were found in our station. These values indicate both high aerosol load and predominance of coarse particles during these events. The aerosol volume size distributions were bimodal, with the fine and coarse radius mode close to 0.19 μm and 2.66 μm, respectively. The mean value of coarse to fine volume concentration ratio (V_c/V_f) was 12±6, showing a predominance of coarse particles. The aerosol single scattering albedo values, $\omega_o(\lambda)$, increases with wavelength. However, the computed values of $\omega_o(\lambda)$ were lower than those reported by other authors for desert dust intrusions. The mixing of desert dust with absorbing particles from anthropogenic origin could explain the low $\omega_o(\lambda)$ values measured in the studied area..

Keywords: Mineral Particles, Atmospheric Aerosol Properties, Principal Plane, Non-spherical Particles.

RESUMEN:

Utilizando medidas fotométricas obtenidas durante las intrusiones de polvo Sahariano que llegaron a Granada desde 2005 hasta 2008 hemos calculado una amplia base de datos de propiedades radiativas del aerosol. Durante estas intrusiones de polvo hemos encontrado altos valores de AOD (440 nm) (0.32±0.17) y bajos valores de α (0.51±0.21). Estos valores indican una alta carga de partículas y el predominio de partículas gruesas durante los eventos. Las distribuciones volumétricas de tamaño son bimodales, con radios del modo fino y grueso centrados en 0.19 μm y 2.66 μm, respectivamente. El valor medio del cociente de los volúmenes de concentración del modo grueso y fino (V_c/V_f) es de 12±6, mostrando el predominio del modo grueso. Los valores del albedo de dispersión simple, $\omega_o(\lambda)$, muestran un incremento con la longitud de onda. Sin embargo, los valores de $\omega_o(\lambda)$ obtenidos son más bajos que los calculados por otros autores en los análisis de polvo del desierto. La mezcla de polvo del desierto con partículas absorbentes de origen antropogénico podría explicar los bajos valores de $\omega_o(\lambda)$ obtenidos en nuestra área de estudio.

Palabras clave: Partículas Minerales, Propiedades del Aerosol Atmosférico, Plano Principal, Partículas no Esféricas.

REFERENCIAS Y ENLACES / REFERENCES AND LINKS

[1]. F. J. Olmo, A. Quirantes, V. Lara, H. Lyamani, L. Alados-Arboledas, "Aerosol optical properties assessed by an inversion method using the solar principal plane for non-spherical particles", *J. Quant. Spectrosc. Ra.* **109**, 1504-1516 (2008).

[2]. B. N. Holben, T. F. Eck, I. Slutsker, D. Tanré, J. P. Buis, A. Setzer, E. Vermote, J. A. Reagen, Y. J. Kaufman, T. Nakajima, F. Lavenu, I. Jankowiak, A. Smirnov, "AERONET-A federated instrument network data archive for aerosol characterization", *Remote Sens. Environ.* **66**, 1-16 (1998).

[3]. L. Alados-Arboledas, H. Lyamani, F. J. Olmo, "Aerosol size properties at Armilla, Granada (Spain)", *Q. J. Roy. Meteor. Soc.* **129**, 1395-1413 (2003).

[4]. T. Nakajima, G. Tonna, R. Rao, Y. J. Kaufman, B. N. Holben, "Use of sky brightness measurements from ground for remote sensing of particulate polydispersions", *Appl. Opt.* **35**, 2672-2686 (1996).

[5]. H. Lyamani, F. J. Olmo, A. Alcántara, L. Alados-Arboledas, "Atmospheric aerosols during the 2003 heat wave in southeastern Spain I: Spectral optical depth", *Atmos. Environ.* **40**, 6453-6464 (2006).

[6]. N. Prats, V. E. Cachorro, M. Sorribas, S. Mogo, A. Berjón, C. Toledano, A. M. Frutos, J. de la Rosa, N. Laulainen, B. A. de la Morena, "Columnar aerosol optical properties during El Arenosillo 2004 summer campaign", *Atmos. Environ.* **42**, 2643-2653 (2008).

[7]. C. Toledano, V. E. Cachorro, A. M. de Frutos, M. Sorribas, N. Prats, B. de la Morena, "Inventory of African desert dust events over the southestern Iberian Peninsula in 2000-2005 with an AERONET Rimel sun photometer", *J. Geophys. Res.* **112**, D21201 (2007).

[8]. O. Dubovik, B. N. Holben, T. F. Eck, A. Smirnov, Y. J. Kaufman, M. D. King, D. Tanré, I. Slutsker, "Variability of absorption and optical properties of key aerosol types observed in worldwide locations", *J. Atmos. Sci.* **59**, 590-608 (2002).

[9]. H. Lyamani, F. J. Olmo, L. Alados-Arboledas, "Physical and optical properties of aerosols over an urban location in Spain: seasonal and diurnal variability", *Atmos. Chem. Phys.* **10**, 239-254 (2010).

1. Introduction

Dust particles interact with solar and thermal radiation modulating Earth´s radiative budget. Sahara desert is the most important source of mineral dust in Europe. The Iberian Peninsula is frequently affected by African air masses with large aerosol load that can modulate the aerosol climatology in different areas, mainly in the South.

Many works obtained desert dust radiative properties using sun-photometric measurements from sky radiance in almucantar configuration. In this paper columnar aerosol radiative properties retrieved during desert dust events over Granada (Spain) from 2005 to 2008 are presented. Columnar radiative properties were computed using the extinction and sky radiance measurements in principal plane configuration by means of a non-spherical inversion code described in [1].

2. Experimental site and instrumentation

Measurements were taken in an urban area at Granada (37.18º*N*, 3.58º*W* and 680 m a.m.s.l.). Granada is a non-industrialized and medium sized city with 300000 inhabitants. The city is located in a natural valley surrounded by mountains with elevations between 1000 and 3350 m a.s.l. The local climate is near-continental with low temperatures in winter and high temperatures in summer. The study area is about 200 km away from the African continent, and approximately 50 km away from the Western Mediterranean basin. Due to its proximity to North Africa the site is frequently affected by Saharan dust intrusions.

In this work, a CIMEL CE-318-4 sun-photometer measuring solar extinction (direct irradiance) and sky radiance in principal plane configuration has been used. The instrument makes direct sun measurements at 340, 380, 440, 670, 870 and 1020 nm, and sky radiance measurements at 440, 670, 870 and 1020 nm. More details about this instrument are given in [2].

3. Methodology

The aerosol optical depth (AOD) at selected spectral channels and the Angström parameter (α) were computed following the methods described in [3].

Columnar aerosol radiative parameters including volume size distribution, single scattering albedo ($\omega_0(\lambda)$) and asymmetry parameter ($g(\lambda)$) were retrieved using the

inversion code of [1]. From the retrieved volume aerosol size distributions the effective radius and the mean modal radius as well as the volume concentration for total, fine and coarse modes were derived following the procedure of [9]. The cutoff radius used in size distributions for fine and coarse modes was 0.5 μm.

Desert dust intrusions over the site were confirmed by the CALIMA project (www.calima.ws). This project uses a large set of information including air masses back-trajectories, satellite data, forecast aerosol models and in situ measurements to predict and confirm desert dust intrusions from Northern Africa over the Iberian Peninsula.

4. Results

CALIMA reported 397 dusty days over the Southern Iberian Peninsula during 2005-2008; 78, 84, 128 and 107 days in 2005, 2006, 2007 and 2008, respectively. Some of these dusty days were accompanied by clouds. The numbers of dusty days with sun-photometer cloud free measurements were 12, 31, 25 and 37 days in 2005, 2006, 2007 and 2008, respectively. Aerosol properties from these events are presented below.

TABLE I.

Mean values of AOD(λ), $\omega_o(\lambda)$ and $g(\lambda)$ computed during desert dust events over Granada from 2005 to 2008.

	440 nm	670 nm	870 nm	1020 nm
AOD ±SD	0.32±0.17	0.26±0.16	0.24±0.16	0.23±0.16
ω_o±SD	0.88±0.02	0.89±0.03	0.90±0.03	0.91±0.03
g±SD	0.69±0.02	0.67±0.02	0.66±0.02	0.67±0.02

TABLE II.

Mean values (M) and standard deviation (SD) of α, r_{eff}, r_g, r_f, V_g, V_f, and V_g/V_f computed during desert dust events over Granada from 2005 to 2008.

	α	r_{eff} (μm)	r_g (μm)	r_f (μm)	V_g $\mu m^3 \mu m^{-2}$	V_f $\mu m^3 \mu m^{-2}$	V_g/V_f
M	0.51	1.05	2.66	0.19	0.19	0.017	12
SD	0.21	0.45	1.46	0.04	0.10	0.006	6

Table I shows the mean values and standard deviation (SD) of AOD (λ), $\omega_o(\lambda)$ and $g(\lambda)$. Table II shows the mean values of α, r_{eff} (effective radius), r_g (coarse mode radius), r_f (fine mode radius), V_g (coarse mode volume concentration), V_f (fine mode volume concentration), and V_g/V_f (volume concentration ratio) during the dusty days that took place over Granada from 2005 to 2008.

The mean value of AOD (440 nm) was 0.32±0.17, with 0.06±0.01 and 1.41±0.01 the minimum and maximum values, respectively (Table I). The high mean value of AOD also showed high standard deviation, indicating a large variation in the atmospheric aerosol load during desert dust events. This large variation could be related to origin of the source and African air mass pathways as well as to the meteorological condition during the transport of the dust. Additional information on aerosol properties over the studied area can be obtained from the analysis of α, ranging from -0.04 to 1.30 with a mean value of 0.51±0.21. Its low mean suggests a large relative contribution of coarse particles during these dust events. Mean values of AOD and α obtained in this study are consistent with those reported in the literature during other desert dust intrusions over the site [1,5]. However, α values obtained here were lower than those obtained (α around 1.4) during Euro-Mediterranean influence episodes [5].

On the other hand, the fine mode volume concentration showed little changes during desert dust events with a mean value of 0.017±0.006 $\mu m^3/\mu m^2$. The mean fine modal radius was 0.19±0.04 μm and the coarse mode volume concentration, V_c, was 0.19±0.10 $\mu m^3/\mu m^2$ (Table II). The standard deviation for V_c indicates a great variation in the coarse-mode concentration during desert dust events. The mean value of V_c/V_f was 12±6, indicating a predominance of coarse particles, characteristic of desert dust. These results are in agreement with the obtained from α.

Both $\omega_o(\lambda)$ and $g(\lambda)$ are key parameters for estimating direct radiative impact of aerosol particles. The $\omega_o(\lambda)$ is defined as the ratio of the scattering coefficient and the extinction coefficient, and is related with the absorptive capacity of the aerosol, taking a value of 1 for

pure scattering particles and below 1 for absorbing ones. Absorption of solar radiation by atmospheric particles results mainly from elemental carbon originated from anthropogenic activities, biomass burning and mineral dust. Particularly, $g(\lambda)$ provides information of the angular distribution of the scattered radiation.

Mean values of $\omega_o(\lambda)$ ranged from 0.88±0.02 to 0.91±0.03 at 440 and 1020 nm, respectively. The most important feature of $\omega_o(\lambda)$ is the increase with wavelength. However, values obtained here were lower than those reported by other authors for pure desert dust [6-8]. The mixing of desert dust with absorbing particles from anthropogenic origin could explain the low $\omega_o(\lambda)$ values obtained during desert dust events over the studied area [9]. The asymmetry parameter showed a distinct wavelength dependence with mean values ranging from 0.69±0.02 to 0.67±0.02 at 440 and 1020 nm, respectively (Table I).

Mean AOD values of 0.28±0.14, 0.36± 0.17, 0.30±0.15 and 0.32±0.19 were obtained in winter, spring, summer and autumn, respectively (Fig. 1). It is interesting to note that for all seasons the AOD median values were lower than the mean values, indicating that the high aerosol load scenarios were occasional. The Angström exponent displays mean values of 0.62±0.31, 0.45±0.26, 0.62±0.31, 0.56±0.27 and 0.57±0.31 for winter, spring, summer and autumn, respectively. In this case, the median values were coincident with the mean values, indicating that the distributions were normal.

5. Conclusions

This paper analyzes the columnar aerosol radiative properties over Granada (Spain) during the desert dust events that occurred from 2005 to 2008, using sun-photometric measurements (extinction and sky radiances in the principal plane configuration) for cloudless days. Dust intrusions were simultaneously confirmed by the CALIMA project. During these dust events high values of AOD and low values of α were obtained. Results indicate a large contribution of coarse particles and bimodal size distributions, with the fine and coarse radius mode close to 0.19 μm and 2.66 μm, respectively.

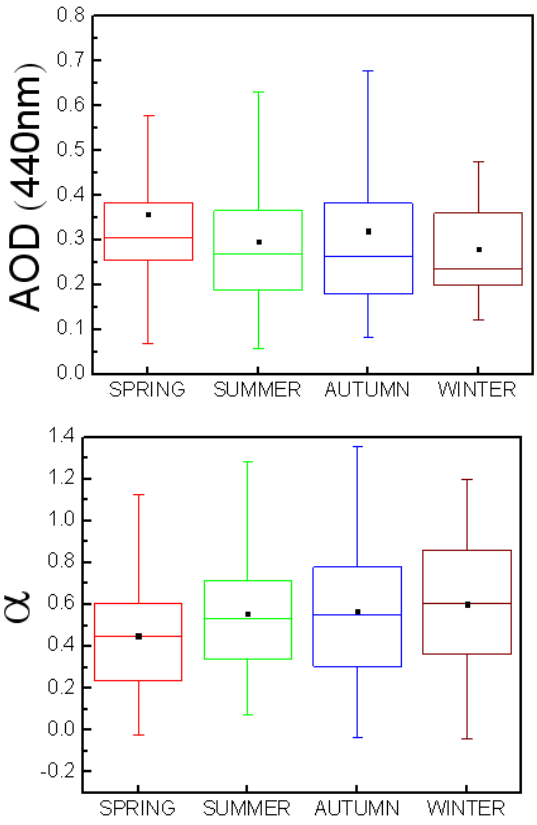

Fig. 1: Seasonal variation of AOD-440 nm and α. The statistics include the values of the mean, the median, the 1st and the 3nd quartile (P25 and P75), as well as the 5th and 95th percentiles (P5 and P95).

However, $\omega_o(\lambda)$ showed lower values than those reported in the literature for pure desert dust. The mixing of desert dust with absorbing particles from anthropogenic origin could explain the low $\omega_o(\lambda)$ values obtained during desert dust events taking place at the studied area.

Acknowledgements

This work was supported by the Andalusian Regional Government through projects Nº: P08-RNM-3568 and P10-RNM-6299. The authors would like express their gratitude to the CALIMA project (www.calima.ws).

