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

Comparative analysis of aerosol observations by sunphotometer (AERONET) and satellite (MODIS): A case study over north-central and southwestern Spain

Análisis comparativo entre observaciones de fotómetros (AERONET) y datos de satélite (MODIS): Un caso de estudio sobre el centro-norte y el suroeste de España

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

ABSTRACT:

The following study is in the logical continuation of recent and ongoing works carried out at GOA-UVA which endeavor to compare and evaluate satellite MODIS (Moderate Resolution Imaging Radiometer)-derived aerosol climatologies against those measured by sun photometers of the AERONET-RIMA network, at El Arenosillo (37.1*N*, 6.7*W*, Huelva) and Palencia (42.0*N*, 4.5*W*), representative of the southwestern and north-central Spanish areas respectively. The following study proposes a detailed analysis of a dust intrusion which was observed over the two regions aforementioned, in March 2004. The analysis is based on the time series of several parameters: the Aerosol Optical Depth (AOD), the Ångström exponent (Alpha), and the fine-mode AOD fraction (FF).

Keywords: Aerosol, Remote Sensing, Satellite, AERONET, MODIS.

RESUMEN:

Este estudio es la continuación de recientes trabajos del GOA-UVA relacionados con la comparativa y la evaluación de climatologías de aerosoles derivadas de datos MODIS (Moderate Resolution Imaging Radiometer) de satélite, con datos de fotómetros de la red AERONET-RIMA en las estaciones del Arenosillo (37.1*N*, 6.7*W*, Huelva) y Palencia (42.0*N*, 4.5*W*), representativas del suroeste y del centro-norte de España. El estudio presenta el análisis detallado de una intrusión de polvo Sahariano sobre la Península Ibérica que ocurrió en el mes de Marzo de 2004, y que se observo en ambas regiones. Los resultados se basan en las series temporales de varios parámetros: el espesor óptico (AOD), el coeficiente de Angström (Alpha), y la fracción del AOD debido al modo fino (FF).

Palabras clave: Aerosoles, Teledetección, Satélite, AERONET, MODIS.

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1. Introduction

The Spanish Gulf of Cadiz is principally characterized by the influence of Atlantic air masses, and by frequent intrusions of African desert dust [1]. This specificity makes it thus a region of great interest to investigate atmospheric aerosol properties and related climate and air quality issues.

Previous studies of Toledano *et al* [2] and Bennouna *et al* [3] focused on two key columnar aerosol properties: the Aerosol Optical Depth (AOD) and Ångström exponent (Alpha), as measured using ground-based remote-sensing measurements from AERONET at the site of El Arenosillo (37.1*N*, 6.7*W*). These studies showed that in this region the annual seasonal patterns of these two parameters is modulated by the two major dust periods (late-winter/early-spring and summer/early autumn), where the transition is represented by a local AOD minimum in spring. Thus the seasonal patterns typically correspond to an increase of the AOD associated to a decrease of Alpha during the months which are affected by frequent intrusions of Saharan dust.

As demonstrated in the work of Bennouna *et al* [3], these overall variations of the climatology are in general satisfactorily reproduced by satellite data from MODIS (Moderate Resolution Imaging Radiometer), and mean monthly climatological values from satellite differ mainly from ground-based during the spring season. On average, monthly values are overestimated by about 30%, and are higher in spring and summer (40-60%).

In the continuation of the above mentioned study, and with the aim to better explain the general agreement and differences between satellite (MODIS) and ground-based (AERONET) climatologies, it was decided to carry out a detailed analysis of various short time series. With this respect, the following results constitute part of a preliminary study, where a particular event is presented: the desert dust event of March 2004.

2. Data description

The ground-based data employed in this study were taken from the AERONET global sunphotometer network [4,5]. The AERONET site of El Arenosillo, which was established and maintained by the Group of Atmospheric Optics (GOA) is also part of the RIMA (Iberian Network for Aerosol Measurements) network, a subnetwork within AERONET. Following AERONET protocols, the standardized sun photometer instruments routinely performs direct sun measurements at the wavelengths of 440, 670, 870 and 1020 nm, at least every 15 minutes. The ground-based time series presented in this study use all available Level 2.0 data (i.e. cloud cleared, and quality assured) from AERONET-RIMA site of El Arenosillo: direct sun for the AOD, and O'Neill inversions for the fine-mode AOD fraction.

To represent the MODIS aerosol data over the AERONET site, the standard Terra-MODIS level 2 aerosol product MOD04 (collection 5) provided by NASA GSFC [6] was used [7]. This product provides the aerosol optical depth over land and ocean at the spatial resolution of 10×10 km^2. Spatial subsets of these MODIS data were extracted to select all pixels falling within a distance of 25 km from the AERONET location,

and spatially averaged to obtain the data time series for MODIS.

3. Results

As shown in Fig. 1, on the RGB true color image of MODIS for the 16 March 2004 at 10:35 UTC, a dust intrusion was observed over both north-central and southwestern Spain. Besides, the 5-hour backward trajectories of the air masses arriving over el Arenosillo at 12:00 UTC as obtained with the HYSPLIT model for 3 levels (500, 1500, 3000 meters) of altitude AGL (Above Ground Level), also support the presence of Saharan desert dust aerosols over these regions on 15th, 16th and 17th March (figures not shown here).

Figures 3 and 4 present the time series between 4th January and 3rd April for the sites of El Arenosillo and Palencia respectively. The time series are represented over a 3 month period so that the dust events can be easily identified. The values of the observations related to the aforementioned dust event are also summed up in Tables I and II. As it can be seen on this graph, the 16 of March corresponds to a peak in the daily AOD (0.74) and to a low daily average of the Alpha (0.55) according to AERONET. For this day, the 25 km average there are no MODIS retrievals over land, however over ocean the dust intrusion is well detected by the MODIS sensor, with an AOD value of 0.88 and an Alpha of 0.54 at the satellite overpass. For the site of Palencia, AERONET time series indicate that the

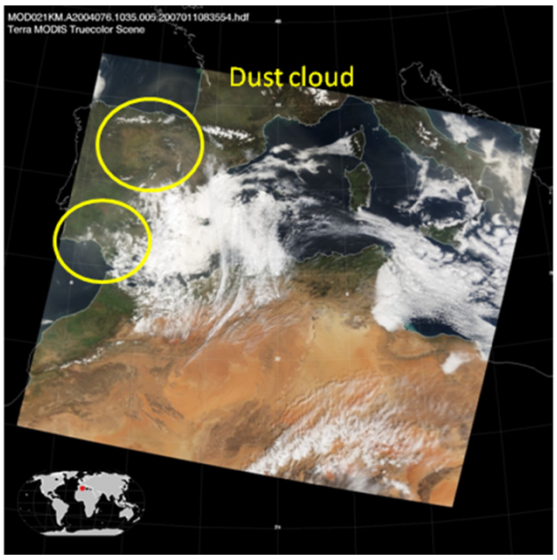

Fig. 1: RGB true color image of Terra/MODIS over Spain on 16 March 2004 10:35 UTC.

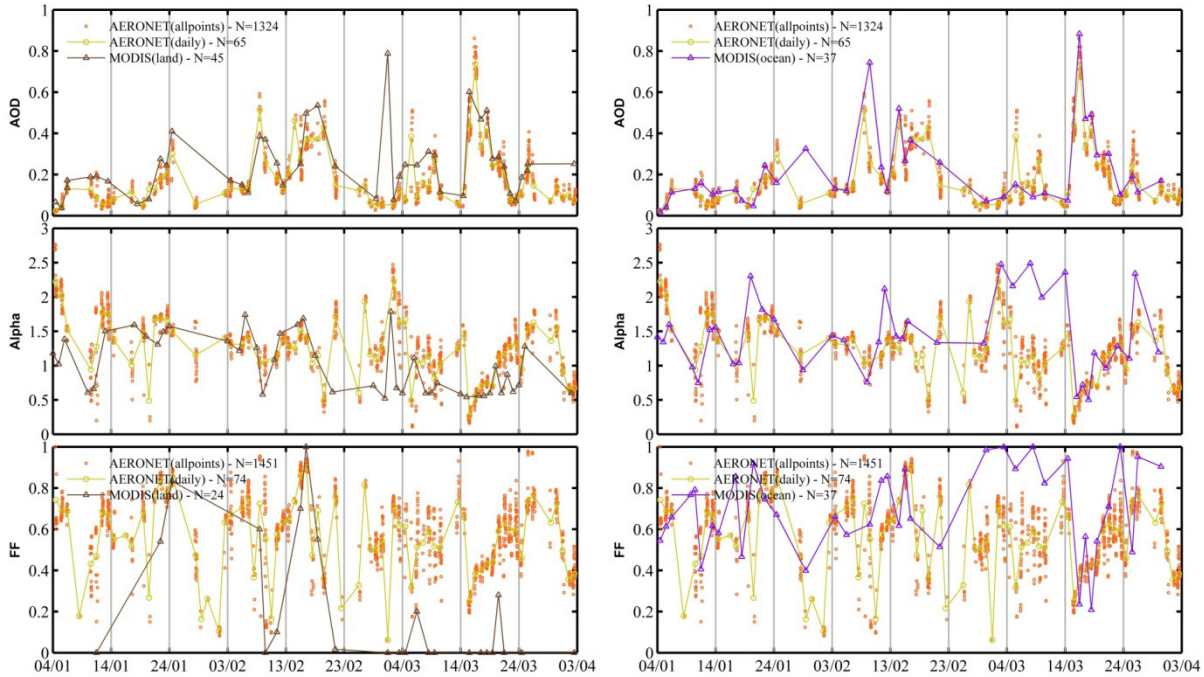

Fig. 2: Time series from AERONET and MODIS over El Arenosillo between 4 January and 3 April 2004, from top to bottom: AOD, Ångström exponent (Alpha) and fine-mode AOD Fraction (FF). The left and right panels correspond to the results obtained with the retrieval algorithm over land and over ocean respectively.

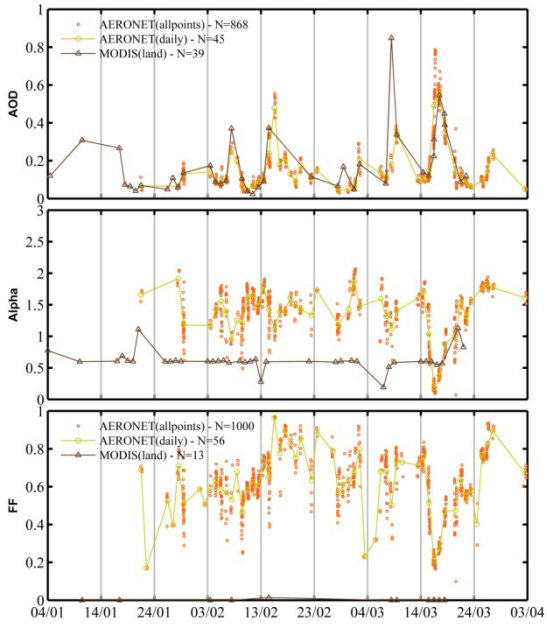

Fig. 3: Same as Fig. 2. for the site of Palencia (MODIS only over land).

TABLE I

AOD, Ångström exponent, and AOD fine-mode fraction from AERONET (daily) and MODIS for 16th and 17th March 2004 at El Arenosillo

	16 March 2004			17 March 2004		
	AERONET	MODIS (ocean)	MODIS (land)	AERONET	MODIS (ocean)	MODIS (land)
AOD	**0.74**	**0.88**	-	0.33	0.47	0.47
AE	0.55	0.54	-	0.70	0.72	0.56
FF	0.38	-	-	0.40	0.56	0.00

TABLE II

Same as Table I for the site of Palencia.

	16 March 2004		17 March 2004	
	AERONET	MODIS (land)	AERONET	MODIS (land)
AOD	0.49	0.27	**0.55**	**0.55**
AE	0.18	0.60	0.37	0.57
FF	0.21	0.00	0.27	0.00

daily AOD reaches a maximum on the 17th March with a value of 0.55. For that day Alpha was on average of 0.35. The MODIS AOD at overpass agrees well with the AERONET data.

4. Conclusions

In general the variations of the AERONET AOD are well captured by MODIS observations. The values and variations of the Ångström exponent are better reproduced by MODIS over ocean (when available) than MODIS over land, as shown for the coastal site of El Arenosillo.

Although the MODIS data for this single event are in reasonable agreement with those of AERONET for both sites, it should be noted when looking at the overall behaviour of extended time series, that the variability of Alpha is very low for MODIS over land data as compared to over ocean. The same behaviour can be seen for the FF parameter. Besides the values of this latter appear unexpectedly very low over land, and this is observed in most cases.

Acknowledgements

The authors would like to thank the teams of INTA-ESAT, AERONET and PHOTONS. We are also grateful to the members of the NASA MODIS science teams for providing the data used for this study. The authors gratefully acknowledge the NOAA Air Resources Laboratory (ARL) for the provision of the HYSPLIT transport and dispersion model used in this publication. Financial supports from the Spanish MICIIN (ref. CGL2008-05939-CO3-00/CLI and CGL 2009-09740) and from the GR-220 Project of the "Junta de Castilla y León "are gratefully acknowledged.

