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Aerosols measurements with a CIMEL CE-318 sun photometer in Camagüey, Cuba

René Estevan[1], Yasmine Benouna[2], Benjamín Torres[2], Juan. C. Antuña[1], Boris Barja[1], Carlos E. Hernández[1], Carlos Toledano[2], David Fuertes[2], Ramiro González[2], Victoria E. Cachorro[2], Ángel M. de Frutos[2]

[1]Grupo de Óptica Atmosférica de Camagüey, Centro Meteorológico de Camagüey, INSMET, Camagüey, CUBA
Tel: +53 32 262397, E-mail: rene@cmw.insmet.cu

[2]Grupo de Óptica Atmosférica, Universidad de Valladolid, Valladolid, ESPAÑA
Tel: +34983423270, E-mail: chiqui@goa.uva.es

SUMMARY

Aerosol Optical Depth (AOD) measurements, carried out with a sun photometer CIMEL CE-318, installed in Camagüey, Cuba, are reported. More than 700 days of measurements are analyzed, of them 400 days corresponds to level 2.0 of Aerosol Robotic Network (AERONET) dataset. These data cover from October 7, 2008 to April 22, 2010. To the level 1.5 corresponds more than 300 days from June 3, 2010 to June 17, 2011. The average value of AOD for the first period (level 2.0) is τ_a(500 nm) = 0.14, while for the second τ_a(500 nm) = 0.17, both cases with relatively high values. These AOD values confirm preliminary results about the Maritime Mixed characteristic for the Camagüey site. Several Saharan dust events are reported during the analyzed period.

Key words: CIMEL, sunphotometer, AOD, Saharan dust, aerosol.

INTRODUCTION

Many techniques and instruments has been developed for aerosols measurements, these includes both, passive and active methods. Camagüey, a former lidar site, have been using different techniques and instruments, including the lidar (Estevan *et al.*, 1998; Fonte and Antuña, 2011). Some years ago a sun photometer was installed as result of a scientific agreement between the Grupo de Óptica Atmosférica from Valladolid University, Spain (GOA-UVA) and the Grupo de Óptica Atmosférica de Camagüey (GOAC-INSMET) belonging to Meteorological Institute of Cuba. The instrument is operated as part of RIMA (Red Ibérica de Medición de Aerosoles). The first results of this joint research on tropospheric aerosols, with a preliminary characterization, were exposed by Estevan *et al*. (2011). From this study, the characteristic of a maritime mixed environment was evidenced, as well as, the similarity between our conditions, as island, and others islands in the Atlantic region (Smirnov *et al*., 2002).

The international community interest about tropospheric aerosols and their influence over solar radiation, the environment and the human being, have also motivated our interest. An important topic in these studies is constituted by the Saharan dust, originated over the North African continent and dragged through the Atlantic Ocean until the Americas over the Trade winds (Prospero and Lamb, 2003). One of the most important interests is to determine the space-temporal characteristics of these events and magnitude of its influence over local conditions, as well as, the contribution of industrial polluted aerosols over background conditions.

MATERIALS AND METHODS

The instrument employed at the Camagüey site is a sun photometer CIMEL CE-318, an automatic multi-spectral sun tracking photometer, designed for very accurate sun measurements. Since the beginning of measurements, October 7, 2008, up to the present, four instruments were operated at Camagüey location. The RIMA- number of these instruments, as well as, the exploitation period, is shown in table 1.

Number	Dates	
	Initial	Final
#425	10/07/2009	05/28/2009
#353	06/04/2009	04/23/2010
#419	06/03/2010	06/17/2011
#424	07/21/2011	current

Table 1. List of instruments used at Camagüey site to the present, also both installation and removal dates listed.

The methods, measurement protocols, data processing, cloud-screening algorithm and inversion techniques employed by AERONET, to derive the aerosol optical properties for measurements, carried out with sun photometer, has been broadly reported (Dubovik and King, 2000; Smirnov *et al.*, 2000; Holben *et al.*, 2001). All dataset employed in the present study has been downloaded from the AERONET web site (AERONET). The variables used in present study are the Aerosol Optical Depth (AOD) and the Ångström Parameter (AP), commonly also named alpha parameter (α).

Datasets

For the all period, since October 10, 2008 to June 17, 2011 a total of 825 days of raw measurements (Level 1.0, according with the AERONET standards), were carried out. From these days, 779 reach the Level 1.5, the cloud screened level, representing the 94.4% of the all measurements days. The maximum stage of AERONET standard (Level 2.0) is the consequence of the instrument post calibration. A total of 401 days achieve this level, covering since October 7, 2008 to April 23, 2010. The photometers #425 and #353 are involved in this period, in which 462 days of raw measurements were carried out, from a total of 563 possible days, which it means a 82.1% of completion. A total of 435 days passed to the next AERONET level (cloud screened), this means that a 94.2% of the measurements days achieve the Level 1.5 while a 86.8% reach the Level 2.0.

In the present study we analyze the period corresponding with the Level 2.0, in the range of dates mentioned above. During this period two months are missing, April and May of 2009, because a failure in the motorized system of the first installed photometer and delays in the arrival of the replacement.

RESULTS

The monthly mean AOD at 500 nm (τ_a) and the corresponding standard deviation (σ^a) for the boarded period, are shown in figure 1. The maximum values for both, monthly mean and standard deviation, take place in July 2009. These maximums, τ_a = 0.26 and σ^a = ±0.14, respectively; are related with several episodes of Saharan dust arriving to the Caribbean region and to the Camagüey measurement site consequently. These aerosols are added to base "line" conditions (maritime and urban and industrial polluted aerosols). Saharan events, as well as, the analysis of 6 months (considered as background period), were accounted for in a preliminary study employing only values of AERONET Level 1.5 (Estevan *et al.*, 2011).

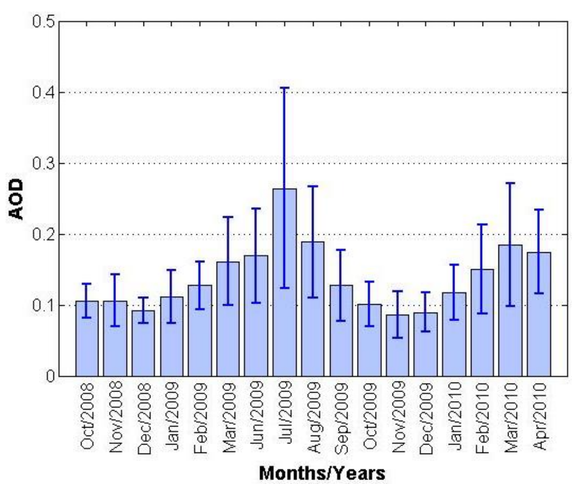

Figure 1. AOD (500 nm) monthly mean values with standard deviation (error lines), corresponding to all period of AERONET Level 2.0 dataset.

The AOD mean value for the actual analysis is τ_a = 0.14, a little higher than the preliminary study but, in this analysis the occurrence of Saharan dust events are included. Secondary maximums were found, mainly, within the summer season (June – August), although important values were found around March for both year 2009 and 2010, respectively. The minimum values of both, monthly means and standard deviation values occur during the winter season (approximately between October and January), when background conditions are established and not disturbances, by the presence of Saharan dust, take place.

The characteristic of maritime mixed conditions for the Camagüey site, obtained in a preliminary study (Estevan *et al.*, 2011), are corroborated in he present analysis. It is shown in the scattergram of AOD versus Ängstrom Parameter (AP, α) shown in figure 2. The values of AP over one are related with continental or urban-polluted aerosols. In the case of maritime aerosols, these can be located in the region with τ_a below to 0.15 and AP below one. On the other hand, presence of Saharan dust is also evident, within the analyzed period, owing to the high values of AOD (τ_a > 0.15) versus the small AP (α < 0.5), associated with the existence of large particles, process consistent with such phenomenon.

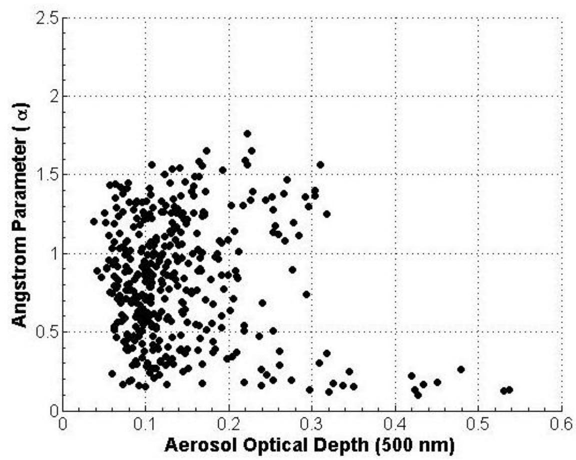

Figure 2. Scattergrams of daily means values of Ångström exponent (440-870nm) versus Aerosol Optical Depth (500nm).

Daily means values of AOD (500 nm) and the Ängstrom Parameter (440-870 nm), are show in figure 3, at the top and bottom, respectively. The disturbance caused by the Saharan dust over the background conditions can be appreciated clearly in this figure. The aerosol background conditions are characterized for this period at Camagüey site, by a mode value (τ_{am}) for AOD at 500 nm of τ_{am} = 0.1 with more than 40% of occurrence.

In the months around July 2009 it could be appreciated (at the top of figure 3) the load of Saharan dust aerosols, with a significant increase of AOD values, which disrupt the pattern of background conditions. Consequently, the effects of such aerosols are clearly registered in the AP behavior (bottom of same figure). With a values scattering, concentrated fundamentally between 0.5 > α < 1.5, characteristic of the maritime mixed environment, the presence of these north African aerosols cause a significant decrease of all AP values, bellow 0.5, during these months. The increase of AOD between February and April, 2010 is not related with Saharan dust events. In these cases the source of aerosols is related, mainly, with industrial and urban polluted air mass from the North American continent.

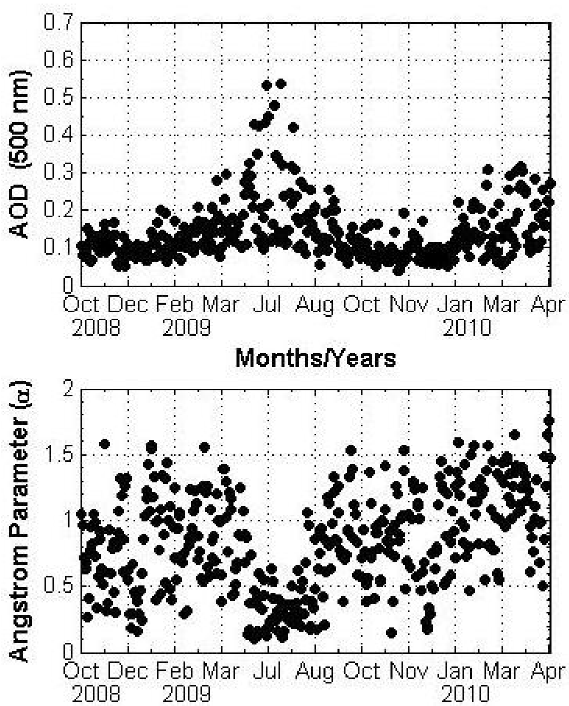

Figure 3. Daily mean values of Aerosol Optical Depth (top) at 500 nm and Angstrom Parameter (bottom) for 440-870 nm.

Practically one year cover the second period analyzed on the present study corresponding to Level 1.5, since June 3, 2010 to June 17, 2011. The AOD values, showed here, have a preliminary character, until that the post calibration procedure for the CIMEL #419 take place. The AOD mean value for this period is 0.17 while the maximum value of 2.36, because the presence of a strong Saharan dust event affecting our site in July 5, 2010, as could be appreciated in the figure 4, through MODIS Terra and Aqua daily level-3 data, produced with the Giovanni online data system.

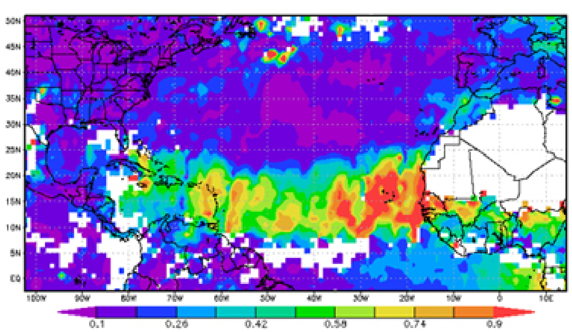

Figure 4. AOD at 550 nm from MODIS Terra and Aqua daily level-3 data, integrating days since July 1 to 6, 2010.

CONCLUSIONS

The preliminary results about the maritime mixed characteristics of Camagüey site, derived with the Level 1.5 of the AERONET data, has been corroborated in the present research. The AOD mean value (τ_a = 0.14) is higher than the obtained in the previous study but in the same order of magnitude and the frequency distribution is centered at τ_{am} = 0.1. The arrival of Saharan dust aerosol to Camagüey site during the summer season, is also clearly demonstrated with the Level 2.0 AERONET dataset, but in this case, with a AOD maximum value of 0.54, lower than reported in the previous preliminary results.

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