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LIDAR RATIO DERIVED FOR PURE DUST AEROSOLS: MULTI-YEAR MICRO PULSE LIDAR OBSERVATIONS IN A SAHARAN DUST-INFLUENCED REGION

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ABSTRACT

A seasonal distribution of the Lidar Ratio (LR, extinction-to-backscattering coefficient ratio) for pure Saharan dust particles has been achieved. Simultaneous MPLNET/Micro Pulse lidar measurements in synergy with AERONET sun-photometer data were collected in the Tenerife area, a Saharan dust-influenced region, from June 2007 to November 2009. Dusty cases were mostly observed in summertime (71.4 % of total dusty cases). No differences were found among the LR values derived for spring, summertime and autumn times (a rather consistent seasonally averaged LR value of 57 sr is found). In wintertime, however, a higher mean LR is derived (65 sr), associated likely with a potential contamination from fine biomass burning particles coming from Sahel area during wintertime deforestation fires period. Results, obtained from a free-tropospheric pristine station (AEMET/Izaña Observatory) under Saharan dust intrusion occurrence, provide a more realistic perspective about LR values to be used in elastic lidar-derived AOD inversion for Saharan pure dust particles, and hence in improving CALIPSO AOD retrievals.

1. INTRODUCTION

The estimation of the extinction-to-backscattering coefficient ratio (Lidar Ratio: LR) from lidar measurements is a crucial task in aerosol research. In contrast to the height-resolved LR retrieval from Raman lidars, an a-priori constant LR value must be introduced in the inversion algorithms applied to elastic lidar measurements in obtaining the aerosol extinction. However, the LR is an aerosol-type dependent parameter. Hence, the elastic approach must be carefully applied to realistic aerosol scenarios with mixture of aerosols. Usually, LR is determined by elastic inversion in an iterative procedure by constraining the extinction profile to the columnar-integrated Aerosol Optical Depth (AOD) [1, 2], as obtained from ancillary instrumentation.

Several aerosol-type LR climatologies have been reported to date, with a special emphasis devoted to dust [i.e., 3-9, among others]. In particular, a single LR value is assumed by CALIOP (the current space-borne elastic lidar) aboard CALIPSO (www-calipso.larc.nasa.gov) for the retrieval of extinction products; although, the CALIPSO aerosol scheme differentiates between two dust categories: 'pure dust' and 'polluted dust' with associated LR values of 40 sr and 65 sr, respectively [10]. However, in the particular case of 'pure dust' aerosols, the LR value is under discussion. Instead, different lidar-derived values are proposed depending on the dust source region, either Sahara desert [i.e., 7] or Arabian sources [i.e., 11]. In addition, based on AERONET (AErosol Robotic NETwork, aeronet.gfsc.nasa.gov) retrievals [6], mean LR values of 55 sr and 43 sr are obtained for dust particles, respectively, from Sahara and Middle East (ME) areas.

The aim of this work is to contribute to a deeper understanding of dust LR variance globally, by proposing a more realistic LR value for pure dust particles coming from the Sahara desert region. Our study is focused on the detection of Saharan dust over the Izaña Observatory (Tenerife, Canary Islands). Dusty profiles observed from June 2007 to November 2009 with synergetic lidar/sun-photometry measurements are analyzed.

2. METHODOLOGY

2.1 Observational area

Measurements were performed at two aerosol stations that are frequently influenced by Saharan dust intrusions during spring and summer months. They are located in the Tenerife Island (Canary Islands) at two distant altitudes:

- the Santa Cruz de Tenerife Observatory (SCO, 28.5ºN 16.2ºW, 52 m a.s.l.), a subtropical coastal site, belonging to several aerosol networks: NASA/AERONET and NASA/MPLNET (mplnet.gsfc.nasa.gov); and
- the Izaña Observatory (IZO, 28.3ºN 16.5ºW), sited in a pristine free-tropospheric environment at 2367 m a.s.l., which is a NASA/AERONET station, as well.

Both sites are managed by the Spanish Meteorological Agency (AEMET).

2.2 Measurements and instrumentation

Simultaneous measurements of both range-resolved lidar profiling and passive columnar-integrated sun-photometry observations were performed, respectively, by using a MPLNET Micropulse Lidar v.3 (MPL-3) located at SCO, and an AERONET Cimel sun-photometer (C-318) at IZO.

The MPL-3 is an elastic lidar, operated by the Instituto Nacional de Técnica Aeroespacial (INTA), with the following primary features: a highly-pulsed (2500 Hz) and low-energy (10 µJ, max.) laser at 523 nm, operational in full-time continuous mode (24 h day^{-1}/365 days year^{-1}), at 75-m vertical resolution and 1-minute integrating time. MPL instrumental details are discussed further [12]. The AERONET C-318 sun-photometer is operated by AEMET, and Level 1.5 (cloud screened) and 2.0 (quality-assured) inversion retrieval products used, including the spectrally-resolved Aerosol Optical Depth at 500 nm (AOD) and Ångström Exponent (AEx).

2.3 LR retrieval for pure dust

The inversion procedure used for retrieving LR at IZO station is shown in more detail in [13]. In short, the elastic inversion is applied to MPL-3 measurements using the IZO/AOD constraint for iterative method convergence, retrieving the LR for pure dust particles. Given the conditions experienced at IZO, being above the marine boundary layer, aerosol intrusions are mostly dominated by Saharan dust particles.

MPL-3 profiles and sun-photometry data are hourly-averaged. LR inversions are performed using AERONET sun-photometer AOD constraint for total signal transmission. Therefore, only day-time lidar profiles are examined.

3. RESULTS

3.1 Selection of the dusty cases

Dusty conditions are defined, as adopted from [14], based on two points: 1) AERONET AOD/AEx data reflect coarse particle presence including high-moderate AOD at 500 nm (AOD > 0.2) and low AEx for the 440/675 nm wavelength pair (AEx < 0.5) over > 40% of the day-time period, and 2) HYSPLIT backtrajectory air masses analysis indicating a likelihood for Saharan origin (North-Africa latitudes > 20ºN). Five-day back-trajectories calculated at four selected altitudes (a.g.l.): 500 m (surface), 1500 m (max. BL top), 3000 m (FT heights) and 5000 m (above IZO station) are examined.

Dusty cases are selected by using these AOD and AEx data at the SCO site and confirming the Saharan origin of air masses. AERONET data from the La Laguna site (also located in Tenerife Island, ~ 8 km from SCO) were used instead from 08 May to 14 August 2007 due to the unavailability of AERONET SCO data during this period. Table 1 shows the seasonal distribution of the arrival of Saharan dust intrusions over Tenerife area from June 2007 to November 2009.

Among 189 dusty days identified using the Saharan dust criterion, 109 coincident with MPL-3 observations were analyzed. Their seasonal distribution shows that Saharan dust intrusions

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mostly arrive during summer-time (51.7% of total) (see Table 1).

Table 1. Statistical analysis of the Saharan dust intrusions over Tenerife for the June 2007 – November 2009 period.

Season	Summer	Autumn	Winter	Spring
Seasonal periods	JJA 2007-2009	SON 2007-2009	DJF 2007/08-2008/09	MAM 2008-2009
Dusty days: total / MPL	105 / 72	33 / 16	16 / 4	35 / 17
Frequency (%)	51.7	17.7	8.8	21.8
Nº profiles analyzed	555	92	13	117

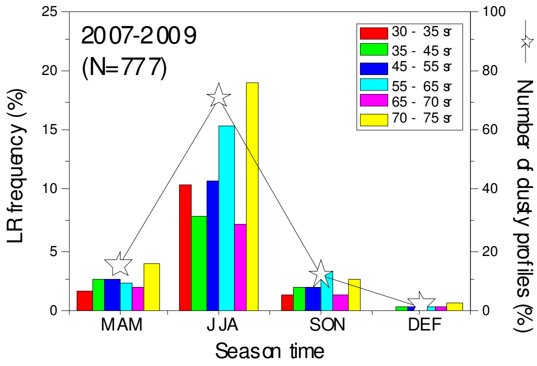

Fig. 1. (Left axis) Seasonal frequency of the retrieved LR for Saharan pure dust particles, as detached in several LR ranges (color bars). (Right axis) Number of dusty profiles examined (in %, star symbols).

3.2. Evaluation of the LR derived for Saharan pure dust particles

LR derived for the Saharan dust sample are assessed seasonally. A total of 777 dusty lidar profiles were examined, divided into 117, 555, 92 and 13 profiles for spring (MAM), summer (JJA), autumn (SON) and winter (DJF) times, respectively. In order to evaluate the seasonal LR distribution, retrieved values were detached for each season time into five LR ranges: 30-35 sr, 35-45 sr, 45-55 sr, 55-65 sr and 65-70 sr. In addition, an extra LR range is included (70-75 sr) for considering a potential contamination of fine-mode biomass burning particles. Results of the seasonal LR distribution obtained for the dusty sample are illustrated in Figure 1.

71.4% of dusty cases correspond to summertime (JJA), less than 20% to spring and autumn, and less than 2% to winter. Results indicate that predominance of a given LR range is not observed. LR are mostly in the ranges of 55-65 sr (15.6%) and 70-75 sr (19.0%) in summertime. Meanwhile, similar values within all the LR ranges are observed for all other periods. The mean LR obtained for each season is 57.4 ± 14.6 sr, 56.6 ± 14.7 sr, 56.6 ± 13.2 sr and 64.9 ± 7.2 sr, respectively, for MAM, JJA, SON and DJF.

In comparison with LR reported for Saharan dust in the literature, those derived in this work are mostly similar. For instance, our results match (except for wintertime) those AERONET-derived mean LR (55 sr) over Sahara [6]. They are closer to that LR (58 sr) proposed by EARLINET (European Aerosol Lidar NETwork, www.earlinet.org), on the basis of multi-year lidar measurements of Saharan dust intrusions over Europe [7]. However, they are higher than that LR of 40 sr assumed by CALIPSO for 'pure dust' aerosols in Level 2 extinction retrievals [10]. Higher LR observed in wintertime likely reflect contamination of fine-mode biomass burning particles coming from Sahel region, where seasonal deforestation is common [15].

4. CONCLUSIONS

Collocated MPL-3 lidar profiling and AERONET sun-photometry data were collected in Tenerife, a Saharan dust-influenced region, from June 2007 to November 2009 in order to retrieve the LR for pure dust particles coming from Saharan sources.

Those obtained LR have been analyzed depending on season. No differences are observed in average for spring, summer and autumn times. A relatively constant seasonally-averaged mean LR value of 57 sr is found. Sample contamination from fine-mode biomass burning particles coming from the Sahel area during wintertime deforestation fires period are likely influencing higher LR retrieved during wintertime. Outside of this latter period, our findings are consistent with recent reports of dust LR.

In general, results obtained from Tenerife/IZO measurements during Saharan dust intrusion occurrence deepens our understanding of LR values and seasonal variance so as to be used in elastic lidar-derived AOD inversions for dusty conditions. Consequently, they can be also addressed to improve the AOD retrievals from CALIPSO measurements over Saharan areas.

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