Atmospheric Environment 142 (2016) 420–429

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Vertical mass impact and features of Saharan dust intrusions derived from ground-based remote sensing in synergy with airborne in-situ measurements

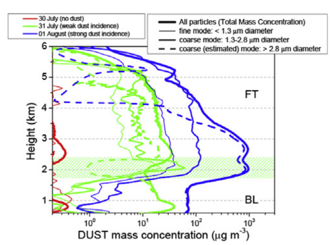
Carmen Córdoba-Jabonero [a, *], Javier Andrey-Andrés [a, 1], Laura Gómez [a, 2], José Antonio Adame [a], Mar Sorribas [a], Mónica Navarro-Comas [a], Olga Puentedura [a], Emilio Cuevas [b], Manuel Gil-Ojeda [a]

[a] Instituto Nacional de Técnica Aeroespacial (INTA), Atmospheric Research and Instrumentation Branch, Ctra. Ajalvir km. 4, Torrejón de Ardoz, 28850, Madrid, Spain
[b] Agencia Estatal de Meteorología (AEMET), Atmospheric Research Centre of Izaña, Sta. Cruz de Tenerife, Spain

HIGHLIGHTS

- Synergy between airborne and Lidar observations for Saharan dust vertical mass impact.
- Optical and microphysical properties reported for Saharan Air Layer characterization.
- Higher dust incidence in FT w.r.t. BL regarding particle fine and coarse size modes.
- Assuming averaged MEE is critical in mass concentration estimation of single layers.
- Good agreement in vertical extinction retrieval between MAXDOAS and LIDAR profiling.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 9 December 2015
Received in revised form
25 June 2016
Accepted 1 August 2016
Available online 4 August 2016

Keywords:
Airborne measurements
Air quality impact
Dust
LIDAR

ABSTRACT

A study of the vertical mass impact of Saharan dust intrusions is presented in this work. Simultaneous ground-based remote-sensing and airborne in-situ measurements performed during the AMISOC-TNF campaign over the Tenerife area (Canary Islands) in summertime from 01 July to 11 August 2013 were used for that purpose. A particular dusty (DD) case, associated to a progressively arriving dust intrusion lasting for two days on 31 July (weak incidence) and 01 August (strong incidence), is especially investigated. AERONET AOD and AEx values were ranging, respectively, from 0.2 to 1.4 and 0.35 to 0.05 along these two days. Vertical particle size distributions within fine and coarse modes (0.16–2.8 µm range) were obtained from aircraft aerosol spectrometer measurements. Extinction profiles and Lidar Ratio (LR) values were derived from MPLNET/Micro Pulse Lidar observations. MAXDOAS measurements were also used to retrieve the height-resolved aerosol extinction for evaluation purposes in comparison to Lidar-derived profiles. The synergy between Lidar observations and airborne measurements is established in

* Corresponding author.
E-mail address: cordobajc@inta.es (C. Córdoba-Jabonero).
URL: http://www.inta.es/atmosfera
[1] Now at: CNRM-GAME, Metéo-France and CNRS, Toulouse, France.
[2] Also at: Groupe de Spectrométrie Moléculaire et Atmosphérique, URM CNRS 7331, UFR Sciences Exactes et Naturelles, Reims, France.

http://dx.doi.org/10.1016/j.atmosenv.2016.08.003

Mass efficiency
MAXDOAS

terms of the Mass Extinction Efficiency (MEE) to calculate the vertical mass concentration of Saharan dust particles. Both the optical and microphysical profilings show dust particles mostly confined in a layer of 4.3 km thickness from 1.7 to 6 km height. LR ranged between 50 and 55 sr, typical values for Saharan dust particles. In addition, this 2-day dust event mostly affected the Free Troposphere (FT), being less intense in the Boundary Layer (BL). In particular, rather high Total Mass Concentrations (TMC) were found on the stronger DD day (01 August 2013): 124, 70 and 21 μg m^{-3} were estimated, respectively, at FT and BL altitudes and on the near-surface level. This dust impact was enhanced due to the increase of large particles affecting the FT, but also the BL, likely due to their gravitational settling. However, the use of an assumed averaged MEE value can be especially critical for estimating the mass concentration of particular layers. Moreover, the potential of MAXDOAS retrieval for aerosol extinction profiling is also evidenced by showing a relatively good agreement with the Lidar-derived extinction profiles, once a particular smoothing procedure is applied to Lidar measurements.

1. Introduction

The vertical distribution of dust plays a significant role in climate-related issues, in particular those associated to its atmospheric radiative forcing (Boucher et al., 2013; Myhre et al., 2013). In addition, height-resolved information of the dust properties is required for both aerosol transport modelling (i.e., de la Paz et al., 2013; Zhang et al., 2013), particularly relevant for particle deposition estimation (Schepanski et al., 2009), and satellite data validation (i.e., Campbell, et al., 2012; Amiridis et al., 2013). In order to obtain this information, a general effort is being made by the ESA (European Space Agency) Earth Observation programs related to the next future Copernicus/Sentinel and EarthCARE (Earth Cloud-Aerosol-Radiation Explorer) missions focused on the vertical monitoring of aerosols and clouds and the retrieval of their macro/microphysical and optical properties for assessment of both the air quality impact and radiative forcing concerns.

Canary Islands offer a suitable region for Saharan dust monitoring, as located downwind of the Sahara desert. The arrival of dust plumes are frequent in this area, mainly in summertime and extended up to high altitudes (Córdoba-Jabonero et al., 2014, 2016). The vertical characterization of individual dust events is relevant for the determination of the so-called Saharan Air Layer (SAL), defined as a mass of warm and dusty air, in order to evaluate the climate impact of such phenomena, even at local scales (Carlson and Prospero, 1972). Indeed, extended campaigns have been carried out over this region and surroundings specially focused on dust research; in particular, both AMMA 2006 (African Monsoon Multidisciplinary Analysis, Formenti et al., 2011) and SAMUM 2006 and 2008 (Saharan Mineral Dust Experiment, Ansmann et al., 2011 and reference therein) must be mentioned for their relevance in desert dust characterization using both ground-based and airborne observations.

In this sense, the AMISOC (Atmospheric Minor Species relevant to the Ozone Chemistry) project was planned as a multi-instrumented campaign (AMISOC-TNF) carried out, particularly, over Tenerife area (Canary Islands, Spain) in summertime. The main goal was the study of the behaviour of minor traces gases under clean skies and heavy aerosol loading as well as the dust impact in air quality and climate-related issues. Among all AMISOC activities, a particular emphasis was put on dust profiling. Indeed, this study reflects the synergy of airborne in-situ instrumentation (Optical Particle Counters, OPC) and ground-based active (LIDAR) techniques to derive, respectively, the height-resolved microphysical and optical properties of particles in the SAL. In addition, the available MAXDOAS (Multi-AXis Differential Optical Absorption Spectrometry) measurements during AMISOC-TNF were also used to retrieve the height-resolved aerosol extinction.

The Total Mass Concentration (TMC) of dust particles, regarding their radiative impact factor, can be also estimated in terms of the Mass Extinction Efficiency (MEE). MEE is a measure of the aerosol effectiveness on solar radiation, relating both optical and microphysical properties. In general, MEE values as reported in the Optical Properties of Aerosols and Clouds (OPAC) database (d'Almeida et al., 1991; Tegen and Lacis, 1996; Hess et al., 1998; www.pole-ether.fr) are higher for smaller particles. Indeed, MEE for dust decreases as effective particle radius increases. Values of 3.1–2.3 m^2 g^{-1} and 0.97–0.16 m^2 g^{-1} are obtained for dust particle size distributions with effective radius within the fine and coarse modes, respectively (see OPAC database, www.pole-ether.fr). In particular, MEE values of 0.5, around 1.0 and 1.09 m^2 g^{-1} were obtained from in-situ measurements performed in close regions to Saharan dust sources as Izaña/Tenerife site (Maring et al., 2000), Morocco (SAMUM, 2006; Kandler et al., 2009) and Cape Verde (AMMA campaign, Chen et al., 2011), respectively, likely in average depending on the different contribution of fine (higher MEE) and coarse (lower MEE) particles. In addition, MEE values of 0.75 and 0.80 m^2 g^{-1} were assumed for campaigns carried out in more distant areas as Puerto Rico (during the Puerto Rico Dust Experiment-PRIDE campaign, Reid et al., 2003) and Barbados (Li et al., 1996), respectively. That previous work reported in Reid et al. (2003) shows the dust vertical profiling during the PRIDE airborne campaign, devoted to the transcontinental transport of Saharan dust particles. An emphasis is put on the vertical distribution, using similar airborne instrumentation as that used in AMISOC-TNF. Whereas Reid et al. (2003) mostly focused on dust particles present over the Caribbean region after their long-range transport from the African continent, our study is mainly motivated on the detection of Saharan dust after short-range transport of dust particles from their African source regions.

Therefore, the aim of this work is twofold: (1) to examine the vertical features of both the dust Lidar-derived optical properties (e.g., extinction coefficients and LR) and the microphysical properties (e.g., particle size distributions and fine/coarse mode (fm/cm) predominance) obtained from airborne in-situ measurements; and (2) to study the potential of combined Lidar and airborne observations in estimating the mass concentration of Saharan dust particles and their vertical incidence with implications in the air quality and health. In addition, the also available passive MAXDOAS-derived extinction profiles are also evaluated in comparison with those retrieved from active Lidar measurements in order to show the potential of this technique lately also used to derive the aerosol extinction profiling. In general, single/multi-layered dust structure, SAL top height, dust incidence in both Free Troposphere (FT) and Boundary layer (BL), Lidar Ratio (LR) estimation, and particle fm/cm predominance are the main aspects