Measurements of Aerosol Optical and Microphysical Properties in Tizi Ouzou

Dehia Belaidi¹2*, Philippe Goloub², Soltane Ameur¹, Thierry Podvin², Abdenour Ambar³, Zohra Ameur¹

¹ Laboratoire d’Analyse et de Modélisation des Phénomènes Aléatoires (LAMPA), Université de Mouloud Mammeri, Tizi-Ouzou 15000, Algérie
² Laboratoire d’Optique Atmosphérique (LOA), CNRS, UMR8518, Université Lille1, 59655 Villeneuve d’Ascq, France
³ Office National de la Météorologie ONM d’Alger, Dar El Beida 16011, Algérie

ABSTRACT

To characterize the optical behavior of atmospheric particles located above the region of Tizi Ouzou, a micro-LIDAR and a sun/sky-photometer have been used. The analysis of three years of observation has revealed a large variability in the optical properties of the particles present in the atmosphere of this region. The aerosol extinction optical depth (τ) at 500 nm varies from 0.03 to about 2. The Angstrom Exponent (α) in the range 440–870 nm, varies from 0 to 1.8 and is indicating a large variability in size. The combination of micro LIDAR and sun/sky photometer measurements allowed us to determine the vertical profiles of the aerosol extinction coefficient (σext). The vertical profile helps to separate local from transported particles origins. The observation site is located in the city and surrounded by high mountains (2300 m asl). The aerosol optical depth at 500 nm and the Angstrom exponent respectively having the values τ > 0.5 and α < 0.25 indicate the high presence of desert dust particles from Saharan origin. This type of particles is frequently observed for α ranging between 0.25 and 0.35. The analysis of back-trajectories helped to identify the probable origin of air masses affecting the region. Our results show that a routinely operating LIDAR / photometer observing system coupled with back-trajectories analysis is a relevant tool for aerosols monitoring. They show, for the first time, the high temporal variability of aerosols present in the atmosphere of the Tizi Ouzou region.

Keywords: Micro LIDAR; Sun/sky-photometer; Optical properties; Vertical profile; Desert dust.

INTRODUCTION

The atmospheric aerosols are small particles suspended in the air. Their spatial distribution depends on various factors, such as geographical location. Over the Ocean and near coastal regions, the atmosphere is mostly charged with marine aerosols (sea salt) and areas near the Sahara desert are often rich in desert dust particles. Big cities produce harmful aerosols affecting human health (De Longueville et al., 2013), degrade air quality and impact the climate (Haywood and Ramaswamy, 1998; Phuleria et al., 2005; Thompson and Eidhammer, 2014). The volcanic eruptions, in turn, produce aerosols particles having a detrimental effect on the climate and the environment (Martucci et al., 2012; Metzner et al., 2012).

The centre of Africa is considered as the most important source of desert dust. The dust particles travel long distances (Ansmann et al., 2003; De Tomasi et al., 2003), carried by the power and the direction of the wind. Several campaigns (AMMA (African Monsoon Multidisciplinary Analyses), SAMUM (SAharan Mineral dUst experiment), SAMUM-2, ACE- (Aerosol Characterization Experiment), SHADE (Saharan Dust Experiment), SHADOW (Study of SaHAran Dust Over West Africa), ...) have been organized to study the optical and microphysical properties of these particles yielding many results (Vitale et al., 2000; Tanrè et al., 2003; Muller et al., 2009; Cavalieri et al., 2010; Flamant et al., 2011; Formenti et al., 2011; Ogunjobi et al., 2012; Yang et al., 2013; Kocha et al., 2013; Kocha et al., 2013; Vesselovsky et al., 2016; Mortier et al., 2016). These properties can be modified when the particles travel a long distance by interacting with other types of aerosols and, more generally, with their environment.

The Mediterranean basin receives a mixture of different aerosols types. Several studies have been conducted to characterize particles in this region. Measurements of aerosols properties have been made at the east side (Bryant et al., 2006), at the center (Di Iorio et al., 2003; Pace et al., 2006) and at the west side of the Mediterranean (Valenzuela et al., 2014; Léon et al., 2015; Denjean et al., 2016).

Our work focuses on the region of Tizi Ouzou. The site
is located at 36°41'54 north and 04°03'20 east, south-west of the Mediterranean Sea and northern Algeria. On their way to Europe, African air masses cross Tizi Ouzou. The latter is therefore a good place to characterize the Saharan dust coming from the Algerian Sahara before it mixes with other types of aerosols, such as the maritime aerosols and anthropogenic aerosols. The characteristics of aerosols in this region are poorly known. The atmosphere likely contains anthropogenic aerosols, desert dust and smoke (the high temperature in summer induces numerous forest fires in the north of Algeria). To characterize the aerosols in this region, we have combined data from LIDAR and sun/sky photometer. The synergy has been used in several studies in other regions (Pelon et al., 2008; Guerrero et al., 2009; Ansmann et al., 2010; Preibl et al., 2011; Mortier et al., 2013, 2016). This approach combines the aerosol optical properties measured by the sun photometer CE318 included in the AERONET (Aerosol Robotic Network) and the backscattered laser signal measured by the micropulse CIMEL LIDAR (CE 370-2) setup on the terrace of LAMPA laboratory (at 36°41'54 North and 04°03'20 East). The photometer has 8 filters (340, 380, 440, 500, 670, 870, 1020 and 1640 nm) and measures the aerosol optical depth and the sky radiance associated to each wavelength. The corresponding AERONET products are available and give access to aerosol properties (Holben et al., 1998; Dubovik et al., 2002). The CE 370-2 LIDAR is a CIMEL micro LIDAR designed for the study of aerosols and clouds. The system is emitting laser pulses at 532 nm, with ten nanoseconds duration pulse and is measuring the signal backscattered by the atmospheric particles and molecules at the same wavelength. Both instruments were installed to characterize the atmospheric particles of the region.

The CE318 is an automatic and autonomous sun/sky photometer developed by CIMEL company. The instrument is associated to a solar panel and rechargeable batteries for energy autonomy. It is composed of a two-axis robot allowing movements in azimuth and zenith planes, so it can target any point in the sky with accuracy better than 0.1°. The photometer is directly connected to a computer that downloads, on a regular basis, the raw data stored in memory and then sends it to the AERONET database (http://aeronet.gsfc.nasa.gov) through the National Service of Observation PHOTONS / AERONET for CNRS/INSU (France).

From the laser emission backscattered by the atmosphere

![Fig. 1. Observation site (36°41'54 North and 04°03'20 East).](image-url)
to the receiving module of the micro LIDAR, one can determine the vertical distribution of aerosols extinction coefficient. The design and use of a LIDAR heating box (temperature higher than 25°C) protected the LIDAR measurement from any possible dew problem, enabling thus LIDAR measurements during night time. During winter, when the temperature drops, dew covers the entrance surface of the system, and prevents totally or partially the backscattered light. Thanks to the heating box designed in the laboratory, we have measured the LIDAR profiles 24 hour a day and 7 days a week. However, in this work, we use daytime data combined with sun photometer data.

Retrievals of Aerosols Vertical Distribution (LIDAR/Sun Photometer Joint Inversion)

The vertical distribution of aerosols extinction coefficient is obtained from the joint LIDAR / photometer inversion. The laser signal backscattered by atmospheric particles coupled with the optical depth measured by the photometer allows the estimation of the vertical profile of the aerosols extinction coefficient ($\sigma_{\text{aer}}(z)$) and the effective LIDAR ratio ($S_a$). Several instrumental corrections are performed before retrieving aerosols properties (correction factor for photon counting underestimation, the weekly afterpulse corrections and the overlap corrections). The received signal is also altered by a radiative noise (strong vertical variations). This high frequency signal has been filtered by multiplying the Fourier transform of the signal by a Gaussian centered at a level of low frequencies (Mortier et al., 2013).

After the implementation above corrections, we applied the method of Klett and Fernald (Klett, 1981; Fernald, 1984) to solve the LIDAR Eq. (1).

$$P(z, \lambda) = \frac{A}{z^2} \left[ \beta_{\text{mol}} + \beta_{\text{aer}} \right] \exp \left\{ -2 \int_{z_0}^{z} \left( \sigma_{\text{mol}}(z') + \sigma_{\text{aer}}(z') \right)dz' \right\}$$

(1)

where $P(z)$ is the LIDAR signal, $A$ is an instrumental parameter (calibration constant), $\beta_{\text{mol}}$ and $\beta_{\text{aer}}$ are respectively the backscatter coefficients by the atmospheric molecules and aerosols. The $\sigma_{\text{mol}}$ and $\sigma_{\text{aer}}$ values are respectively the scattering molecular and aerosol extinction coefficients, $z_0$ is the minimum altitude for the vertical sounding ($z_0 = 240$ m). The zone below $z_0$ is also called blind zone.

The proper inversion method requires the knowledge of the LIDAR ratio. The ratio ($S_a = \sigma_{\text{aer}}/\beta_{\text{aer}} = (4 \times \pi) (\omega_0 \times p(\lambda))$) is assumed vertically constant and $\omega_0$ is the single scattering albedo, $p(\lambda)$ is the phase function in the backscattering direction.

The LIDAR equation is written again in the Eq. (2).

$$P(z) = \frac{A}{z^2} \left[ \frac{\sigma_{\text{aer}}}{S_a} + \beta_{\text{mol}} \right] \exp \left\{ -2 \int_{z_0}^{z} \left( \sigma_{\text{mol}}(z') + \sigma_{\text{aer}}(z') \right)dz' \right\}$$

(2)

Solving this equation (obtaining $\sigma_{\text{aer}}(z)$) requires the choice of a value for the LIDAR ratio. By integrating $\sigma_{\text{aer}}(z)$ along the profile from $z_0$ up to the reference altitude $z_{\text{max}}$, the LIDAR aerosol optical depth $\tau_{\text{lidar}}$ is computed. The reference altitude $z_{\text{max}}$ is taken at altitude higher than 6 km, where the signal can be mostly attributed to molecular scattering and the aerosol contribution is negligible. The $\tau_{\text{lidar}}$ must be equal to $\tau_{\text{photometer}}$ if the LIDAR ratio is correctly chosen. Iterations over the ratio $S_a$ allows then to converge to the right profile and the right $S_a$. The uncertainty on the LIDAR ratio $S_a$ has several sources. The first source is linked to the fact that we considered a vertically constant LIDAR ratio and the second to the choice of the reference altitude which yields a small additional error (Chazette et al., 2002). In the bottom layer, the residual uncertainty in the overlap function correction and the missing first 240 m are the primary source of error. The error in the overlap function is close to 10% above 600 m, and it is up to 50% close to the ground (Leon et al., 2009; Mortier et al., 2013).

Identification of Aerosols via their Optical Properties

The aerosol extinction optical depth ($\tau$) is the primary direct optical parameter provided by the photometer. It provides information about the aerosol load (integrated over the atmosphere column) and is directly used in our joint LIDAR/sun photometer retrievals. Uncertainty of aerosols optical depth is 0.01 at $\lambda > 440$ nm and around 0.02 at $\lambda < 440$ nm (Holben et al., 1998). In the following part, we analyze the temporal variations of the aerosol optical depth at the wavelength of 500 nm, for the region of Tizi Ouzou.

The relationship between the aerosol optical depth ($\tau$) and the wavelength ($\lambda$) is given by the Angstrom exponent ($\alpha$). It describes the spectral dependence of the aerosol optical depth and is an indicator of aerosol size. The Angstrom exponent can be calculated by considering a couple of optical depths at $\lambda_1 = 440$ nm and at $\lambda_2 = 870$ nm.

$$\alpha = -\ln \left( \frac{\tau_{\lambda_1}}{\tau_{\lambda_2}} \right) \left( \frac{\lambda_1}{\lambda_2} \right)^{-1}$$

(3)

The uncertainty of $\tau$ impacts the Angstrom exponent by 0.03–0.04 (Schuster et al., 2006).

From the spectral optical depth (340, 380, 440, 500, 675, 870, 1020 and 1640 nm) and the spectral sky radiances measured by the sun photometer, other aerosols properties can be derived by AERONET processing (Dubovik et al., 2002). We have considered, in this work, the single scattering albedo, the sphericity parameter and the aerosols size distribution (level 1.5 and level 2.0 of data). Since the level 2.0 is not available we used the level 1.5 of data. When the AOD at 440 nm is less than 0.4 but still near 0.4, we can consider this data as reliable data.

Identification of Aerosols via their Origin

We use in this part the back-trajectories computed from HYSPLIT model (Single Particle Lagrangian Integrated Hybrid Trajectory). This model allows us to follow the spatial
RESULTS AND DISCUSSION

LIDAR Ratio from LIDAR and Sun Photometer Inversion

In this part we show the LIDAR ratio resulting from the joint inversion described previously. During the three years of observation (2012–2014) at Tizi Ouzou site, this parameter has varied widely within the interval [4–90] sr (Fig. 2). We have found around 4690 inversions in cloud-free conditions (Level 2.0 AERONET aerosol optical depth), knowing that the LIDAR and the sun photometer have been setup in April 2012 and that there was a period, from January to May 2013, with both instruments out of service (re-calibration for the photometer and a technical problem for the LIDAR). In 2014 the two instruments were operational throughout the year. We have found 771 inversions for 2012 with a mean value of 36.4 sr, 2115 inversions with mean value of 38.8 sr for 2013 and 1804 inversions with a mean value of 45.3 sr for 2014. This variation in mean values is due to the large diversity of aerosols in this region. The absence of instrument in early spring 2012 and 2013 very likely explains the difference in the average Sa values between 2014, 2012 and 2013. The average value of SA in 2014 without the Sa value of early spring is 38.7 sr, which is similar to the average in 2012 and 2013, while the average value of SA in February, March, and April 2014 is 51.6 sr. The difference between years can be explained by the presence of particles having a higher LIDAR ratio during early spring in the region.

Fig. 2. LIDAR ratio measured at Tizi Ouzou site in 2012 (a), 2013 (b) and 2014 (c).
In Fig. 3 we show a three-year seasonal variation of the LIDAR ratio at Tizi Ouzou site. In this figure, the divisor segment in the box represents the median; the top and the bottom box limits represent the upper quartile (UQ) and lower quartile (LQ), respectively. The difference between UQ and LQ is the interquartile distance (IQD). The crosses are the outlier points, whose value is either greater than UQ + 1.5 × IQD or less than LQ – 1.5 × IQD; a vertical line ending in a capital T is the largest value that is not an outlier; a vertical line ending in an inverted capital T is the lowest value that is not an outlier. We can see clearly, in our results, the seasonal variations of the LIDAR ratios (Sa) which have reached high values at the end of winter and the beginning of spring: February, March and April with 59 ± 18 sr, 63 ± 28 sr and 50 ± 13 sr respectively. These high values are very likely explained by the presence of desert dust transported from the Sahara. In this period of the year, this region is generally characterized by a strong southern wind coming from the Algerian Sahara. The values of LIDAR ratio are often observed for the dust particles at the wavelength of 532 nm. Typical Sa values around 59 ± 11 sr were found for the dust particles over Europe and around 55 ± 6 sr in the Sahara during the SAMUM field campaign (Muller et al., 2007). Values of LIDAR ratios corresponding to the dust particles were found to range, in Northern Europe, within the range 40–80 sr (Ansmann et al., 2003). The LIDAR ratio measured over Granada (south of Spain) varied between 50 and 65 sr for the dust plume (Guerrero et al., 2009). The mean LIDAR ratio found during an exceptionally strong Saharan dust over Portugal is 53 ± 7 sr (Preißler et al., 2011).

In June and July, Sa values become lower, with values of 24 ± 5 sr and 25 ± 8 sr, respectively. The lower Sa values could be justified by the high presence of marine aerosols in this region, given that the observation site is located at only 30 km south of the Mediterranean coast. Similar values were found for marine aerosols. Sa = 23 ± 3 sr were found in the north Atlantic during the ACE campaign and Sa = 23 ± 5 sr were found in the tropical India ocean during INDOEX and INDOEX (Muller et al., 2007).

In August, Sa values become higher than those of the two previous months (June and July) and lower than the spring ones. These higher Sa values (44 ± 16 sr) are probably caused by the influence of particles produced by forest fires or by the mixture of desert dust with anthropogenic aerosols, given that in August there are less rainfall to clean the atmosphere and many forest fires caused by high temperature.

In autumn, values respectively around 29 ± 14, 37 ± 12 and 29 ± 12 sr for September, October and November, can be interpreted as a polluted marine aerosol. Such values were also found within the range 30–40 sr in the case of polluted marine aerosol in Tropical Indian Ocean during INDOEX (Müller et al., 2007).

In winter, values around 46 ± 17 and 47 ± 25 sr are found in our study during December and January respectively. These values are likely induced by the predominance of the biomass burning particles, given that the biomass burning emissions are maximum in December in the Northern hemisphere (Lioussé et al., 2010). Similar values were found for fresh smoke in the free troposphere over Portugal and aged smoke transported from North America and Siberia to Germany, with Sa = 51 ± 2 sr (Nepomuceno Pereira et al., 2014) and Sa = 53 ± 11 sr (Muller et al., 2007).

In this section, we have presented the LIDAR ratio measured in different aerosol situations, such as dust, marine aerosols, biomass burning aerosols, mixed dust and polluted marine aerosols. The observed variability LIDAR depends on the ability of the particles to absorb and scatter the radiation according to its chemical composition, and depends also on the phase function at 180°, depending, in its turn, on the shape and size of particles.

**Aerosol Optical Depth**

As we see in Fig. 4, the aerosol optical depth at 500 nm follows seasonal variations. Highest values are observed during summer and early spring. Aerosols responsible for high values of the optical depth in early spring are from other sources because the optical depth cannot reach very high values if those aerosols were only local. Moreover, the northern region of Algeria is not rich in industrial activities which may cause a high optical thickness. And the region is not a desert region, so the optical depth increases because of the presence of updraft. The only local aerosols that could increase the optical depth in the region are aerosols caused by intense wildfires. Knowing that the forest fires...
in this region are recorded in July and August (in summer), not in spring, therefore if the optical thickness increases instantaneously in this region during the spring, it means that particles are coming from other regions.

In summer, the observed high values of aerosols optical depth can be explained by the weakness of rainfall atmospheric cleaning and by the aerosols’ production by forest fires and by transported desert dust.

We now summarize the extreme values registered during the three years. The aerosol optical depth reached its maximum in June and August 2012, with 1.23 and 1.13, respectively. Maximum value was reached in 2013 in August with a value of 0.89. Early 2014, it was in February with the highest recorded value of the entire studied period (τ = 2.05). The minimum value observed was obtained around 0.02, just after precipitations that often help to clean the atmosphere. These different cases will be analyzed in the following section.

**Aerosol Size Distribution**

During the studied period, the aerosol size distribution derived from AERONET inversion was also considered in three different cases in the city of Tizi Ouzou. In the majority of the cases (55%), the amplitudes of the fine and coarse modes of the size distribution are equivalent (Fig. 5(b)). In the second case (42%), the amplitude of coarse mode (mainly dominated by the desert aerosol origin) is superior or equal to three times the amplitude of fine mode (Fig. 5(a)). The third case (3%) is characterized by the amplitude of fine mode which is bigger than the amplitude of coarse mode (Fig. 5(c)). Microphysical properties show that there are several types of aerosols in the Tizi Ouzou region with different sizes. By observing the aerosols size distribution and the vertical profile of extinction, we can conclude that, when coarse mode is predominant, the extinction coefficient (σ_{ext}) is higher in altitude and can reach the value 0.31 km⁻¹ at altitude z = 2700 m, σ_{ext} = 0.13 km⁻¹ for z = 3900 m and σ_{ext} = 0.08 km⁻¹ for z = 4750 m. Conversely, when the fine mode prevails, extinction profiles show the lowest values in the upper layers. It can reach the value of σ_{ext} = 0.08 km⁻¹ from z = 800 m to z = 1000 m and σ_{ext} < 0.01 km⁻¹ at z > 1800 m.
Identification of Desert Dust

In this section, we present cases where the dust particles were identified. Firstly, we use aerosol optical depth and Angstrom exponent to classify aerosols. During the three under study years, the Angstrom exponent has exhibited different values each time aerosol optical depth increased. It has reached very small but positive values for 29 April, 20 June, 05 August, 18 October 2012 and for 27 July, 27 August, 27 September 2013. It has also reached very small values for 16 and 18 February, 20 June, 03 July for 2014. One can notice that maximum aerosol optical depth and minimum Angstrom exponent have been measured for 18 February 2014. We present in Fig. 6 some cases with the lowest Angstrom exponent and high optical depth. The low values of Angstrom exponent correspond to a weak variation of extinction efficiency with wavelength. The values, ranging from 0 to 0.25 for the above mentioned days, indicate a clear predominance of coarse aerosol type consisting of particles from desert origin. These values of the Angstrom exponent are close to those found by Pace et al. (2006) for other sites affected by the Saharan aerosols. Thresholds on the optical depth and the Angstrom exponent ($\tau > 0.25$ and $\alpha < 0.35$ respectively) have been selected by Marconi et al. (2014) to identify if the Saharan desert aerosols are predominant in the atmospheric column. For the rest of the studied period, the Angstrom exponent remains low, whereas desert particles

Fig. 6. Daily variation of Angstrom exponent and aerosol optical depth during a desert dust event.
decrease in number. We have noticed that Angstrom exponent is (i) lower than 1 in 60% of observations; (ii) lower than 1.6 for 97% of the observations and (iii) does not exceed 1.8 of the remaining 3%.

Other optical properties retrieved by AERONET inversion such as the single scattering albedo (w0), the sphericity parameter and the real refractive index, vary depending on the aerosol type. The desert aerosol is characterized by low absorption in the visible (Dubovik et al., 2002) and the near infrared. The real part of the refractive index (n) in those cases is 1.52 ± 0.05 and the sphericity parameter is lower than 1%. For 75% of the studied cases, the percentage of sphericity is lower than or equal to 10%.

Secondly, we have performed an analysis of air mass trajectories for those cases to confirm that, for the selected days, the detected aerosols are originating from the Algerian Sahara (Fig. 7).

Tizi Ouzou city is surrounded by very high mountains (Fig. 1). The desert dust aerosols can reach the region and be detected only when they are located in an altitude above of the top of the mountain (2300 m). We can note that the significant values of extinction coefficient at elevated heights (2500 m–5000 m) are due to the presence of aerosols transported from other sources and have overpassed the mountains. We mention one such example of extinction profile for dust particles detected at Tizi Ouzou site in Fig. 8. We can clearly see two aerosol layers. The first is located between 500 and 1000 meters, the second between 2000 and 4000 m.

![Fig. 7. Back trajectory examples for days where the aerosol optical depth is high. Left, Angstrom exponent $\alpha < 0.20$. Right Angstrom exponent between 0.20 and 0.30.](image-url)
Identification of Anthropogenic Aerosols

Other situations have been observed where both optical depth and Angstrom exponent increased. For example, in 2012, on July 30th, August 22nd and September 21th, on September 2nd, in 2013 and on October 14th in 2014. The increase of the Angstrom exponents associated with the increase of the aerosol optical depth show that there are other particle types with higher spectral variation of extinction efficiency. Di Sarra et al. (2008) and Pace et al. (2005) reported that pollution particles and biomass burning particles are characterized by high Angstrom exponent.

Very high sphericity percentages (92–98%) are registered on September 2nd 2013. The associated air mass trajectories on Fig. 9 show that the detected aerosols are coming from Europe and therefore are very likely anthropogenic aerosols. These particles exhibit high light absorption rate in the
visible and near infrared. Fig. 10 shows how the single scattering albedo is spectrally varying for dust particles and pollution particles.

CONCLUSIONS

The remote sensing instruments, installed on the roof of the LAMPA Laboratory, University of Tizi Ouzou, have allowed us to characterize the atmosphere in the region of Tizi Ouzou for a period of three years from 2012 to 2014. Our results revealed the main characteristics of aerosols in the atmosphere around the city.

By combining back-trajectories, AERONET size distributions and LIDAR vertical profiles, we found out that, when the majority aerosols are coming from the Sahara, size distribution presents a predominant coarse mode, and the vertical distribution indicates a very important layer in high altitudes. Conversely, when the back-trajectories indicate that the air masses are coming from the Mediterranean and neighboring towns, the coarse mode is reduced significantly and the vertical distribution shows the absence of aerosols in the upper layers. Since the mountain separating the Sahara region from the region of Tizi Ouzou is higher than the mountains that surround the northern side, the Saharan particles are present only at high altitudes. In contrast, the particles coming from the Mediterranean and those of the region of Tizi Ouzou do not rise above 1800 m height.

The analysis of aerosol optical properties has allowed to characterize the optical behavior of those particles. These properties could give us a second feature of particle types existing in this region. As we have shown, high and moderate values of the optical depth associated with low values of Angstrom exponent, indicate the presence of particles of desert origin. We have considered two criteria to operate a

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**Fig. 9.** Origin of air masses of aerosols characterized by high sphericity (98%).

**Fig. 10.** Spectral albedo single scattering of particles for case with low sphericity and low Angstrom parameter (dust) and for case with high sphericity and high Angstrom exponent (pollution).
first particle classification. When the angstrom exponent is between 0 < \alpha < 0.25 the presence of dust particles is very important in the atmosphere. And when it is between 0.25 < \alpha < 0.35 the presence of dust particles is strong enough to remain dominant. Throughout the studied period, our results show that most of the Angstrom exponent values are < 1.6. For 75% of the studied cases, the percentage of sphericity is less than or equal to 10\%.

The pollution aerosols coming from Europe following the air masses are characterized by their high sphericity (sph \approx 98\%) and their low coarse mode concentration (their size distributions is the mixture of coarse and fine spherical particles). The optical depth associated to these particles is \tau = 0.26 \pm 0.05 and their Angstrom exponent is \alpha = 1.51 \pm 0.09.

In conclusion, the two remote sensing instruments have allowed to measure, for the first time, the characteristics of aerosols in south coast of the Mediterranean region. This article has shown the value of the LIDAR / photometer coupling for aerosol monitoring.

These results may be very useful for the dust transport models. This site may contribute with other sites currently in operation, to improve our understanding of the Mediterranean aerosol characteristics and to estimate better their radiative forcing.

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