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# Particle optical properties at a Central Mediterranean site: Impact of advection routes and local meteorology

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ABSTRACT

A multiwavelength integrating nephelometer and a PM10 sampler have been used to continuously measure optical properties and mass concentrations of particles at the ground level with the main aim of determining airflow and local meteorology effects on particle optical properties and PM10 mass concentrations. Measurements have been performed at Lecce (Italy), a coastal site in the Central Mediterranean and included scattering ($\sigma_p$) and hemispheric backscattering ($\beta_p$) coefficients, and hemispheric backscattering fraction ($\beta_p/\sigma_p$) at three wavelengths (450, 525, and 635 nm), in addition to PM10 concentrations. The scattering Ångström exponent (å ($\lambda_1$, $\lambda_2$)) for different wavelength pairs ($\lambda_1$, $\lambda_2$), and the scattering Ångström exponent difference (Δå = å (450 nm, 525 nm) − å (525 nm, 635 nm)) have been calculated to estimate the airflow impact on the relative weight of fine and coarse mode particles. The yearly mean values ± 1 standard deviation of $\sigma_p$ (450 nm), $\beta_p$ (450 nm), $\beta_p/\sigma_p$ (450 nm), å (450, 635 nm) and Δå are equal to 100 ± 50 $Mm^{-1}$, 12 ± 6 $Mm^{-1}$, 0.13 ± 0.02, 1.1 ± 0.4, and 0.2 ± 0.2, respectively. $\sigma_p$ is well correlated to PM10 mass concentrations (r = 0.96) and the PM10 mass scattering cross section is equal to 3.6 ± 0.1 $m^2\ g^{-1}$. The back trajectory cluster analysis has identified 5, 5, 7 and 7 distinct airflow types reaching the study site at 271, 500, 1500 and 3000 m above the sea level, respectively, with only slight differences in airflow type among the four arrival heights. We have found that $\sigma_p$ and $\beta_p$ values and their respective dependence on wavelength are strongly dependent on airflows. Therefore, we have shown that the in situ particle properties and the local meteorological parameters vary with advection routes. Given the dependence of å, Δå, and $\beta_p/\sigma_p$ on particle size and shape, their strong association with airflows has indicated that the mean size distribution of sampled particles varies with air mass history and it has been shown that å, Δå, and $\beta_p/\sigma_p$ values allow a satisfactory differentiation of the particle properties associated with different advection routes. More specifically, å and Δå values have allowed distinguishing the airflows mainly responsible for the advection of fine mode particles from the ones which are mainly responsible for the advection of coarse mode particles. These results have provided a satisfactory understanding of the dependence on air flows of the mass scattering cross section values which vary from 2.9 ± 0.2 $m^2\ g^{-1}$ to 4.3 ± 0.1 $m^2\ g^{-1}$ with air flows. The airflow analysis has also allowed understanding the seasonality of the particle optical properties being linked to the airflow seasonality.



## 1. Introduction

Aerosol composition and sources in the Mediterranean Basin are quite complex, including not only anthropogenic aerosols from human activities of the industrialised surrounding regions,

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but also natural aerosol from desert areas (e.g. northern Africa) and the Mediterranean Sea (e.g. Perrone et al., 2013). Several studies indicated that the aerosol radiative forcing is among the highest in the world during Mediterranean summer (e.g. Lelieveld et al., 2002). In situ (e.g. Perrone et al., 2011a; Collaud Coen et al., 2013), ground- and satellite-based remote sensing measurements (e.g. Santese et al., 2008; Perrone et al., 2012; Perrone et al., 2011b) are regularly performed worldwide to gain a deeper understanding of aerosol effects on climate and the environment. Aerosol effects depend on particle size and composition and the knowledge of the aerosol optical properties (e.g. scattering and absorption coefficients) is required to understand their effects on climate. Integrating nephelometers and absorption photometers are currently used to characterise aerosol optical properties at the ground level. Lyamani et al. (2010) reported measurements of aerosol optical properties obtained from December 2005 to November 2007 at Granada, an urban site in south-eastern Spain. They found that both aerosol scattering and absorption coefficients were characterised by a marked seasonal dependence with maxima in winter, and that the fine mode particles were dominant mainly in winter. A clear diurnal pattern of the aerosol scattering and absorption coefficients was also observed in all seasons, which was attributed to the diurnal evolution of the planetary boundary layer (PBL) and to local anthropogenic activities. Esteve et al. (2012a) which have reported aerosol scattering measurements performed at Valencia (Spain) also found that the daily variation of the aerosol scattering properties was due to the traffic and the evolution of the PBL. The influence of the back trajectory pathways on the in situ measurements of aerosol properties was also investigated by Esteve et al. (2012b). They found that the aerosol scattering properties were sensitive to the back trajectory pathways. The highest scattering coefficients were obtained under the influence of air masses from North Africa and the European continent. The lowest scattering coefficients were obtained for arctic-type air masses. Measurements of aerosol scattering and absorption performed at Montseny, a regional background site in the Western Mediterranean Basin, were reported by Pandolfi et al. (2011). They found that on average, mean values of aerosol scattering and absorption coefficients were quite low compared with values reported in literature in more industrialised areas around the Mediterranean Basin. Moreover, a high level of variability was also observed as a function of the origin of the air masses. Surface aerosol scattering properties measured during a period of seven years (2002–2008) at Évora, Portugal were reported by Pereira et al. (2011). They show in the paper that both seasonal and daily cycles of the scattering and backscattering coefficients were related to local production and transport of particles from elsewhere. Long-term trends of in-situ aerosol optical properties measured within the framework of the WMO-GAW program at Finokalia (Greece) were recently analysed by Collaud Coen et al. (2013). They report that Finokalia was the only European station for which a statistically significant decreasing trend in the aerosol scattering coefficient was found. As mentioned, continuous measurements across the world are required to establish a comprehensive picture of the aerosol properties and their impact on climate. In fact, the European Commission has strengthened the networking of different sites by founding, as an example, the ACTRIS (Aerosol, Cloud and Trace gases Research InfraStructure networks) Project to improve data quality and access (Collaud Coen et al., 2013). Multiwavelength nephelometer measurements performed at a coastal site of south eastern Italy, from December 2011 to November 2012, are analysed in this study in order to contribute to the characterisation of the aerosol optical properties in the Central Mediterranean. More specifically, one year results of scattering ($\sigma_p$) and hemispheric backscattering ($\beta_p$) coefficients, hemispheric backscattering fractions ($\beta_p/\sigma_p$) at three wavelengths (450, 525, and 635 nm), scattering Ångström exponents (å ($\lambda_1$, $\lambda_2$)) for different wavelength pairs ($\lambda_1$, $\lambda_2$) and scattering Ångström exponent differences (Δå = å (450 nm, 525 nm) − å (525 nm, 635 nm)) are reported. It will be shown that å and Δå values allow to estimate the airflow impacts on the relative weight of fine and coarse mode particles (Schuster et al., 2006 and references therein). Daily PM10 measurements performed by the Regional Air Quality Agency (http://www.arpa.puglia.it/web/guest/qariainq) at a site that is ~0.5 km away from this study have been used to investigate the relationship of aerosol scattering properties with simultaneous PM10 mass concentrations. Back trajectories combined with statistical analyses have then been used to examine the long-range transport impact on $\sigma_p$, $\beta_p$, ($\beta_p/\sigma_p$), å, Δå, and PM10 mass concentrations, as well as on the local meteorology. The impact of the main advection routes on the particle optical properties at the ground level represents one of the main topics of this study. Atmospheric particles are quite affected by long-range-transport contributions at the study area and all over the Central Mediterranean, as several previous studies have already revealed (e.g. Santese et al., 2008; Pavese et al., 2009; Santese et al., 2010; Perrone et al., 2013). Sampling site, instruments and methodology are presented in Section 2. Results and discussion are presented in Sections 3. Summary and conclusion are reported in Section 4.

## 2. Sampling site, instruments and methods

### 2.1. Site description

Nephelometer measurements were performed from December 2011 to November 2012 on the roof of the Mathematical and Physics Department of the University of Salento, at ~10 m above the ground level (a.g.l.). PM10 mass measurements were performed 0.5 km away from it, at ~2 m from the ground. The Mathematical and Physics Department is in a flat peninsular site (40.33°N; 18.11°E), 6 km away from the town of Lecce (~95,000 inhabitants), and ~20 km away from both the Ionic and Adriatic Seas (Fig. 1). A coal power plant and a large industrial area are about 35 and 100 km away from it, respectively. The monitoring site of this study can be categorised as rural background according to Larssen et al. (1999). Therefore, it may be considered as representative of coastal sites of the Central Mediterranean away from large sources of local pollution (Perrone et al., 2013; Basart et al., 2009). The Balkan and northern Africa coasts are ~100 and 800 km away from it, respectively.

### 2.2. Instruments

A LED-based integrating nephelometer (model Aurora 3000, ECOTECH, Australia) was used to measure particle scattering