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A study of aerosol particle sizes in the atmosphere of Athens, Greece, retrieved from solar spectral measurements

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Abstract

This work aims at determining the aerosol particle radii in the atmosphere of Athens. Such a work is carried out in Athens for the first time. For this purpose, solar spectral direct-beam irradiance measurements were used in the spectral range 310–575 nm. To estimate the particle radius from aerosol optical depth retrieval, a minimization technique was employed based on the golden-section search of the difference between experimental and theoretical values of the aerosol optical depth. The necessary Mie computations were performed based on the algorithm LVEC.

In this study, the mean particle radius of a given distribution was calculated every 30 min during cloudless days in the period November 1996 to September 1997. The largest particles were observed in the summer and the smallest during winter. The result was verified by the increased values of the aerosol optical depth and the turbidity factors calculated in the summer. The differences in the diurnal variation from season to season are attributed to the prevailing wind regime, pollutant emission and sink rates in the atmosphere of Athens.

Keywords: Aerosol optical depth; aerosol size distribution; solar spectral irradiance; Athens; Greece

1. Introduction

Aerosol particles play a key role in air quality and atmospheric physics and chemistry. They interfere with weather and modify climate, participate in cloud development as condensation nuclei, change the electrical properties of the atmosphere and interact with atmospheric radiation (Charlson et al., 1991). Therefore, they intervene in the global radiation budget and atmospheric chemical cycles and they also modify the optical properties of the atmosphere (Haywood and Boucher, 2000). The climatic effect of aerosols is closely related to their physical properties and size, the surface albedo and the

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relative altitude between aerosol layer and clouds (Abel et al., 2005; Kinne and Pueschel, 2001). Tropospheric aerosol properties are generally associated with microphysical phenomena and atmospheric dynamics that determine the size distribution and chemical composition of the aerosols.

Aerosol characterization is an important task in aerosol studies using atmospheric optical depth data (D'Almeida et al., 1991; Cachorro and Tanré, 1997; Bates et al., 1998). Many studies deal with particle-size distribution, complex index of refraction and other size parameters in atmospheric columns worldwide (Dubovik et al., 2002; Vitale et al., 2000; Cachorro et al., 2000). With the establishment of the Aerosol Robotic Network (AERONET) an effort for global aerosol monitoring is attempted and their optical and physical properties (e.g. size distribution, single scattering albedo, asymmetry factor and refractive index) are achieved through the Dubovik and King (2000) algorithm. The size and the shape of the suspended particles, in conjunction with their chemical composition, deal with the important scattering and absorption processes in the atmosphere (Molnàr and Mészáros, 2001). They found that submicron particles with diameter <1 μm are responsible for 82% and 7% of the scattering and absorption of the solar radiation, respectively.

Due to the variety of the regions surrounding the Mediterranean, different types of particles can be found throughout the region, having both strong temporal and spatial distribution (Antoine and Nobileau, 2006; Barnaba and Gobbi, 2004); desert dust, originating from Sahara, polluted aerosols produced mainly in industrialized areas of Continental and Eastern Europe, aerosols formed over the Mediterranean itself or transported from the North Atlantic and biomass smoke often produced from seasonal forest fires. The various aerosol types display different optical and physicochemical characteristics. Their properties, such as optical depth, chemical composition, size distribution, single scattering albedo, asymmetry factor and vertical distribution vary largely, thus affecting the radiative and energy balance in different ways (Horvath et al., 2002; Markowicz et al., 2002).

Furthermore, Greece is one of the most interesting regions for aerosol studies, because soil dust from the neighboring North African desert areas, and the emission of local aerosols, such as sulfuric, nitric and carbonaceous particles, is increasing due to rapid urbanization. Therefore, the location of Athens offers a unique opportunity to monitor aerosols from different sources. On the other hand, the identification of a clear aerosol type over Athens is rather impossible due to the variety of sources and mixing mechanisms. Recent studies focusing on this characterization via aerosol interactions with solar radiation led to rather contradictory results (Kaskaoutis and Kambezidis, 2006; Kaskaoutis et al., 2006b). This work aims at determining the aerosol particle radii in the atmosphere of Athens for the first time. For this purpose solar irradiance measurements covering the period November 1996 to September 1997 were used in conjunction with the LVEC model. The particle radius is investigated according to the season, wind regimes and air mass origin.

2. Topography, data collection and methodology

2.1. Topography and climatology

Athens is a Mediterranean city of about 3.5 million people (census of 2001) located in an oblong basin with an area of 450 km^2. The main axis of the basin lies in the

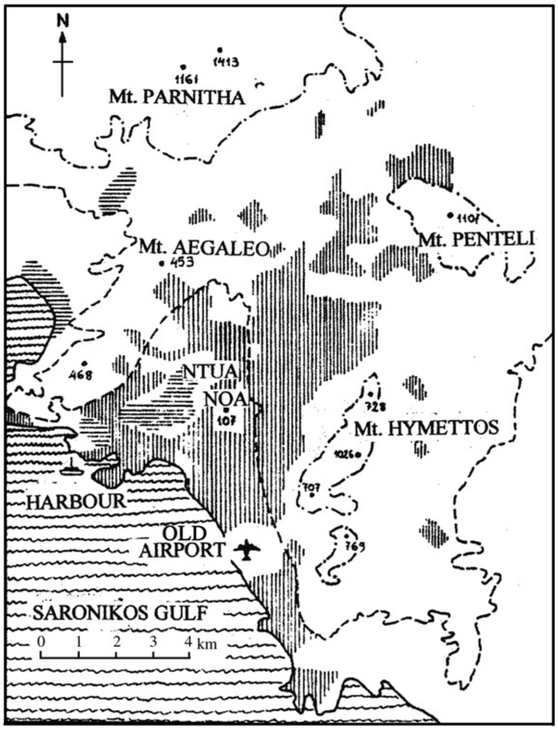

Fig. 1. Map of the Athens basin. The vertical lines indicate the residential areas, while the horizontal ones show the industrial areas. The summits of the mountains are presented together with their altitude in m a.s.l. The dashed line is the 100-m contour, while the dashed-dotted line refers to the 500-m elevation. The locations of the measuring site (NTUA) and the meteorological station site (NOA) are shown. The Hellinikon Airport that was in operation at the time of the measurements ceased its operation in March 2001.