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Spatial distribution of PM_1 and PM_{10} during Saharan dust episodes in Athens, Greece

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Abstract. The objective of this study is to present and analyse the spatial distribution of PM_1 (particulate matter with diameter less than 1 μm) and PM_{10} (particulate matter with diameter less than 10 μm) within the greater area of Athens (GAA), Greece, during two extreme Saharan dust episodes in 2006 and 2008. Two portable detectors, based on light scattering method, were used to record the particulate matter concentrations. The samples were collected in the same morning hour of the day which coincided with the peak of vehicles traffic. We analysed the recorded data on normal days and on days with extreme Saharan dust events in order to find out the exceedances of the particulate matter concentrations. Using Kriging method, the spatial patterns of PM_1 and PM_{10} concentrations were constructed for GAA. It is already known that particulate matter represent the main hazard in cardiovascular and respiratory syndromes within the most polluted cities of Europe, which confront high traffic problems, amplified by Saharan dust episodes, which are frequent especially in the Southern Europe, during spring time. The results of the performed analysis showed that during these episodes, PM concentrations over exceed the thresholds set by the European Union, exacerbating the human health in Athens.

1 Introduction

The development of mega cities resulted in large emissions of particulate matter (PM) in the atmosphere, which link to air quality deterioration. Monitoring of the PM improves knowledge in order to understand and manage significant environmental problems. PM is a mixture of particles that vary in size, morphology, chemical composition and concentration and derive from nature and human sources. Many atmospheric factors contribute in their expansion but mainly the wind conditions influence their dispersion in the air. The chemical composition of PM can vary widely as a function of its main emitting sources and the chemical reactions which take place in atmosphere. Respirable ambient PM includes a large number of organic and inorganic compounds; many of them are toxic and/or carcinogenic. Among these there are the carcinogenic polycyclic aromatic hydrocarbons and the heavy metals. Long range transport of aerosol particles is considered among the most important PM sources and it can contribute to elevated PM values. Lenschow et al. (2001) have shown that mean annual kerbside PM_{10} concentrations can be interpreted by approximately 30% long range transport, 30% urban increment and 30% traffic related emissions. In a more recent research, Kerschbaumer and Lutz (2008), studying the emission source influence on PM_{10} concentrations in Berlin, found that local emissions influence total PM_{10} concentrations, only by approximately 40%, while transport procedures from outside the city are responsible for 60% of the total PM_{10} concentrations. Several papers show the contribution of African desert to the PM values mostly in south Europe regions (Artíñano et al., 2003; Papayannis et al., 2005). Recent epidemiological studies have observed a negative impact of ambient particle concentrations on human health including increases in cardiovascular and respiratory symptoms and diseases, hospital and emergency department admissions (Pope et al., 2002; Franchini and Mannucci, 2007; Chen et al., 2007; Grigoropoulos et al., 2008). The adverse effects of PM on public health seems to depend more on the number of particles inhaled and the duration of inhalation, than the particle dimension or the nature composition.

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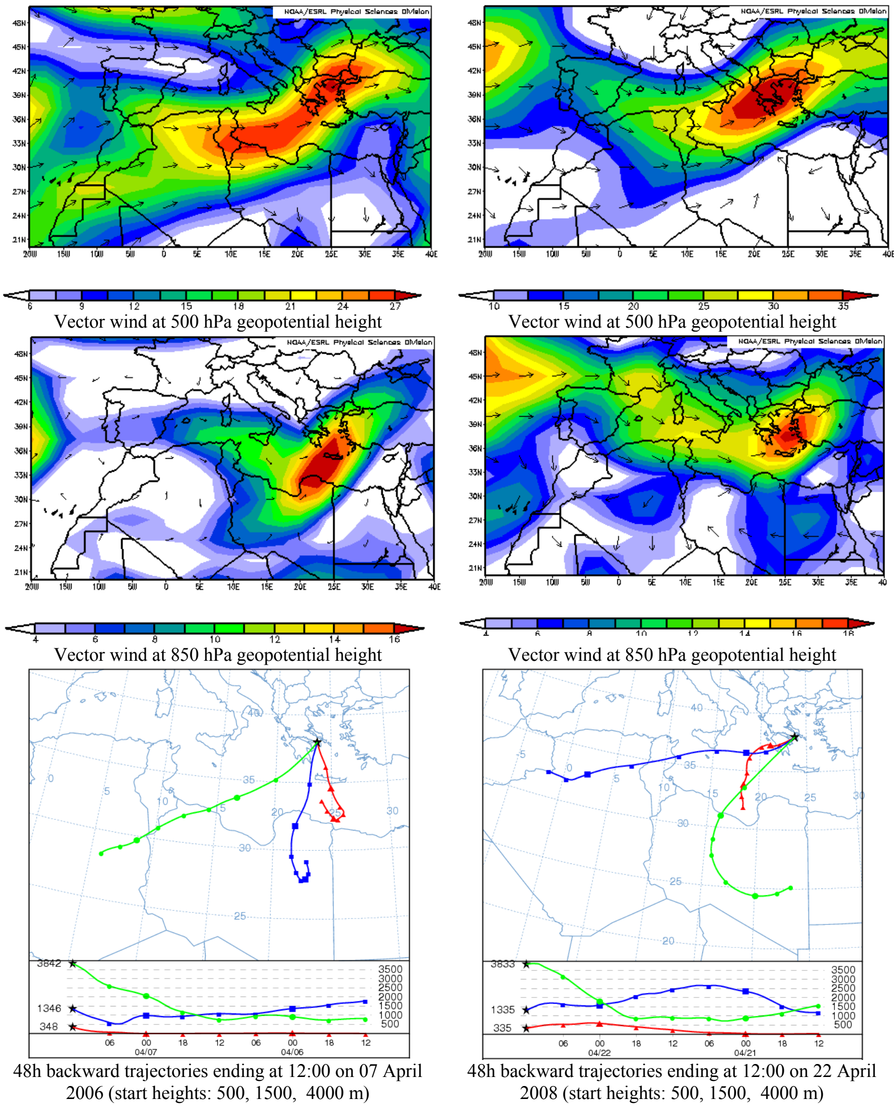

Figure 1. Wind vectors and backward trajectories for the two Saharan dust episodes on 7 April 2006 (left panel) and 22 April 2008 (right panel).

In the present study the spatial distribution of the PM_1 and PM_{10} in the greater Athens area (GAA) during two extreme Saharan dust episodes is analysed. In this point it is worthy to mention that PM_1 measurements are rare within GAA.

2 Data and methodology

The data consist of PM_1 and PM_{10} concentrations (μg/m^3), which were recorded during morning time (07:00–08:45 LT; LT=UTC+2) at six sites (Aristotelous, Omonoia, Syntagma, Syngrou, Faliro and Piraeus) within GAA. Two detectors (Aerocet 531-MetOne instruments) based on light scattering method, were used. All the necessary calibrations, including flow rate and zero tests, were carried out in a weekly basis, according to the factory instructions. In order to present the wind flow during the Saharan dust episodes, daily mean composites of vector winds at 500 and 850 hPa were plotted, based on NCEP/NCAR Reanalysis. Furthermore, the 48 h backward trajectories were calculated using the HYSPLIT 4 model of Air Resources Laboratory of NOAA (Draxler and Rolph, 2003; Rolph, 2003) for three different levels: 500, 1500 and 4000 m (a.m.s.l.). Finally, the spatial distributions of PM_1 and PM_{10} concentrations within GAA were carried out by the application of the Kriging method.

3 Results and discussion

Figure 1 depicts the vector winds at 500 and 850 hPa, along with the backward trajectories during the two Saharan dust episodes, which are more frequent in spring time

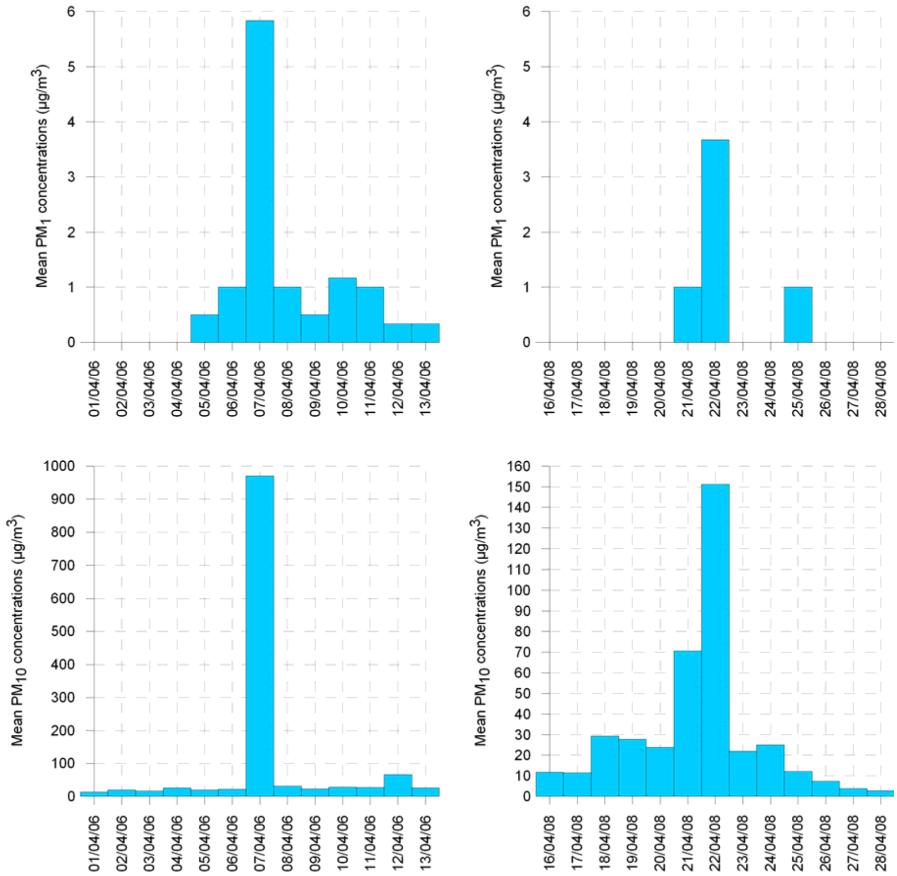

Figure 2. Mean PM_1 and PM_{10} concentrations for the two Saharan dust episodes on 7 April 2006 (left panel) and 22 April 2008 (right panel), in GAA.

(Kosmopoulos et al., 2008). It is clear that the first examined episode on 7 April 2006 is more intense than the second on 22 April 2008. The mean PM_1 concentrations reached $6\,\mu g/m^3$ during the first episode and about $4\,\mu g/m^3$ during the second (Fig. 2). Both values are considered high for the public health, because the background of PM_1 concentrations within GAA, as it has been presented in a recent study conducted during the period 1 October 2006–30 September 2007 (Grigoropoulos et al., 2008), ranged from $0.44\,\mu g/m^3$ (Omonoia) to $1.24\,\mu g/m^3$ (Faliro) during the warm period of the year while during the cold period of the year, higher concentrations of PM_1 appeared and variated from $0.53\,\mu g/m^3$ (Piraeus) to $3.19\,\mu g/m^3$ (Faliro). Furthermore, Grigoropoulos et al. (2008) asserted that PM_1 concentrations greater than $4\,\mu g/m^3$in the warm period of the year seems to approximately 8folds the risk (odds ratio=7.833, 95% C.I.: 0.469–130.748, significant level=0.152) of observing the daily number of patients with sinus arrhythmias in the upper 90th percentile compared to the lower 10th percentile .

Extreme high PM_{10} concentrations ($\sim 1000\,\mu g/m^3$) appeared on 7 April 2006 while lower concentrations ($\sim 150\,\mu g/m^3$) were recorded on 22 April 2008 (Fig. 2). Grivas et al. (2004) have reported that the daily average PM_{10} concentrations at four sampling sites within the area of Athens ranged from 32.9 to $83.2\,\mu g/m^3$, during the period between June 2001 and May 2002. According to the follow-up Council Directive (1999/30/EC) the limit value for the daily PM_{10} average is $50\,\mu g/m^3$ and should not be exceeded more than 35 times a calendar year. The spatial distributions of PM_1 and PM_{10} concentrations are depicted in Fig. 3. High concentrations appear towards the foot of the Hymettus Mountain, because of the prevailing southwestern wind blow. Athens basin is surrounded by three main mountains, the Parnes at the north, the Penteli at the northeast and the Hymettus at the southeast and for this reason is more vulnerable to southwestern wind blow.

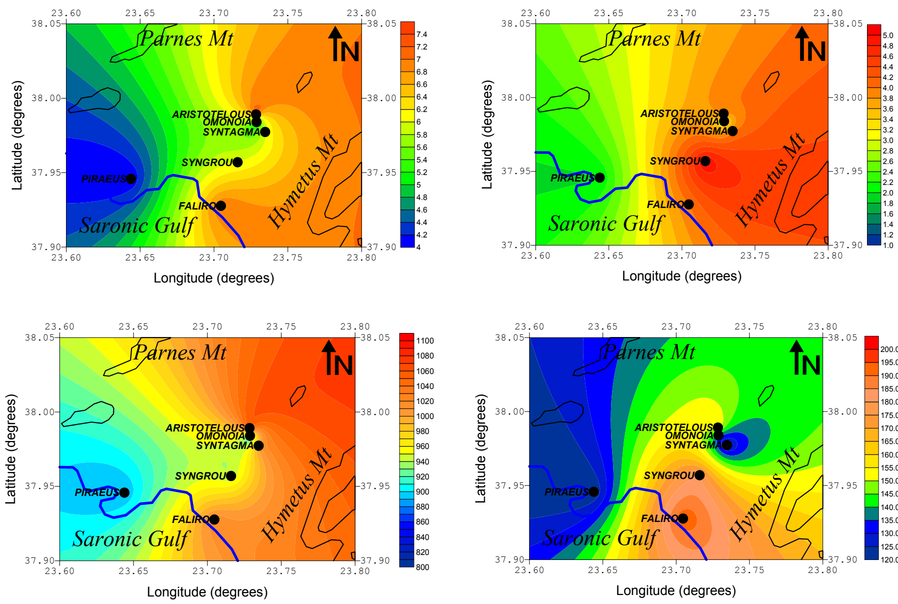

Figure 3. Spatial distribution of PM_1 (upper graphs) and PM_{10} (lower graphs) concentrations during the two Saharan dust episodes on 7 April 2006 (left panel) and 22 April 2008 (right panel), in GAA.

4 Conclusions

The transport of Saharan dust towards Greece results in high PM_1 and PM_{10} concentrations recorded in six sites of the GAA. These episodes affect mainly PM_{10} concentrations, which over exceed the thresholds set by the European Council Directives and exacerbate human health.

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