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Impacts on particles and ozone by transport processes recorded at urban and high-altitude monitoring stations

J.F. Nicolás [a,*], J. Crespo [a], E. Yubero [a], R. Soler [a], A. Carratalá [b], E. Mantilla [c]

[a] Laboratory of Atmospheric Pollution (LCA), Miguel Hernández University, Av. de la Universidad s/n, Edif. Alcudia, 03202 Elche, Spain
[b] Department of Chemical Engineering, University of Alicante, P.O. Box 99, 03080 Alicante, Spain
[c] Instituto Universitario CEAM-UMH, Parque Tecnológico, C/Charles R. Darwin 14, E-46980 Paterna, Spain

HIGHLIGHTS

- Coarse particles at the mountain site are 40% higher than at the urban site in summer.
- Stagnant urban episodes can provoke particle increases at the mountain station.
- Stagnant events affect mainly particles in the 0.5–2 μm range at the mountain station.
- During Saharan outbreaks, O_3 levels at the mountain site undergo a decrease (3–17%).

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ABSTRACT

In order to evaluate the influence of particle transport episodes on particle number concentration temporal trends at both urban and high-altitude (Aitana peak-1558 m a.s.l.) stations, a simultaneous sampling campaign from October 2011 to September 2012 was performed. The monitoring stations are located in southeastern Spain, close to the Mediterranean coast.

The annual average value of particle concentration obtained in the larger accumulation mode (size range 0.25–1 μm) at the mountain site, 55.0 ± 3.0 cm^{-3}, was practically half that of the value obtained at the urban station (112.0 ± 4.0 cm^{-3}). The largest difference between both stations was recorded during December 2011 and January 2012, when particles at the mountain station registered the lowest values. It was observed that during urban stagnant episodes, particle transport from urban sites to the mountain station could take place under specific atmospheric conditions. During these transports, the major particle transfer is produced in the 0.5–2 μm size range. The minimum difference between stations was recorded in summer, particularly in July 2012, which is most likely due to several particle transport events that affected only the mountain station. The particle concentration in the coarse mode was very similar at both monitoring sites, with the biggest difference being recorded during the summer months, 0.4 ± 0.1 cm^{-3} at the urban site and 0.9 ± 0.1 cm^{-3} at the Aitana peak in August 2012. Saharan dust outbreaks were the main factor responsible for these values during summer time. The regional station was affected more by these outbreaks, recording values of >4.0 cm^{-3}, than the urban site. This long-range particle transport from the Sahara desert also had an effect upon O_3 levels measured at the mountain station. During periods affected by Saharan dust outbreaks, ozone levels underwent a significant decrease (3–17%) with respect to its mean value.

1. Introduction

Interesting atmospheric studies have been made possible thanks to the installation of monitoring stations at high altitude sites in order to characterize regional background environments. The same studies would be difficult at ground level sites.

In Europe, the study of atmospheric particulate matter (PM) at these mountain stations, e.g. Jungfraujoch (Switzerland — 3580 m a.s.l.), Monte Cimone (Italy — 2165 m a.s.l.) or Montseny (Spain — 720 m a.s.l.) has allowed researchers to establish reliable PM background levels. Other studies also show the impact of both the regional and long-range transport of polluted air masses on these kind of environments (Schwikowski et al., 1995; Káiser et al., 2007; Marinoni et al., 2008; Pey et al., 2010a) and determine the main causes of the daily and seasonal variability (Henning et al., 1999; Marinoni et al., 2008; Cristofanelli and Bonasoni, 2009; Querol et al., 2009). Therefore, an important aspect of the research has been the analysis of how the

* Corresponding author. Tel.: +34 966658325; fax: +34 966658397.
E-mail address: j.nicolas@umh.es (J.F. Nicolás).

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PM generated in urban and industrial environments, under specific meteorological conditions, can contribute to the PM value registered at these regional background stations. Marinoni et al. (2008) at Monte Cimone station recorded maximum values of fine fraction particles during summer period due to the vertical transport of polluted air masses. Pey et al. (2010a) recorded PM_1 peaks during polluted episodes in winter characterized by anticyclonic synoptic scenarios. This is also partly due to secondary aerosol formation along the trajectory of air masses from urban locations to the elevated rural sites.

Due to the height and the lack of anthropogenic activity at these sampling points, remote mountain stations are suitable to determine precisely the impact of air masses from Sahara desert impact on particle concentration (Bonasoni et al., 2004; Marinoni et al., 2008) and on the tropospheric ozone decrease (Bonasoni et al., 2004). Bonasoni et al. (2004) observed an ozone concentration reduction between 4 and 21% with respect to their monthly average values during twelve Saharan dust outbreaks between June and December 2000. Similarly, Umann et al. (2005) recorded a decrease of 30% in the ozone levels at the Izaña station (2360 m a.s.l.) during a Saharan dust transport. These studies suggest that mineral dust particles may act as a reactive surface in the heterogeneous destruction of the ozone (Cristofanelli and Bonasoni, 2009).

Measuring at elevated regional environments presents another advantage, that is, to obtain concentration profiles that can help us, by subtraction, to discriminate what is the real contribution attributable to a particular anthropogenic location. A graphic example of this method can be seen in Lenschow et al. (2001). This distinction, using the chemical composition of PM, is also presented in Pey et al. (2010b).

Most of the high-mountain stations show common features, such as a lack of human activity or low concentration values for the majority of pollutants. Nevertheless, depending on where its particular geographical position is, regional background stations can be affected by different contributions of different pollutants according to the origins of the air masses in which they are transported. Both, atmospheric dynamics and the main sources of particles in each area can determine the concentration levels and the seasonal variability obtained at these sampling points.

The western Mediterranean basin, which is the study area analyzed in this work, has a peculiar atmospheric dynamic that provokes a clear temporal pattern in the levels registered at the regional background locations. In Querol et al. (2009), the main factors affecting the complex atmospheric dynamic in the western Mediterranean basin, such as the scarce summer precipitation or the influence of the Azores high-pressure system, are described. During warm periods, the atmospheric conditions characterized by the lack of advection, favors the recirculation of air masses and the occurrence of Saharan dust outbreaks. During cold periods, Atlantic air masses bring clean, fresh air removing the regional aged air masses. Furthermore, polluted air masses from central and northern Europe can reach the study area. Lastly, episodes involving the stagnation of air masses can be generated, leading to the increase of atmospheric pollution (Pey et al., 2010a).

Recently, a new regional background station has been placed on the top of mountain range. This mountain station is located in southeastern Spain, close to the Mediterranean coast. With this new elevated sampling point, it is expected to determine the following:

- the aerosol size distribution and number concentration at this regional background station (RS) and the difference when compared with the ones obtained at an urban background station (US). In doing this, an estimation of the real particles load attributable to urban sources can be obtained. Their seasonal variations will also be assessed. All of this will be discussed in Section 3.2.
- the influence that local and synoptic transports of air masses have upon aerosol parameters and tropospheric ozone at the RS. The inputs of particles at this point coming from coastal emissions and from Sahara Desert will be investigated (Sections 3.3 and 3.4).

2. Experimental

2.1. Measurement sites

The study is a general assessment of the main factors governing the total particle number concentration at the RS (N_{RS}) and the US (N_{US}). In order to achieve this, two locations whose features were the most appropriate to represent these environments inside the province of Alicante in southeastern Spain, were chosen. On a synoptic scale, this region belongs to the Western Mediterranean Basin (Fig. 1), and its local and regional meteorology characteristics have been discussed in the introduction. The study area is situated in a semiarid region with low annual precipitation levels recorded at urban sites (in general less than 300 $l \cdot m^{-2}$). A brief orographic and geographic description of the study region can be found in Caballero et al. (2007). The two main characteristics of this region are that the area is barely industrialized and that its major cities are located very close to the coast.

The first sampling location represented a regional background site. The sampling point (38°39′N; 0°16′W; 1558 m a.s.l.) was located on top of a mountain range, in a military area (EVA n°. 5) belonging to the Ministry of Defence and situated 25 km from the Mediterranean coast (see Fig. 1). The station is located specifically at the named "Aitana peak".

The second monitoring site, about 57 km southeast of the RS, represents an urban background environment. The station is located in the city of Elche (38°16′N; 0°41′W; 95 m a.s.l.), 12 km from the coast (Fig. 1). Specifically, the measurement site is placed on the roof of a building at the Miguel Hernández University, approximately 15 m above ground level in a ventilated area. The main meteorological characteristics of the urban area can be consulted in Nicolás et al. (2009).

2.2. Data collection

The study period comprised from October 2011 to September 2012. In that period particle number concentration and size distribution along with O_3 levels and meteorological parameters in the two stations aforementioned were measured.

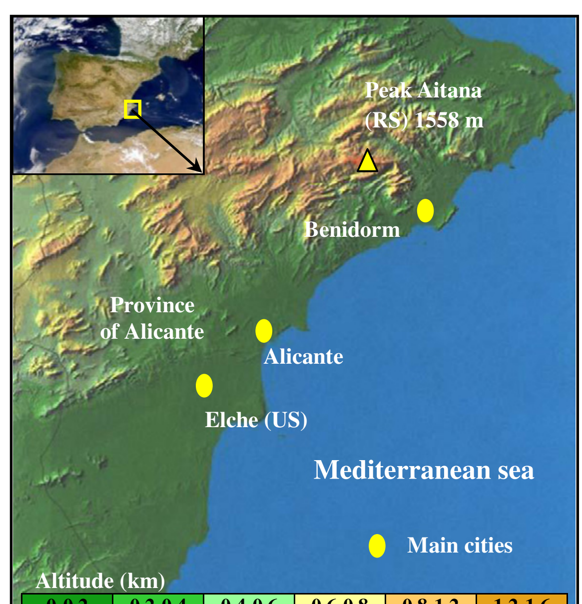

Fig. 1. Location and topography of the monitoring sites (US and RS) on the Spanish Mediterranean coast.