Atmospheric Research 155 (2015) 26–36

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

Ground-based measurements of long-range transported aerosol at the rural regional background site of Monte Martano (Central Italy)

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ARTICLE INFO

Article history:
Received 8 September 2014
Received in revised form 25 November 2014
Accepted 26 November 2014
Available online 9 December 2014

Keywords:
Atmospheric aerosol
Long-range transport
Saharan dust
EC/OC

ABSTRACT

Aerosol mass (PM_{10} and $PM_{2.5}$) and chemical composition recorded in the 2009 at the rural background station of Monte Martano (MM, Central Italy) are presented in this work. The site, located at 1100 m (asl), features relatively low aerosol mass levels, due to the little influence of local anthropogenic pressure, and is influenced mainly by long-range transport phenomena. Chemical composition of PM_{10} and $PM_{2.5}$ at MM is characterized by high levels of organic matter (OM), sulfates and nitrates, followed by crustal material, and ammonia. Sea Spray and elemental carbon (EC) accounted for a minor part of the total PM mass. The mass trends (PM_{10} and $PM_{2.5}$) and chemical characteristics (OC, EC, major ions, trace elements) are compared with those of other similar sites in Europe and discussed in the framework of an extensive analysis of back trajectories (BT). As a result, three main advection routes to Central Italy (Northern Africa, West Mediterranean and Eastern Europe) have been individuated on the basis of the BT analysis and show significantly different $PM_{2.5}/PM_{10}$ and OC/EC ratios. Major ions and trace elements trends are also discussed within this framework, showing that annual averages are more influenced by long-range transport from Eastern Europe, which is the prevalent advection route to MM (and Central Italy) also according to BT analysis. Finally, the data collected allowed to estimate the impact of Saharan dust on PM_{10} which amounted to 22 μg m^{-3} per intrusion event (22 events). The impact on $PM_{2.5}$ resulted in 11 μg m^{-3} per intrusion event.

1. Introduction

Tropospheric aerosols affect human health, ecosystems, visibility and climate through their properties such as the mass and number concentrations and, particularly, their chemical composition and structure (see for instance Kolb and Worsnop, 2012). Aerosol often contain species quite stable in the atmosphere, where they can be formed and transported far from the sources (Laj et al., 2009), with an impact which is often difficult to be discerned because of the continuous transformation and aging of the airborne particles due to gas condensation, coagulation and chemical reactions (Rudich et al., 2007).

The impact of long range transported aerosol on the particulate matter (PM) mass concentration and chemical

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http://dx.doi.org/10.1016/j.atmosres.2014.11.021
0169-8095/

speciation recorded on a site can vary substantially due to the source area, indeed, and also to synoptic/mesoscale meteorology, and to local wind conditions. The location of the measurement site has a great influence on the type and quality of data through its own pollutant sources and exposition. Indeed, field measurements that will help in understanding the impact of long-range transported pollutants, and more specifically the transformation of aerosol in the atmosphere during the transport from sources to receptor sites, are one of the current important activities to be developed in atmospheric research (see for example Calvo et al., 2013).

To this aim, regional background stations are located far enough from industrial and urban areas (i.e. Putaud et al., 2010) in order to provide a good relief of the atmospheric trends of composition in the lower troposphere away from local anthropogenic pressure. Sometimes these sites are located at medium or high elevation and this condition, though not recommended, makes them well suited for the monitoring of long-range pollutants transport (Marenco et al., 2006; Pio et al., 2011; Cusack et al., 2012; Querol et al., 2013). Meanwhile, high altitude sites may pose some challenges as far as the arrangement, maintenance and quality of performances of the instrumentations there at work. Special care and a proper technical approach are, thus, required.

In the present paper we describe trends and chemical composition of atmospheric aerosol sampled at a rural regional background site in Central Italy. The site has been established at the beginning of 2009 at a mid-elevation (approximately 1100 m asl) on the Martani mountain chain (Umbria, Central Italy) and is particularly well suited for monitoring long-range air mass intrusions. The site is continuously running since 2009 and has recently joined the WMO Sand and Dust Storm-Warning Advisory and Assessment System (SDS-WAS) program for automatic evaluation of modeled dust forecasts (http://sds-was.aemet.es/forecast-products/dust-observations/in-situ-measurements/monte-martano), as the southernmost measuring site of this network in Italy. Ground measurements as those carried out at MM, once carried out on a long term basis, are important for verifying derived results for both remote sensing and modeling studies of long-range trans-boundary air pollutions.

The main objective of the present paper is the description of the general aerosol phenomenology (mass concentration, chemistry, advection routes) that can be observed at the MM site, based on the data collected in the first year of measurements. Particular attention will be given to the carbonaceous fraction aerosol and its relationships with prevalent air masses at the site.

2. Experimental

2.1. Site description and equipment

Monte Martano (MM) is a medium altitude background site for air quality monitoring and atmospheric chemistry studies located in Central Italy, on the ridge of the Martani mountain chain (latitude 42°48′19″; longitude 12° 33′55″; altitude 1100 m asl). The location of the site is illustrated in Fig. 1, as the endpoint of a back trajectories cluster analysis whose results will be discussed further on. The site lies above the timberline (forest of beeches and oaks up to 900 m asl) and faces a completely free horizon (360°). Local winds are mainly from the western quarters with prevailing NNE and SSW direction (inset in Fig. 1). The nearest (~5 km) small village is located ~700 m below in altitude and the closest major human settlement of the area is Foligno (~50,000 abitants, 260 m asl) established at 20 km in NE direction. Overall, local anthropogenic contaminations at MM are small and limited, also due to the moderate elevation of the site. An estimation of the height of the boundary layer (BLH) has been performed exploiting the *diagmet* pre-processor of the Eulerian CHIMERE model (http://www.lmd.polytechnique.fr/chimere/) and the meteo data fields from the COSMO NWP model (http://www.cosmo-model.org/). Briefly, in this simulation the BLH is considered as the maximum of the boundary layer height calculated from the Richardson number profile (Troen and Mahrt, 1986) and a more convectively based boundary layer height calculation. The latter is based on a simplified and diagnostic version of the approach by Cheinet (2002). The BLH estimations have been performed with an hourly resolution for the entire 2009, at the nearest grid cell which covers also the Foligno City. Results are reported in Fig. 2 as 24 h averages, 12 h "night" averages (6 pm–6 am) and 12 h "daily" averages (6 am–6 pm), as a function of the Julian day. The calculations evidence that MM is perturbed by the boundary layer only in summertime and, moreover, that the site is always in the free troposphere during the night. Present evaluations are consistent with direct measurements of aerosol vertical profiles performed by us in Terni, approximately 50 km south to MM (Ferrero et al., 2012; Moroni et al., 2012, 2013). This simulation suggests a possible night/day sampling strategy for future campaigns (see i.e. Andrews et al., 2011).

The measuring station, which is installed inside an air-conditioned cabin, is equipped with a Dual Channel SWAM low volume sampler (FAI Instruments) for PM_{10} and $PM_{2.5}$ samplings. This instrument measures the aerosol mass by a ß rays attenuation method exploiting a single and integral source (^{14}C with 3.7 MBeq/100 μCi nominal activity) plus detector system. The use of spy filters of the same population as the operating filters and subjected to ß attenuation ancillary measures and the strict control of temperature and relative humidity allow removing the systematic errors connected with fluctuations of the air density in the measurement area, of the filtering medium mass, of the detector efficiency. The mass measurement reproducibility, as stated by the manufacturer, is $\pm$15 μg for a sampling spot area of 7.07 cm^2 which is the one used at MM. Smaller or larger sampling spot area can also be exploited with the SWAM device but the one presently used resulted the best compromise between sensitivity to the relatively low aerosol concentrations and amount of filter area available for the various chemical analyses. The sampling PM_{10} and $PM_{2.5}$ heads have been modified to include a heating systems and a condensed water drain system in order to avoid the formation of ice cups.

Standard meteorological parameters (temperature, relative humidity, radiation, wind speed and direction) are also recorded at the MM station. The 2009 averaged temperature was 283.9 K, with minimum and maximum recorded values of 267.4 and 303.3 K, respectively (see Fig. 2). All the measured data are automatically transmitted via GSM connection directly to the lab every 4 h.