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Dust concentration in PM_{10} samples and comparison with model results

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Abstract

PM_{10} samples collected at a costal site of south eastern Italy have been analyzed with the main aim of investigating the dust impact on particulate matter concentration and composition. Chemical analyses have revealed that the mass percentages of Al, Fe, Na, Mn, K, and Ti were larger in dust-affected samples than in dust-free samples. The mass percentages of Cr, Cu, V, Ni, Pb, and Zn which are mainly of anthropogenic origin were similar in dust-free and dust-affected samples. Analytical back trajectories and the Barcelona Super Computing Center-Dust REgional Atmospheric Model (BSC-DREAM) have been used to infer and evaluate the amount of dust at the ground level of the monitoring site.

Keywords: PM_{10}; chemical composition; dust impact.

1. Introduction

It is widely recognized that atmospheric particles are responsible for human health and environment problems. The European Monitoring and Evaluation Programme (EMEP) has been established in Europe for international co-operation to solve transboundary air pollution problems (www.emep.int). In fact, EMEP is a scientifically based and policy driven programme under the Convention on Long-range Transboundary Air Pollution (CLRTAP). Intensive monitoring periods (IMP) at several European sites have been established within EMEP to classify aerosol properties and sources across Europe. Mineral

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dust was simultaneously determined at 16 regional background sites in spring–summer 2012, and at 15 in winter 2013 within the third EMEP IMP, with the main aim of investigating the variability of the mineral dust composition across Europe. To this end, chemical speciation measurements were performed in PM_{10} samples.

Results on the chemical composition of PM_{10} samples collected over south eastern Italy during dust outbreaks are presented in this study, to further contribute to the dust characterization across Europe. More specifically, results on the chemical speciation in PM_{10} samples collected during the 9-13, July 2012 and the 4-10, August 2012 dust outbreaks, respectively will be presented. The HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model version 4.8, from NOAA/ARL (Draxler and Hess, 1998), was used to compute backward trajectories and infer the advection of dust over southeastern Italy. Then, the BSC–DREAM (Barcelona Super Computing Center-Dust REgional Atmospheric Model) was used to demonstrate/support the advection of dust particles at the ground level of the monitoring site. To this end, the PM_{10} mass concentrations monitored during the above mentioned Sahara dust outbreaks have been compared with the dust concentrations retrieved from the BSC-DREAM model (www.bsc.es) for the study area of this paper.

2. Methods

2.1 Site description and sample collection

The PM_{10} sampling was performed on the roof of the Mathematical and Physics Department of the University of Salento, at ~10 m above the ground level (a.g.l.). 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. 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 categorized 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). The Balkan and northern Africa coasts are ~100 and 800 km away from it, respectively.

A low volume (2.3 m^3 h^{-1}) HYDRA-FAI sampler was used to collect 24-h PM_{10} samples on 47-mm-diameter quartz fiber filters, pre-heated for 1 h at 700 °C.

2.2 Analytical techniques

Organic and elemental carbon and selected elements were measured in the collected samples. The thermal optical transmittance technique by means of the Sunset Carbon Analyzer Instrument was used with the NIOSH5040 protocol to determine EC and OC mass concentrations in a 1.5 cm^2 punch of the filter sample (Perrone et al., 2011). Six trace elements (Ni, Cu, V, Mn, Pb, Cr) were analyzed via Graphite Furnace Atomic Absorption Spectroscopy (GF-AAS, Perkin Elmer PinAAcle Z900). Eight elements (Ca, Mg, K, Na, Fe, Al, Zn and Ti) were analyzed by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES, Varian Liberty 110 spectrometer).

3. Characterization of the dust outbreaks by the BSC-DREAM8b

Fig. 1 shows the dust loading over northern Africa and southern Europe provided by the BSC-DREAM8b model for 9 July, 2012 at 12 UTC. Fig. 1 reveals that south eastern Italy was affected by dust since 9 July. The evolution with time of the dust concentration at 3940, 2067, 1027 and 86 m above the ground level (a.g.l) from July 8 up to July 14, which has been retrieved from the BSC-DREAM8b model for the monitoring site of this study (40.3 °N, 18.1 °E), is shown in Fig. 2. It is worth noting from Fig. 2 that dust particles are firstly advected at high altitudes. The advection of dust particles at 86 m a.g.l. starts on the night of July 10 and lasts up to July 14. Note that HYSPLIT back trajectories (https://ready.arl.noaa.gov/HYSPLIT.php) and MODIS images (http://lance-modis.eosdis.nasa.gov/) support the advection of dust over south eastern Italy.

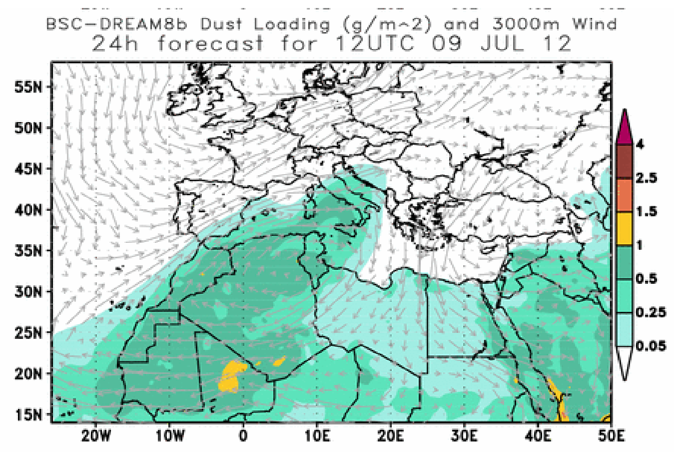

Fig. 1. Dust loading (g m^{-2}) from the BSC-DREAM8b model.

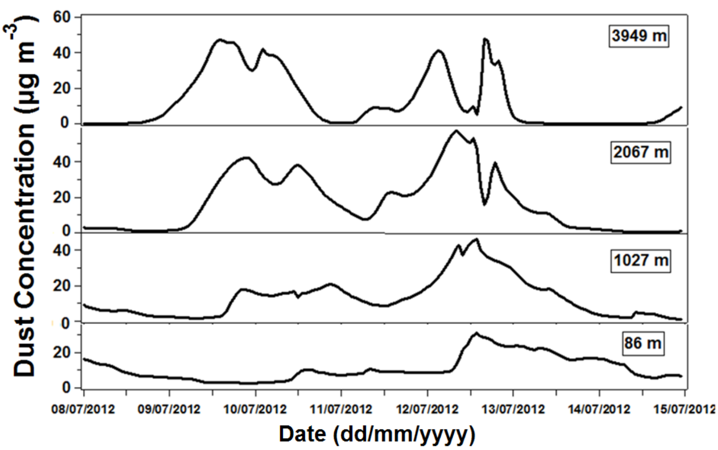

Fig. 2. Time evolution of the dust concentration (µg m^{-3}) from 8 to 14 July, 2012 at the monitoring site of this study (40.3 °N, 18.1 °E) and at selected altitudes above the ground level, from the BSC-DREAM8b model.

Fig. 3 shows the time evolution of the dust concentration from August 4 to August 10, 2012, retrieved from the BSC-DREAM8b model at selected altitudes a.g.l. of the monitoring site of this study. One observes from Fig. 3 that the advection of dust particles at 2067 m and 1027 m a.g.l. occurs since the early morning of August 4. Conversely, the advection of dust particles at 86 m a.g.l. occurs since the early morning of August 5 and significantly decreases on August 10. Note that HYSPLIT back trajectories (https://ready.arl.noaa.gov/HYSPLIT.php) and MODIS images (http://lance-modis.eosdis.nasa.gov/) support the BSC-DREAM8b results.

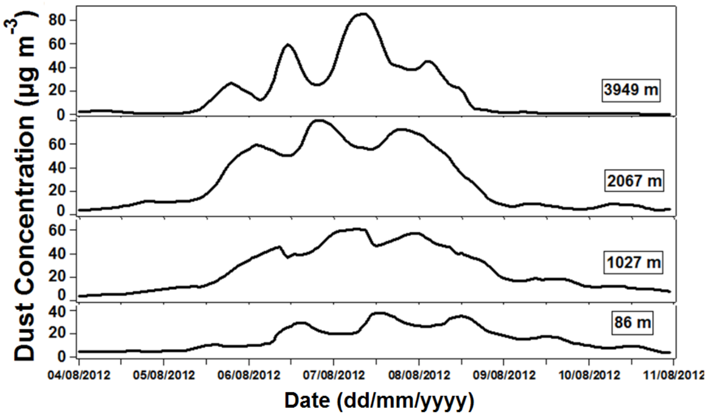

Fig. 3. Time evolution of the dust concentration (μg m^{-3}) at 3949, 2067, 1027, and 86 m a.g.l. retrieved from 4 to 10 August, 2012 at the monitoring site of this study (40.3 °N, 18.1 °E) from the BSC-DREAM8b model.

4. Results on the concentration and composition of PM_{10} samples and discussion

Fig. 4.(a) and Fig. 4.(b) (full dots) show the 24-h PM_{10} mass concentrations from July 8 to July 14 and from August 4 to August 10, respectively. Open dots show in both figures the 24-h mass concentration of dust particles from the BSC-DREAM8b model at 86 m a.g.l.

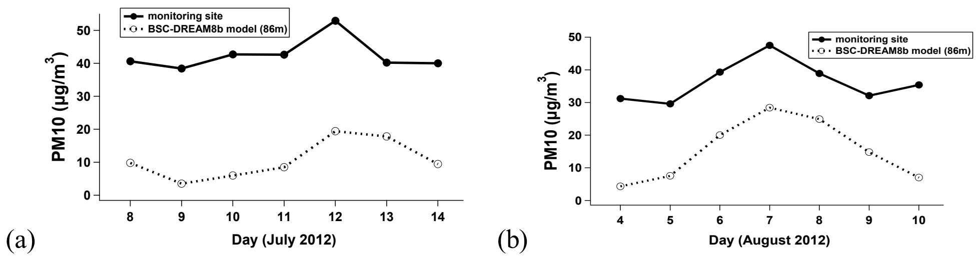

Fig. 4. 24-h PM_{10} mass concentrations (full dots) from (a) 8 to 14 July, 2012 and (b) 4 to 10 August 2012. Open dots show the 24-h mass concentration of dust particles from the BSC-DREAM8b model at 86 m a.g.l.

Table 1 provides the mass concentration of some 24-h PM_{10} samples collected prior to and during the advection of dust at the ground level. If we assume that July 9 was a dust free day (Fig. 2), Fig. 4.(a) (full dots) reveals that the PM_{10} mass concentration has increased of 15 μg m^{-3} on July 12, as a consequence of the advection of dust particles. This result is in satisfactory accordance with the one provided by the BSC-DREAM8b model (Fig. 4.(a), open dots), which reveals that the dust particle concentration has increased of 16 μg m^{-3} from 9 to 12 July, 2012. It is also worth noting from Fig. 4(full dots) that the PM_{10} mass concentration decreases of 12 μg m^{-3} from 7 August (dust day) to 10 August (dust-free day). This last result is in reasonable accordance with the one provided by the BSC-DREAM8b model (Fig. 4.(b), open dots), which shows that the dust particle concentration decreases of 21 μg m^{-3} from 7 to 10 August. The mass percentages of the chemical species measured in the PM_{10} samples of Table 1 are given in Table 2 to highlight the impact of the dust particles on the PM_{10} chemical composition.

Table 1. Mass concentrations of 24-h PM_{10} samples collected on selected dust and dust-free days.

Date (dd/ mm/yyyy)	Mass Conc. (μg m^{-3})
09/07/2012 (dust-free day)	38
12/07/2012 (dust day)	53
07/08/2012 (dust day)	47
10/08/2012 (dust-free day)	35

Table 2 reveals that the mass percentages of Al, Fe, Na, Mn, K, and Ti are larger in dust-affected samples than in dust-free samples. Conversely, the mass percentages of Cr, Cu, V, Ni, Pb, and Zn which are mainly of anthropogenic origin are similar in dust-free and dust-affected samples. These results are in accordance with previous studies (e.g., Perez et al., 2008; Contini et al., 2010). Ca, OC, and EC mass percentages appear to be not affected by dust outbreaks.

Table 2. Mass percentages of chemical species in dust and dust-free PM_{10} samples.

Chemical specie	Dust day		Dust-free day	
	12 July	7 August	9 July	10 August
Al	2,65	2,76	1,34	1,29
Cr	0,01	0,01	0,01	0,01
Cu	0,03	0,03	0,07	0,01
Fe	2,05	2,02	1,32	0,93
Na	7,01	7,15	1,21	1,16
Mn	0,06	0,05	0,04	0,03
V	0,01	0,02	0,02	0,01
Zn	0,04	0,06	0,05	0,04
Ni	0,018	0,023	0,020	0,026
Pb	0,014	0,023	0,019	0,022
K	1,14	1,26	0,94	0,73
Mg	0,77	0,76	0,88	0,84
Ca	5,75	5,24	7,36	2,50
Ti	0,18	0,19	0,07	0,07
OC	13,7	25,6	30,5	17,5
EC	3,70	7,15	10,38	2,62

In conclusion, paper results have revealed that the advection of dust particles affect both the mass concentration and the chemical composition of PM_{10} samples. It has also been highlighted in the paper that columnar dust loading images as the one of Fig. 1 do not provide any information on the impact of dust particles at the ground level. In fact, Fig. 1 reveals that the dust loading over south eastern Italy was within the 0.05-0.25 g m^{-2} range at 12:00 UTC of 9 July. However, dust particles do not impact the ground particulate matter concentration at 12:00 UTC of 9 July, in accordance with Fig. 2. This comment is further supported by the chemical analysis data reported in Table 2, which reveal that the mass percentages of the main elements of crustal origin (Al, Fe, Mn, and Ti) were larger in the 12 July PM_{10} sample than in the 9 July PM_{10} sample. Hence, one must be aware that the use of columnar dust loading images, as the ones provided by MODIS or by numerical models (e.g. Fig. 1), cannot always be used to support the advection of dust particles at the ground level. Dust particles from desert regions are generally lifted to high altitudes a.g.l. before the advection over Europe and as a consequence, may not affect the ground level.

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