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Quantification of natural contribution on PM_{10} exceedances in Southern Italy: an experiment performed in the framework of the I-AMICA project

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Abstract

Results concerning the assessment of the contribution of natural sources (e.g. mineral dust) on PM_{10} exceedances in Southern Italy are presented. This study was carried out for the Convergence Regions (i.e., Campania, Apulia, Calabria and Sicily) in the framework of the I-AMICA project (Infrastruttura di Alta Tecnologia per il Monitoraggio Integrato Climatico – Ambientale), as part of the National Operative Programme (NOP) funded by MIUR (Ministero dell'Istruzione, della Università e della Ricerca) and by the European Union. So far, in the Convergence Regions, only short-term experiments based on PM_{10} measurements were performed for single sites. There are no experiments in which synchronous observations were compared and analysed in different regions of Southern Italy. Thus, a work about the characterization of atmospheric phenomena influencing the entire Southern part of the Italian peninsula is illustrated in this paper. Ground based observations of PM_{10} levels, as well as aluminium concentrations, were analyzed for a six months period (i.e., March - July 2007). A method for Saharan Dust Events (SDEs) identification, which ingests the time series of PM_{10} simultaneusly collected at background stations (i.e., rural, sub-rural, sub-urban, urban and industrial), was developed. The identification of dusty days was confirmed by the aluminium concentrations, a proxy of desert dust outbreaks. Once the list of days with dust is obtained, their impact on mean concentrations of PM_{10} is determined using a statistical approach (i.e., an optimizational tool). During a six months period, our method recognized four Saharan Dust Events associated with simultaneous exceedances for 80% of considered sampling

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sites. Such events resulted in an increase of 0.5 μg/m^3 of PM_{10} levels averaged overall picked out stations.

Keywords: Saharan dust event, PM10 exceedances, I-AMICA project.

1. Introduction

Mineral dust, as one of the most abundant aerosols in the atmosphere, affects climate by absorbing solar and terrestrial radiation (Foster et al., 2007) and has important implications regarding air quality (Prospero, 1999).

In the framework of the I-AMICA project (Infrastruttura di Alta Tecnologia per il Monitoraggio Integrato Climatico – Ambientale), as part of the National Operative Programme (NOP) funded by MIUR (Ministero dell'Istruzione, della Università e della Ricerca) and by the European Union, an experiment over Southern Italy was performed. One of the tasks of this project is to set up a method for Saharan Dust Events (SDEs) detection associated with simultaneous PM_{10} exceedances (Directive 2008/50/EC on ambient air quality and cleaner air for Europe). However, detecting SDEs, and subsequently quantifying their contribution to PM levels is complex. So far, only two measurement-based methods were developed and published: the Spanish-Portuguese Reference (SPR) method, and the Tel Aviv University (TAU) method. A comprehensive assessment of both of them is reported in Viana et al. (2010). In the same paper analysis of temporal correlation between the Saharan dust factor – as calculated by PMF (Positive Matrix Factorization) - and aluminium (Al) was used for identifying the SDEs.

The purpose of this work is to provide a different approach for SDEs detection based on time series of PM_{10} concentration simultaneously collected not only at rural background stations – as suggested by the mentioned methods – but also at sub-rural, sub-urban and urban ones. It is worth to notice that this method does not replace the already existing ones, but it wants to be an attempt to shed light on a different technique for the detection of major SDEs associated with simultaneous PM_{10} exceedances over a given area (e.g., domain of 300 km x 300 km).

2. Dataset and method

2.1 Observations description

The observations used for this study were downloaded from the European air quality database AirBase (http://www.eea.europa.eu/data-and-maps/data/airbase-the-european-air-quality-database-8). Currently in the Southern Italy there are 123 sampling sites, of which 24 are classified as background (i.e., 1 rural, 14 suburban and 9 urban). Table 1 reports the number, the name, spatial coordinates and the typology of the 24 background stations.

Table 1. The list of the stations with name, spatial coordinates and typology.

N	Station Name	Lon; Lat; Alt (m a.s.l.)	Typology
1	Lecce	18.1E; 40.4N; 10m	Rural
2	Augusta	15.1E; 37.2N; 30m	Suburban
3	Palermo	13.3E; 38.1N; 141m	Suburban
4	Napoli	14.2E 40.8N 145m	Suburban
5	Taranto	17.3E; 40.4N; 145m	Suburban
6	Mesagne	17.8E; 40.5N; 10m	Suburban
7	Campi Salentina	18.0E; 40.4N; 10m	Suburban
8	Grottaglie	17.4E; 40.5N; 200m	Suburban
9	Catania	15.0E; 37.4N; 82m	Suburban
10	Agrigento	13.5E; 37.3N; 180m	Suburban
11	Casamassima	15.2E; 40.6N; 100m	Suburban
12	Locri	16.2E; 38.2N; 10m	Suburban
13	Milazzo	15.2E; 38.2N; 28m	Suburban
14	Ragusa	14.7E; 36.0N; 501m	Suburban
15	Ragusa2	14.5E; 36.7N; 24m	Suburban
16	Taranto	17.28E; 40.41N; 10m	Urban
17	Taranto2	17.22E; 40.42N; 10m	Urban
18	Partinico	13.1E; 38.0N; 0m	Urban
19	Termini Imerese	13.6E; 37.9N; 0m	Urban
20	Enna	14.2E; 37.5N; 0m	Urban
21	Cosenza	16.2E; 39.3N; 200m	Urban
22	Crotone	17.1E; 39.0N; 10m	Urban
23	Ragusa	14.7E; 36.9N; 598m	Urban
24	Catania	15.6E; 37.5N; 135m	Urban

The sampling site of Lecce is the unique site classified as rural background. The remaining ones are suburban (14) and urban (9). Nevertheless, there is no long period with simultaneous measurements for these sampling sites. Our experiment was carried out over a six-months period, between March and August 2007. In such period PM_{10} levels were simultaneously registered for the five stations of Augusta, Palermo, Napoli, Agrigento and Taranto2.

2.2 A short method description and results

The proposed method provides the list of days in which concentrations of PM_{10} greater than law limit established by the Directive 2008/50/EC (i.e., 50 $\mu g\ m^{-3}$) simultaneously were observed. Our method classifies a day as a "*dusty day*" if simultaneous exceedances of daily levels of PM_{10} are observed for 80% of considered stations (i.e. in this case for four stations out of five). However, a method evaluation was carried out using one of most important elements used as tracer of desert dust in the air, the aluminium. Fig. 1 shows the time series of PM_{10} levels collected at the five stations mentioned above (upper time series of Fig. 1), and those of aluminium concentrations (lower time series of Fig. 1) registered at Rende and Lecce sampling sites, on Tyrrhenian and Adriatic side of Southern Italy respectively.

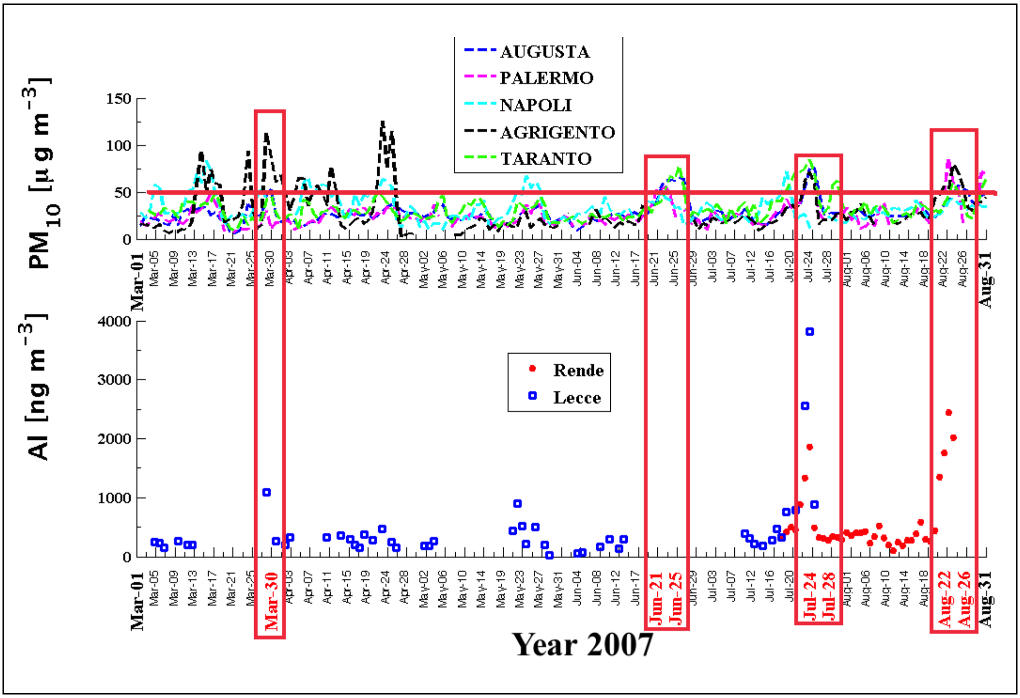

Fig. 1. Time series of PM_{10} concentrations measured at Augusta (15.1E; 37.2N; 30m a.s.l.), Palermo (13.3E; 38.1N; 141m a.s.l.), Napoli (13.3E; 38.1N; 141m a.s.l.), Agrigento (13.3E; 38.1N; 141m a.s.l.) and Taranto (17.22E; 40.42N; 10m a.s.l.) in the upper panel, those of aluminium registered at Rende (16.18E; 39.34N, 480m a.s.l.) and Lecce (18.18E; 40.38N; 49m a.s.l.) in the lower one. The period ranges from 1st March to 31st August 2007. The red rectangles represent the *dusty days* according to our method.

As reported in the Fig. 1, simultaneous PM_{10} exceedances registered for the 80% of the considered stations correspond to higher concentrations of aluminium on Tyrrhenian and/or Adriatic sampling sites (i.e., Rende and Lecce). In addition, data generated by deterministic modelling system (not shown here) devoted to the forecast of Saharan dust transport over North Africa, Middle East and Europe domain (http://www.bsc.es/earth-sciences/mineral-dust-forecast-system/bsc-dream8b-forecast/north-africa-europe-and-middle-ea-0) confirm that for the dates provided by our algorithm (i.e. reported in the red rectangles of Fig. 1) SDEs were forecasted over Southern Italy. Once the list of *"dusty days"* is obtained, firstly the number of exceedances associated with natural events can be pointed out – as plotted in Fig. 2 -, secondly a quantitative estimation of contribution to PM_{10} levels of those days can be calculated by using a statistical approach – as reported in Fig. 3.

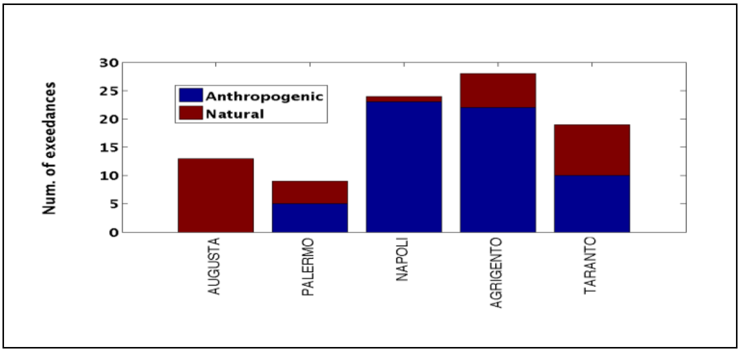

Fig. 2. The number of PM_{10} exceedances (i.e. larger than 50 μgm^{-3}) associated with SDEs (in brown) is indicated for each station. The blue histograms represent the number of exceedances not caused by natural events (i.e. due to anthropogenic sources).

Such information is very useful for those regions of Mediterranean basin in which often SDEs result in PM_{10} levels that exceed the air quality standard daily threshold. In fact, by using a tool like this, it would be possible to demonstrate and subtract the exceedances attributable to natural sources (EC, 2011).

On the other hand, a quantitative estimation of the impact of *"dusty days"* on PM levels can be calculated by using a statistical approach. The best fit of positive right skewed curve over the occurrence of PM_{10} concentrations can be determined with the optimal values of mode and standard deviation. The formula used for the fitting of the data is the following (1):

$$y = f(x|\mu,\sigma) = \sigma^{-1} exp(\frac{x-\mu}{\sigma}) exp(-exp(\frac{x-\mu}{\sigma})) \quad (1)$$

where μ and σ are the mode and standard deviation, respectively. Fig. 3 shows the optimal curves of two datasets (i.e., with and without dusty days).

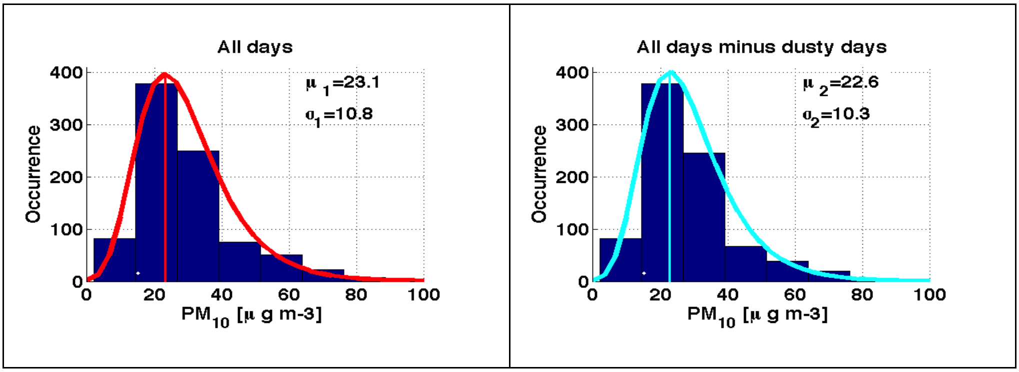

Fig. 3. Optimal curve calculated on the occurrences of PM_{10} values collected over all five stations listed in Fig. 2. In the left panel the right skewed curve (in red) calculated overall data; in right panel that computed over non *"dusty days"*. Optimal values of mode μ and of standard deviation σ were calculated for both datasets.

As expected, the optimal mode value calculated over non dusty days is lower than 0.5 μg/m^3. It could be considered as the net impact of *"dusty days"* on PM_{10} levels averaged over the five sites. Besides, σ presents the same difference. Notice that this exercise was performed using the data measured over a group of stations as the first application of this approach. Actually, it should be implemented with the data collected for a single station to determine the net load of each event to subtract to the daily values – as reported in literature (EC, 2011).

3. Conclusions

The results achieved for an experiment regarding a six-months period over Southern Italy aimed at detecting the SDEs and quantifying their impact on PM_{10} levels are briefly illustrated in this paper. Encouraging outcomes were pointed out, both in terms of capability of our method in recognizing the major SDEs, and in estimating the net contribution of so-called *"dusty days"* on PM concentrations. Given the complexity of issue related to these two tasks, a simplified - but pragmatic - method was provided to shed light on the major SDEs that generally occur in Southern Italy by using only the synchronous ground measurements of bulk mass of the aerosols. Nevertheless, it should be kept in mind that, SDEs are not the unique natural phenomena that might cause a concomitant and significant increase of PM levels over a given area, but also volcanic eruptions, biomass burning and/or long rang range transport of some crustal components coming from different arid areas, which were not taken into account in this study.

4. Acknowledgements

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