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Study of Saharan dust influence on PM_{10} measures in Sicily from 2013 to 2015

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ABSTRACT

Nowadays, particulate matter, especially that with small dimension as PM_{10}, $PM_{2.5}$ and $PM_{1,}$ is the air quality indicator most commonly associated with a number of adverse health effects. In this paper it is analyzed the impact that a natural event, such as the transport of Saharan dust, can have on increasing the particulate matter concentration in Sicily.Consulting the data of daily PM_{10} concentration, acquired by air quality monitoring network belonging to "Agenzia Regionale Protezionedell' Ambiente" (Environmental Protection Regional Agency), it was possible to analyze the trend from 2013 to 2015. The days, in which the limit value was exceeded, were subjected to combined analysis. It was based on three models: interpretations of the air masses back-trajectories, using the atmospheric model HYSPLIT (HYbrid Single-Particle Lagrangian Integrated trajectory); on the calculation of the concentration on the ground and at high altitude particulate applying DREAM model (Dust REgional atmospheric model) and on the calculation of the concentration of mineral aerosols according to the atmospheric optical thickness (AOT) applying NAAPS model (Navy Aerosol Analysis and Prediction System).The daily limit value exceedances were attributed to the transport of Saharan dust events exclusively when the three models were in agreement with each other. Identifying the natural events, it was possible to quantify the contribution of the Saharan dust and consequently the reduction of the exceedances number. To quantify the contribution of Saharan dust on daily PM_{10} concentration, it was calculated the regional background in according to precautionary approach recommended by "Guidance on the quantification of the contribution of natural sources under the EU Air Quality Directive 2008/50/EC", when the application of the method cannot be validated with chemical analysis, as in this case. In this study is obtained, as the most important quantitative goal, the convergence of the three models to the same result. So, is evident that exceedances of the daily limit value that occurred from 2013 to 2015 in Sicily can be attributed, in most cases, to the Saharan dust intrusion.

1. Introduction

The increasing modern agriculture and irrigation systems, which leads environmental issues as air pollutions, has been deeply studied on the last decade. We recall, for instance, the studies of Valipour (2015a,b); Valipour (2016a,b,c) and Yannopoulos et al. (2015).

The awareness of the public opinion and institutions to environmental issues in recent years encouraged the development of methodologies for the collection and analysis of air pollutants. Considering the amount of air daily inhalated by an individual (from 6 to 9 l/min at rest condition, 60 l/min during moderate exercise), it is possible to better realize the importance for the health and the risks associated with polluted air respiration.

Nowadays, in the major Italian and European cities, the most evenly dispersed pollutant is particulate matter (Künzli et al., 1999; EEA, 2015; Capizzi et al., 2015). Suspended particulates, especially those ones with small aerodynamic diameter such as PM_{10}, $PM_{2.5}$, PM_1, are the most commonly air quality indicators associated with several adverse health effects (Caramagna et al., 2015; Strano et al., 2015). Due to their intrinsic characteristics, they are able to remain in atmosphere for a longer time, representing so a danger to the health of humans, animals and plants. Epidemiological studies done by Research on Cancer showed that the particulate increase facilitates the appearance of chronic lung disease; the formation of various malignancies and rises the mortality from cardiovascular and respiratory diseases. Studies done during the last decade showed an association between levels of air pollutants and the daily

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number of deaths or hospital admissions for respiratory and cardiovascular causes (Glinianaia et al., 2004; Maisonet et al., 2004). The possible damage for the human body may derive from the type of particle which could be toxic by itself, or more frequently, due to the substances deposited on it. Particulate matter can be considered the means which allows the penetration into the respiratory system of human body, of potentially harmful substances (Schwartz et al., 1996; Norris et al., 1999; Pope, 2000a,b; Ostro et al., 2006; Dockery and Stone, 2007; Kampa and Castanas, 2008). In addition to the damage on health, particulate matter has a very important role on global climate change (Charlson et al. 1992; Duro et al., 2014, 2016). It has effects in the propagation and absorption of solar radiation, on the atmospheric visibility and in the processes of vapor condensation, favoring the formation of smog and fog (Wexler and Ge, 1998; Kaufman, 2006). Although the pollution originated by human activities is the most accused in the deterioration of air quality, pollution of natural origin such as Saharan dust intrusion must not be underestimated. Concerning the specific health effects connected to Saharan dust intrusion, there are not firm and adequately shared evidences yet, further investigations aimed to understand the role of natural events in air pollution and the consequent effects on human health are needed (Linares et al., 2010).

Generally, these intrusions can cause abnormal rise in PM_{10} concentration values, and, in some cases, contribute to excess the limit values fixed by European Directive 2008/50/EC. European Directive requires that, in all Member States the average daily concentration of PM_{10} should not exceed, more than 35 times during a calendar year, the limit value of 50 $\mu g/m^3$. However, it allows to separate exceedances due to natural contributions, if this natural occurrence is demonstrated with sufficient certainty. The guidelines issued by the European Commission in 2011 established the basic elements for the identification and evaluation of the desert sands impact on PM_{10} levels measured in air quality monitoring stations (European Commission, 2011; Marelli, 2007). Consulting the data of daily PM_{10} concentrations, acquired by three measuring stations belonging to the air quality monitoring network of the *Agenzia Regionale Protezione dell'Ambiente* (Environmental Protection Regional Agency), it was possible to analyze the trend from 2013 to 2015. The days in which limit value exceedances were recorded, they were submitted to combined analysis. This analysis is based on interpretations of the back-trajectories of air masses, which was obtained by HYSPLIT model (Hybrid Single Particle Lagrangian Integrated Trajectory) (Draxler and Hess, 1997; Draxler et al., 2010); the calculation of the concentration of particulate matter in soil and altitude was obtained applying DREAM model (Dust Regional Atmospheric Model) (Basart et al., 2012); while the calculation of the concentration of mineral aerosols as a function of the atmospheric optical thickness (AOT) was obtained using NAAPS model (Navy Aerosol Analysis and Prediction System) (Jaffe et al., 2004). Exceedances of the daily limit value (DLV) were attributed to the transport of Saharan dust events when the three models (simultaneously verified) applied during the days gave the same results. Identifying the natural events, it was possible to quantify the contribution of the Saharan dust and consequently to reduce, where possible, the number of exceedances recorded from 2013 to 2015 in the three monitoring stations considered.In this work is analyzed the impact of a natural event, such as the transport of Saharan dust, which may have on the increase in particulate matter concentration in Sicily.

The novelty of this investigation is the approach followed by guidelines, which provides for the combined analysis of the weather conditions, the model forecasts, satellite observations, measurements of PM_{10} and the suggestion of a working methodology for the assessment of transport events sand applicable in each zone that is object of interest, (see e.g. Pey et al., 2013; Querol et al., 2009). So, it is possible to extend the results to other regions with similar conditions. In this study the authors did not measure $PM_{2.5}$ because the analyzer present in the monitoring stations does not allow to acquire these concentrations. The authors intend to improve the research in this direction.

2. Measuring of daily PM_{10} concentration

The daily data of PM_{10} concentrations, originating from the three stations which belong to the air quality monitoring regional network were analyzed. The monitoring stations were selected in purpose of the climatic variability that affects the region. In detail, the monitoring station identified as Partinico (PTN) represents Western Sicily, the monitoring station identified as Enna (ENN) represents Central Sicily and the monitoring station identified as Misterbianco (MRB) represents Eastern Sicily (Fig. 1 and Table 1). Such monitoring stations adopt the β-ray attenuation method, for the measurements of the mass concentrations of PM_{10}. According to the Directive 2008/50/EC the daily concentration of PM_{10} must not exceed, more than 35 times during a calendar year, the limit value of 50 $\mu g/m^3$, while the annual average should not exceed 40 $\mu g/m^3$. In order to verify compliance with the limit values, it was analyzed the trend of the daily PM_{10} concentrations detected in the three monitoring stations from 2013 to 2015 (Figs. 2–4). The trends have shown compliance with the limit values prescribed by the regulations for the three years analyzed. Moreover it was possible to identify days with anomalous PM_{10} concentrations. In the majority of cases the abnormal concentrations have affected the three measurement sites simultaneously. This has helped to narrow the hypotheses about possible causes excluding, for example, the urban traffic and assuming instead a Saharan dust event.

3. Identification of Saharan dust intrusion

The guidelines issued by European Commission set out the basic elements for identification and evaluation of impact of desert dust on PM_{10} levels measured in air quality monitoring stations, without requiring knowledge about character particulate. In order to identify the episodes of Saharan dust transport in Sicily, a combined analysis based on weather conditions, on model predictions and action on the ground was conducted. The methodology applied in this work takes account of the following:

- Interpretation of the daily weather conditions by analyzing the back-trajectories of air masses, with HYSPLIT model (HYbrid Single-Particle Lagrangian Integrated Trajectory) developed by National Oceanic and Atmospheric Administration, USA (NOAA),

Table 1
Identification of monitoring stations.

Station	ID	Location	Altitude (m.a.s.l.)	PM_{10} monitoring method
PA-Partinico	PTN	38°02′58.9″N 13°07′07.2″E	182	β-Attenuation
EN-Enna	ENN	37°33′51.8″N 14°16′54.5″E	920	β-Attenuation
CT-Misterbianco	MRB	37°30′56.4″N 15°00′38.5″E	177	β-Attenuation