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Atmospheric composition variability in the framework of I-AMICA Italian Southern Mediterranean infrastructural project

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Abstract

The study and monitoring of absorbing aerosol and greenhouse gas variability due to natural and anthropic emissions capture great attention in the scientific community to study air quality and to investigate different climate scenarios, in particular in the Mediterranean Basin that is an hot spot for climate change. In order to strengthen the environmental observation system in the Southern Italian Convergence Regions I-AMICA (Infrastructure of High Technology for Environmental and Climate Monitoring), a three year Italian National Operative Program (PON) project co-founded by the European Regional Development Fund, is being developed. The project also aim to strengthen the environmental monitoring in the South of Italy adopting both stationary and mobile in-situ stations for aerosols and greenhouse gases and remote sensors, such as Raman lidars and wind lidars for atmospheric profiling. This work is based on the first observations performed at two stations: Lecce, a urban background station in the Apulia region and Lamezia Terme a background station in Calabria region. Differences in concentration levels and in physical properties of aerosol at the two stations will be investigated. Three case studies of long-range transport of natural aerosol creating exceedances of Air Quality Standard (AQS) daily threshold for PM$_{10}$ will be investigated showing that the simultaneous analysis in the two sites helps in identifying these events and in evaluating their impact on atmospheric aerosol concentrations.

Keywords: Aerosol; air quality; long-range transport.
1. Introduction

The Mediterranean Basin, as stated by the European Environment Agency (EEA, 2012) is one of the regions that have been most deeply affected by climatic change in the last decades. Increasing urbanization, vehicle use, and industrial activities, reflected in pollutant emissions to the atmosphere, have made this one of the most vulnerable and climatically sensitive regions. The study and monitoring of absorbing aerosol and greenhouse gas variability due to natural and anthropogenic emissions is crucial to predict the implication on climate scenarios and air quality in this area (considered an hot spot of climate change). Natural sources of aerosol are the vast majority of global annual input of particles into the atmosphere (80-85%). The main contributions come from sea spray followed by advection of desert dust and volcanic and fires emissions and are mainly in the coarse fraction (>90%) (Marelli et al., 2007). The European air quality Directive (2008/50/EC) provides Member States with the possibility to subtract the contribution of natural air pollution sources before comparing atmospheric concentrations with air quality standards. The I-AMICA project, based on a network of observation stations in South Italy and in modeling activities, provides a comprehensive methodology aimed at quantifying the influence of aerosols in terms of direct and indirect effects on climate and air quality. Due to the geographical location, this area is affected by local and long-range transported marine, desert (from Sahara), and anthropogenic (from continental Europe or ship traffic) aerosols. This network of observation stations is dedicated to environmental-climate monitoring for atmosphere, agricultural and forest systems, sea and coasts, and for developing new advanced monitoring methods. These applications are also devoted to identify, define, and quantify the contributions that natural processes (e.g., wildfires, desert dust transport, salt wedge introgression, biosphere-atmosphere and biosphere-hydrosphere exchanges) have in affecting the air quality and the environmental-climatic conditions in Southern Italy. In this work we present preliminary results on the physical properties of aerosol at the two stations in Apulia and Calabria with specific aim in showing how the use of simultaneous measurements in two Regions helps in the determination of the impact of long-range transport of aerosol from natural sources on PM10 and PM2.5. This will be done discussing three case studies characterized by high PM levels caused by intrusions of different natural aerosols.

2. Experimental

Continuous measurements of PM10 and PM2.5, aerosol size distribution and meteorological parameters are performed at the two observation sites of Lecce (Apulia) and Lamezia Terme (Calabria) since summer 2013. The CNR-ISAC station (N 38° 5′, E 16° 1’) of Lamezia Terme is a coastal background site, located in an isolated position 500 m inland from the Tyrrenian coastline. The atmospheric circulation is dominated by the breeze system that has an important role in defining local meteorology. The CNR-ISAC station of Lecce is located inside the University Campus (N 40° 20′ 10.8″, E 18° 07′ 21.0″ WGS84), at about 3.5 km SW of the town of Lecce and it can be considered an urban background site. Measurements were carry out in both sites by an OPC FAI (Multichannel Monitor) which classifies particles in 22 size bins in the 0.28÷10μm range, while PM10 and PM2.5 mass concentration measurements are performed by β–ray attenuation method using a low volume (2.3 m³/h) FAI SWAM 5a-Dual Channel Monitor. Meteorological data are also collected by a Vaisala automatic weather station located close to the instruments. All measurements are available in near-real time on I-AMICA web site (http://www.i-amica.it).
Periodical manual gravimetric measurements performed simultaneously with the automatic measurements at the two stations guaranteed the accuracy of the measurements. Figures 1a-b show the temporal trend of daily PM10 and PM2.5 values measured by SWAM in Lecce and Lamezia Terme, respectively.

Fig. 1. Daily averages PM10 and PM2.5 from the stations of Lecce (a) and Lamezia Terme (b) from July 2013 to April 2014. Different scales were adopted for y-axes.

In general, PM10 and PM2.5 observed in Lecce (averages 29.6 µg/m³ and 19.8 µg/m³ respectively) are larger than those measured in Lamezia Terme (averages 15.2 µg/m³ and 8.7 µg/m³) even if the ratios PM2.5/PM10 are similar: 0.65 (± 0.19) at Lecce and 0.61 (± 0.19) at Lamezia. The correlation between the two fractions is significant in Lecce ($R^2=0.85$) but less strong in Lamezia ($R^2 = 0.30$). This result could be a consequence of the major influence of anthropogenic emissions in the Lecce site, clearly reflected in the number size distribution as showed by Fig. 2 which reports the comparison of corresponding Lecce (red triangles) and Lamezia (black squares) number size distribution, averaged between July 2013 and January 2014. The larger PM concentrations measured in Lecce are essentially due to a larger contribution of fine particles with diameter lower than 1-2 µm likely associated to anthropogenic aerosol.

Fig. 2. Comparison of number size distributions measured in Lecce (a) and Lamezia Terme (b) stations.

Diurnal trends of aerosol number concentrations (Fig. 3a–b), averaged over the entire sampling period, were compared considering fine (0.28-0.90µm) and coarse (1.10-10µm) fractions separately. Fig. 3a shows a clear daily pattern of fine fraction at both the sites with lower concentration during daytime with respect to nighttime. At both the sites traffic contribution is visible early in the morning (around 7:00 AM). Fig. 3b shows that the concentration levels of coarse particles are much more similar at the two sites with almost absent daily pattern in Lamezia Terme and a slight increase of concentration in nocturnal hours in Lecce.
3. Results

Large amounts of PM can be emitted from various sources of natural origin and long range transported. Mineral dust, sea salt, volcanic eruptions, wild land fires, are the most important natural sources contributing to aerosol loading in Mediterranean area countries. During the sampling campaign, the analysis of PM10 and PM2.5 levels recorded at the two sites, together with size distribution and atmospheric dynamics by back-trajectory analysis allowed to identify three different events (marked with dates in Fig. 1) simultaneously recorded in Lecce and Lamezia Terme.

Case study 1
The event of 19th - 20th January 2014 is a typical case of Saharan dust transport affected Southern Italy as confirmed by the DREAM simulations (www.bsc.es) and by the HYSPLIT back-trajectories (not shown). The Saharan intrusions over the study area occur when air masses over the Sahara desert move northward over the Italian Peninsula (Rodriguez et al., 2001). This results in an increase in PM10 levels due to the high mineral load of the Saharan air masses. Indeed, high PM10 daily levels, 4-5 times larger than the mean average values, were registered at the two stations during this event, 34 μg/m³ and 28 μg/m³ on 19th January, 180 μg/m³ and 61 μg/m³ on 20th January, at Lecce and Lamezia Terme respectively.

Diurnal trends of coarse number concentrations (Fig. 4) showed that the large particles associated with Saharan dust dominated during the events. At Lecce, a sharp decrease in particulate levels was induced by rainfall at 14-15 p.m. showing the efficiency of wet scavenging on coarse particles. The PM10 and PM2.5 concentrations observed at the
station of the Apulia regional monitoring network (managed by ARPA Puglia) showed high levels of PM10 in Lecce Province with minimal effect on PM2.5 (Fig. 4).

**Case study 2**
The event of 19\textsuperscript{th} November 2013 is characterized by an increase by a factor 10 of PM10 levels with respect to typical level in Lamezia Terme. The “intense” event in Lamezia was also visible, with lower intensity and longer duration, in Lecce 5-6 hours late, as shown in Fig. 5. The diurnal trends of number concentration reports an increase only for the coarse fraction. The distance between the two sites is about 220 km and the delay between the peak in the particle number concentrations at the two sites is compatible with a transport at about 40 km/h as evidenced by the HYSPLIT back-trajectories. The event was associated to the advection of volcanic ash due to the Etna eruption of 17\textsuperscript{th} November 2013 which originated a plume moving NE as confirmed by HYSPILIT back-trajectories together with MOLOCH (M\textit{Odello LOCale in H coordinates}) meteorological forecasts. The SEM-EDX quantitative analysis of the daily filters collected in Lamezia during 18-20 November allowed an unambiguous attribution of the volcanic origin of the particles (Calidonna et al., 2014).

**Case study 3**
A further interesting case study showing the influence of the Saharan plume on daily PM10 levels occurred on 11/02/2014. The diurnal trend of coarse particle number concentration supported the occurrence of a short-lasting (but very strong) long-range advection of Saharan dust (Fig. 6). A 2-hour delay was pointed out between the event peak in Lamezia and Lecce, but with very high PM10 levels registered at the two stations. The simultaneous analysis performed in the two sites excludes possible mistakes with local sources on these kind of short-time events.
Fig. 6. Time trends of coarse and fine particles in the two sites on 11 - 12 February 2014 (1 min averages).

4. Conclusions

The β-attenuation measurements could be considered as a reference in both sites given their good agreement with the gravimetric method. The mass and the number concentrations observed in Lecce are significantly larger than those observed in Lamezia. This is mainly due to larger concentrations of particles < 1-2 µm in Lecce, indicating a larger contribution of anthropogenic sources in Lecce. There are similar diurnal trends in the two sites with smaller concentrations of fine particles in diurnal hours with respect to nighttime. The two sites are often influenced by long-range transport of dust from natural aerosol (desert dust and volcanic). The information collected simultaneously in the two background sites, placed at large distance one from the other in two southern areas overlooking the Adriatic and Tyrrhenian Sea, permitted to identify natural aerosol long-range transport events in the South of Italy and to evaluate their impact on PM10 and air-quality levels. Therefore, this study confirms the importance to strengthen the environmental observation system in the Central Mediterranean and Southern Italian Regions, one of the objectives that the PON I-AMICA, is pursuing.

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