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First evidence of volcanic plume observed in a central Mediterranean marine observatory

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Abstract

Continuous measurements of PM_{10} and $PM_{2.5}$, aerosol size distribution (for Dp ranging from 280 nm to 10 μm) and meteorological parameters are continuously performed since 1st August 2013 at the CNR-ISAC Climatic Observatory of Lamezia Terme (40°3N, 18°1E, 50 m a.s.l.), in the framework of the PON/ERDF I-AMICA Project. In this work, we present and discuss a special event which occurred on 19th November 2013, when a significant increase of PM_{10} (up to 75 μg m^{-3}) was observed. During the night between 16th and 17th November, an explosive eruption occurred at Mt. Etna. The analysis of HYSPLIT, i.e. three-dimensional back-trajectories, ending in Lamezia together with MOLOCH (MOdelloLOCale in H coordinates) meteorological simulations suggested that the volcanic plume from Mt. Etna affected Lamezia Terme on 19th November. Moreover, for this case study, SEM-EDX analyses on PM_{10} filters revealed the presence of large abundances of sulphur minerals, further corroborating the possibility that the large PM_{10} value observed at the measurement sites could be tagged to the advection of volcanic ash.

Keywords: PM10; Calabria; Mediterranean basin; aerosol advection; Etna eruption.

1. Introduction

Climate changes are one of the most topical research fields. The continuous observation of anthropic and natural emissions such as sea-spray, mineral dust (i.e., from Sahara desert), as well as of volcanic ash has to be performed in order to investigate the

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contribution of natural processes to atmospheric composition variability. The Italian peninsula insinuates in the Mediterranean along an axis of more than 12° of latitude (1200 km), providing a natural and unique platform for observing the environment and the climate of southern Europe and Mediterranean basin, two widely recognised "hotspot" regions for climate change and air quality .

In the framework of the Italian National Operative Program (PON)/European Regional Development Fund (ERDF) project I-AMICA, the Climatic Observatory of Lamezia Terme (40°3N, 18°1E, 50 m a.s.l.), managed by National Research Council of Italy (CNR) – Institute of Atmospheric Science and Climate (ISAC), has been recently upgraded to perform continuous observations of meteorological parameters and aerosol chemical-physical properties. The geographic position of this Observatory, located along the west coast of Calabria region, allows to investigate the variability of anthropogenic and natural aerosol emissions, with a special emphasis on sea-spray, mineral dust (i.e., from Sahara desert), as well as volcanic ash emitted by two active volcanos: Mt. Etna (about 170 km SSW from Lamezia) and Mt. Stromboli (about 85 km NNW).

In the night between 16th and 17th November 2013, a paroxystic eruption occurred at Mt. Etna, accompanied by a huge pyroclastic column extending several kilometres up into the atmosphere.

The amount of daily PM_{10} (i.e., the mass of particulate matter with Dp < 10 μm) recorded at Lamezia Terme since 1st August 2013, was usually much lower than 50 μg m^{-3} , i.e. the daily average concentration indicted by UE air quality legislation as daily limit value. However, in concomitance with some special events, higher PM_{10} values can be observed.

In this work, we present and discuss a high PM_{10} event which occurred at Lamezia Terme on 19th November 2013. A multidisciplinary study, including in-situ and satellite observations and analysis of atmospheric circulation, lead to the conclusion that the occurrence of this event can be likely tagged to the eruption occurred at Mt. Etna two days before.

2.Experimental set-up

The CNR-ISAC Climatic Observatory of Lamezia Terme is located in the Calabria region, a mountainous peninsula located at the southern tip of Italy, about 50 km wide and 300 km elongated in the N-S direction within the central Mediterranean basin (Fig. 1).

Fig. 1. Geographical location of Lamezia Terme and Mt. Etna (courtesy by Google Map).

The measurement site is located in a flat area at about 500 m from the coastline at the west end of the only existing sea-to-sea valley connecting the Tyrrhenian and the Ionian Seas (the so-called Marcellinara gap). As reported by Federico et al. (2010), the coastal flow regime is characterised by synoptic and sea-breeze winds coming from the same direction i.e. West. Moreover, sea breeze (from W to E) and land breeze (from E to W) might act in phase with upslope and down-slope winds, thus reinforcing the local breeze system.

At the measurement site, PM_{10} and $PM_{2.5}$ mass concentration measurements are performed by β–ray attenuation method using a low volume (2.3 m^3/h) FAI SWAM 5a-Dual Channel Monitor, while aerosol size distribution for $0.28 < Dp < 10$ µm is determined by an Optical Particle Counter (FAI Multichannel Monitor). A Wind-LIDAR Zephir©, continuously provide the vertical wind velocity and direction up to 300 m over the measurement site. All these measurements are available in near-real time on I-AMICA web site (http://www.i-amica.it/i-amica/?page_id=1122).

PM_{10} filters sampled in the period 18th – 20th November 2013, were analysed by using the Scanning Electron Microscope (SEM) at the DiBEST-University of Calabria. The instrument is a Philips Quanta 200 FEI; all the observation were carried out in backscattered electrons (BSE) without previous coating. Qualitative compositional analyses were also performed on single fragments in order to identify the different compositional classes of particulate. For this purpose we used an energy dispersion System (EDAX, Genesis 4000).

3. In-situ observations

On 19th November 2013, a remarkable peak in PM_{10} concentration (71.6 µg m^{-3}) was observed at Lamezia Terme, corresponding to an increase of factor 10 in respect to the atypical PM_{10} levels observed at this measurement site. This event represents the only exceedance of the UE air-quality daily limit value observed during the period August – December 2013.

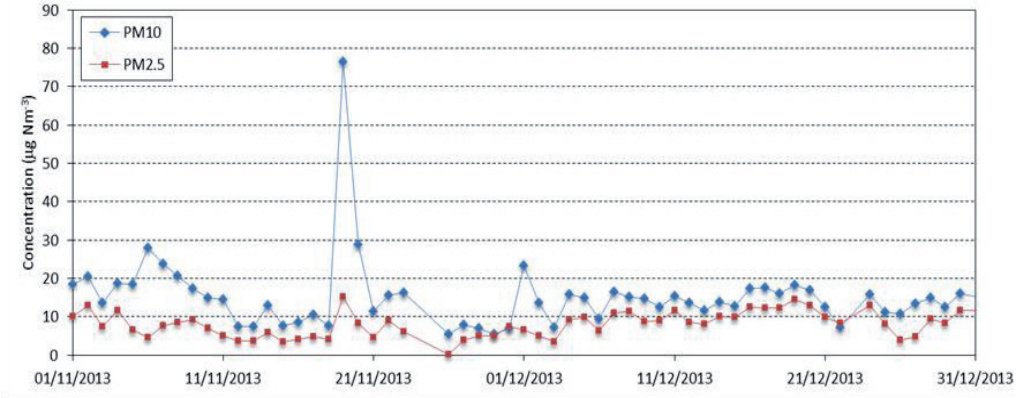

Fig. 2. Daily PM10 (blue) and PM2.5 (red) concentrations (µg m^{-3}) at Lamezia Terme from 1st November to 31st December 2013.

As reported by Fig. 3, for this day, the particle size distribution detected by the OPC revealed a sudden increase of the particle concentration around 11:00 (UTC+1), especially

for the coarse fraction (i.e., aerosol with Dp> 1 μm). Simultaneously, the local wind circulation detected by Wind Lidar showed a change in direction and speed (Fig. 3): the wind direction suddenly changes from NE to SW for the lowest 300 m; at the same time the speed suddenly decreases (here not reported). During the 19th November in the afternoon (around 17:00), a easterly flow was observed for the lowest 100 m. This wind behavior was also observed the day after (20th November 2013), thus testifying that the local circulation is affected by the breeze system, which interacted with the synoptic circulation (Federico et al., 2010). The comparison between the local circulation variability with the spectrum of the particle size distribution (Fig. 3) indicated that the largest increase of coarse aerosol particle occurred in concomitance with wind from SW, even if a significant amount of coarse aerosol particle was present until 20th November at 00:00 (under NE circulation at the surface).

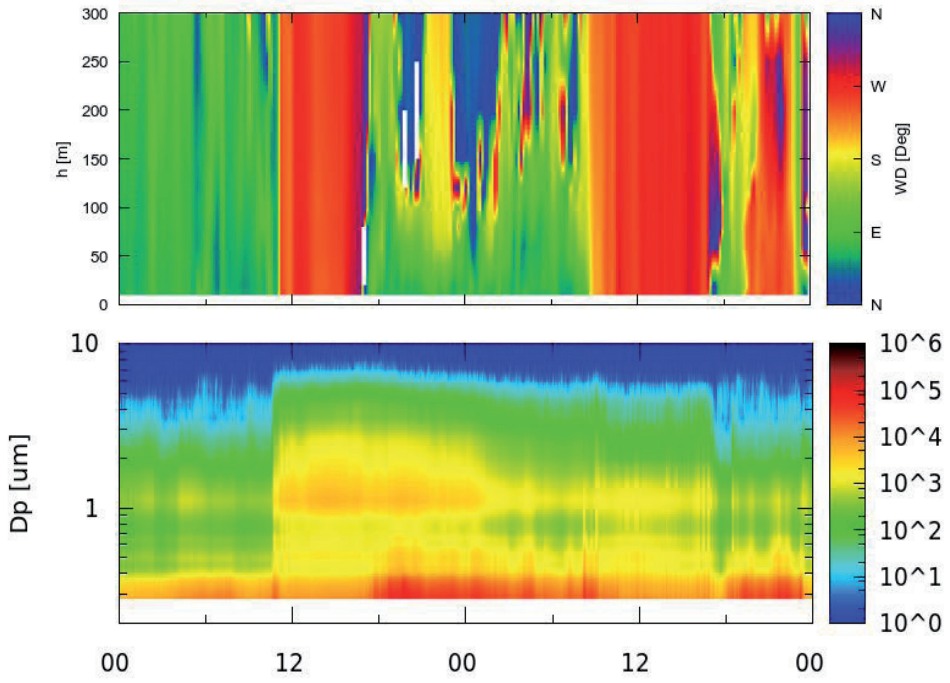

Fig. 3. Upper plot: time series (since 19th November 2013 at 00:00 until 21st November 2013 at 00:00) of vertical wind direction (see the colored scale) Bottom plot: time series (since 19th November 2013 at 00:00 until 21st November 2013 at 00:00) of aerosol particle concentrations (see the colored scale, expressed as # lt^{-1}). X-axis reports local time (hours).

The analysis of PM_{10} filters by SEM pointed out that, on 19th November 2013, the sampled filter was much richer in aerosol particles than the previous day. On 20th November 2013, the PM_{10} filter was also rich in particles, but much less than the previous day (see Fig. 4). Qualitative analysis of aerosol particles collected on 19th November 2013, allowed to identify fragments of different nature. A first class is represented by fragments with silicatic composition and irregular shape (Fig 5a), even if aggregates of different minerals and glass are also present (Fig.5b). Halite (probably due to sea-spray), lime and organic particles (mainly pollen grains), were also present. However, the most abundant population of

fragments is represented by gypsum and other sulphur mineral (Fig. 5c) suggesting that the volcanic ash could significantly affect the aerosol at Lamezia Terme.

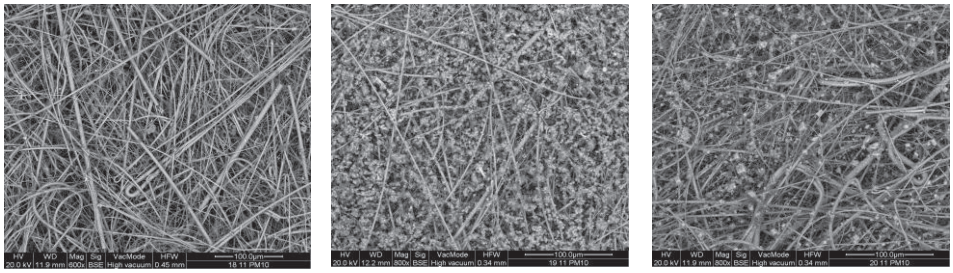

Fig. 4. SEM analyses on PM_{10} filters on 18th (left), 19th (centre) and 20th (right) November 2013.

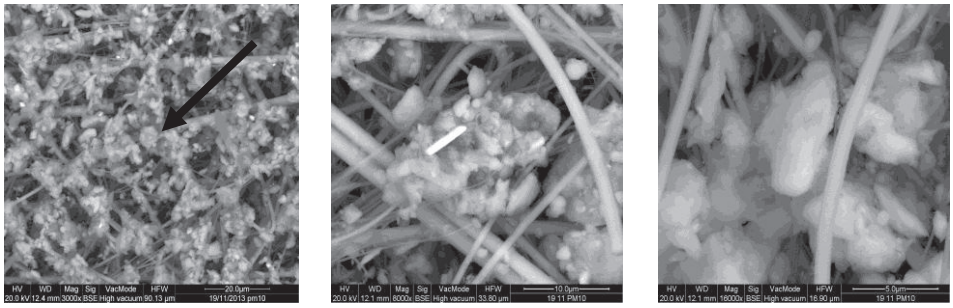

Fig. 5. Different particles recognised by SEM analysis on the PM_{10} filter sampled during 19th November 2013: silicatic particle (left), aggregate of glass and minerals(centre), sulphate mineral (right).

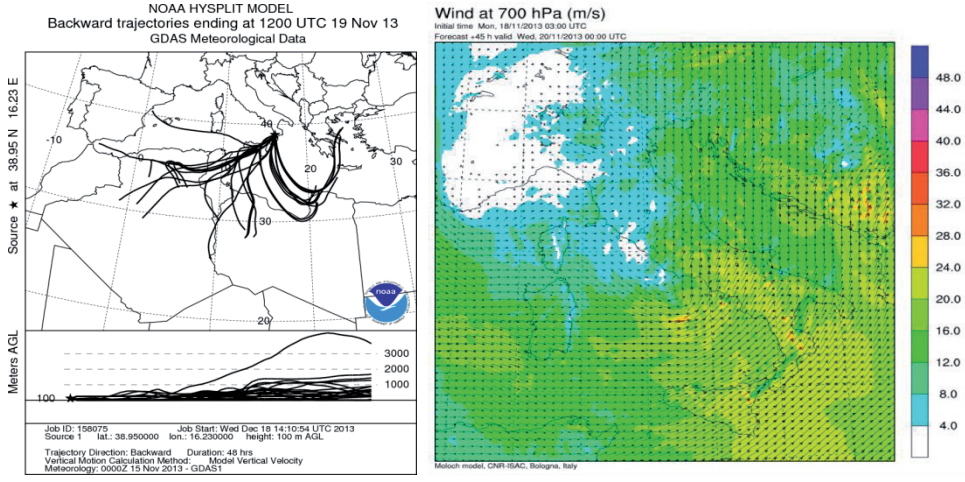

Fig. 6. Ensemble of 5-day backward trajectories ending at Lamezia Terme (left) on 19th November 2013 (left), wind direction at 700 hPa as computed by the deterministic modelling system MOLOCH for November 18th 2013 (right).

4. Atmospheric circulation analysis

In order to determine the synoptic origin of air-masses reaching the measurement site, 5-day back-trajectory ensembles were calculated with the HYSPLIT model (Draxler and Hess, 1998). The model calculations were based on the GDAS meteorological field produced by NCEP with a horizontal resolution of 1° x 1°. Even considering the spatial spread of the ensemble members moving backward in time, these analyses (Fig. 6, left), supported the occurrence of atmospheric circulation able to favour the north-easterly advection of the eruption plume. Basing on these elaborations, an emission age of about 1-2 days can be estimated for the volcanic plume at Lamezia Terme. To further corroborate the hypothesis that the plume of volcanic ash emitted during the eruption of November 16th – 17th could affect Lamezia Terme, data generated by deterministic modeling system MOLOCH (http://www.isac.cnr.it/dinamica/projects/forecasts/moloch/) were used (Fig. 6, right): a cyclonic circulation influenced the Southern Italy, favoring the spreading of air masses from Sicily towards Calabria regions.

Finally, the SO_2 vertical column amount based on NASA OMI satellite observation (here not shown), showed high values above Mt. Etna on 17th November, clearly related to the volcanic eruption. On 19th November the SO_2 plume, even if diluted, was located exactly above the Calabria Tyrrhenian coast, thus confirming the arrival of the volcanic plume over the measurement site.

5. Closing remarks

In this work, we investigated the impact of a volcanic ash plume on the surface PM_{10} variability observed on November 2013 at Lamezia Terme, a coastal site in the Calabria region. Continuous atmospheric observations were carried out in the framework of the I-AMICA Project. A case study of high PM_{10} observed on 19th November 2013 was extensively investigated by using in-situ measurement (i.e. aerosol size distribution, mass concentration and wind profile), qualitative analysis through SEM-EDX, modelled meteorological parameters and satellite observations of SO_2 column. The location of the I-AMICA Observatory at Lamezia Terme, strategically located in the southern tips of the Italian peninsula, appears to allows to monitor all this events at short term observation and to collect long term observation for climate change causes.

6. Acknowledgements

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