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The atmospheric impact of volcanic activities in the Mediterranean Sea investigated during a measurements cruise campaign

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Abstract

The Mediterranean Sea is a geologically young area with structures tectonically active, where the emissions from numerous volcanic activities are influencing the ecosystem. Moreover, the volcanic ashes and the gases emissions are troubling also for the human health, causing injuries and even deaths when the eruption are meaningful. The goal of the measurements cruise campaign "Minerva 2017"was to investigate in a unique expedition the natural influence of several active volcanoes located widespread over the Mediterranean basin. The route of the campaign, which was performed aboard the Research Vessel "Minerva Uno" during summer 2017 (18th of August - 7th of September), included some marine sampling stations near to volcanoes, as well as, the Mount Etna (Sicily, South Italy), Stromboli and Vulcano belonging to the volcanic archipelago of the Aeolian Islands (Italy), and near to the Solfataras of the Phlegraean Fields (near to Naples, Italy). The volcanic ashes were part of the Particulate Matter (PM), indeed during violent eruptions occurred very large concentrations of it. To investigate the impact of volcanoes on the particulate, during the campaign, the PM was sampled as Total Particulate Matter (TPM) and into two different size fractions, $PM_{2.5}$ and PM_{10}, collecting them on quartz filters through the Echo PM - Instruments (Tecora). The mean values recorded for $PM_{2.5}$, PM_{10}, and TPM, were 11.4 ± 3.1 μg m^{-3}, 17.5 ± 5.1 μg m^{-3}, 21.6 ± 5.7 μg m^{-3}, respectively. Moreover, the measurements of radioactivity were performed by the SM200 AB (OPSIS) which, by the beta mass technique, provided the information about the beta-emitter radon

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daughters. The radon, a natural gas released by the crustal surface and magmas, has been considered as a geochemical tracer indicating that the sources of the monitored air masses were coming from the volcano and/or from the land. This cruise campaign has been also useful to perform preliminary studies on the possibility to include radon measurements in our research program and evaluate its concentration of activity, of as a function of various marine, geological and environmental parameters in both our samples of air and marine water. Furthermore, to better establish the volcanic source, the behavior of chemical gases (O_3, NO_x, and SO_2) and meteorological parameters had been jointly discussed, highlighting the SO_2 which, among the others, represents a marker for volcanoes. In this way, the volcanic influence was identified for 4 sites: Phlegraean Fields, Stromboli, Panarea, and Vulcano.

Keywords: Volcanoes, Particulate Matter, Radioactivity, SO2

1. Introduction

The Mediterranean basin is characterized by a significant number of active volcanoes, mainly in the Italian territory. Many volcanoes are present on both Italian peninsula and isles. The volcanic emissions, especially at high levels, can cause several damages on both environment and human health (Eisele et al.,1981; Malandrino et al., 2013). Therefore, in the last years, the volcanic emissions had been aim of studies by the scientific community to understand their chemical composition as well as, their impact on the air quality and the ecosystem.

With regard to air quality, among others gases, the particulate matter is one of the troubling pollutant that is being monitored. The particulate matter (PM) consist of particles with different size of their aerodynamic diameter. However, the $PM_{2.5}$ and PM_{10}, dimension of the of the particles with a diameter smaller than 2.5 μm and 10 μm, respectively, are the main two groups on which the samplings in ambient air have been focused in the last decades (Querol et al., 2004, Bencardino et al., 2014, Bove et al., 2016). PM sources are diverse and could be of natural origin (beyond the volcanic ashes, also the biomass burning, the Saharan dust, and sea spray), as well as of anthropogenic origin (industries, vehicular or ship traffic). While the natural PM produces mainly the larger particles, the anthropogenic PM prevalently contributes in emissions of finer particles.

The aim of this study was to identify the volcanic influence, hence, the PM of the volcanic origin thanks to the auxiliary parameters like SO_2, and Rn, that are considered as markers of volcanoes, and the wind coordinates, especially the wind direction. Rn is a geochemical tracer of volcanic emissions; indeed the higher Rn concentration precedes volcanic emission (Cigolini et al., 2005; Burtun et al., 2004). Moreover, due its release by the rocks and soils, it could be considered as a land air marker. We used the SO_2 as a further volcanic tracer (Edner et al., 1994), while the presence of NO_x allowed to exclude natural events.

Furthermore, we investigated over the Rn sampling methods in air and in water, obtaining preliminary results which, will aid to establish the best method to measure Rn in this context.

1.1 Description of the campaign

The “Minerva 2017” cruise campaign had been planned to investigate the volcanic activities present in the Western Mediterranean Sea. The campaign was performed aboard

the research vessel Minerva UNO, and started from the Brindisi harbour (Apulia, Italy) on the 18th of August and docked in the Messina harbour (Sicily, Italy) on the 7th of September. The route explored areas near the volcano Etna, the Aeolian Islands (Stromboli, Vulcano, Panarea), and the Solfataras of the Phlegraean Fields (near to Naples, Italy). The route is reported in the Fig.1.

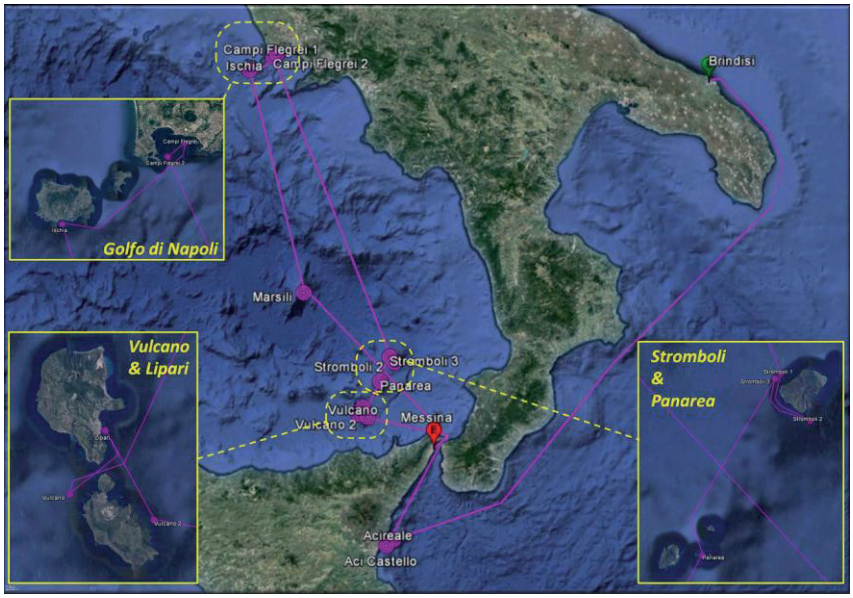

Fig. 1. Route of the cruise campaign "Minerva 2017"

2. Methods

Total Particulate Matter (TPM), $PM_{2.5}$, and PM_{10}, had been collected on quartz filters through the Tecora Echo PM - Instruments. The filters had been conditioned at 50% RH and 25 °C for 24 hours before and after sampling, hence the gravimetric mass was calculated.

The Analyzer API 200AU and the API 100E monitored respectively NO_x and SO_2 with a temporal resolution of 1 minute.

On the other hand, the SM200 AB (OPSIS) measured the radioactivity through beta emitter daughters of radon every hour. Moreover, the Pylon Model AB5 Radon Monitor coupled to the Lucas scintillation cells measured the radon in air and in water. The samples of water were collected avoiding the bubbling, at different depth thanks to the "Rosette Multisampler". We chose to analyze the water at the surface (about 2 m) and at the bottom (depending on the site). The measurements of the water samples had been performed after 10 minutes of degassing.

Meteorological parameters were recorded through the meteorological station of Research Vessel using 1 minute of time resolution.

The data analysis was performed through the Software R (version 3.4.1), in particular using the package "openair" (version 2.1-5).

3. Results

The Table 1 shows the sites of the route with the corresponding acronyms used in this work, Start and End Time, and the geographical coordinates (latitude and longitude). To identify the peaks for each parameter, in Fig. 2 is reported the time variability of the normalized values of TPM, PM_{10}, $PM_{2.5}$, SO_2, NO_2, NO, and radioactivity. The mean values recorded for $PM_{2.5}$, PM_{10}, and TPM, were respectively 11.4±3.1 μg m^{-3}, 17.5±5.1 μg m^{-3}, 21.6±5.7 μg m^{-3} that were compatible with the past measurements recorded over the Mediterranean Sea (Bencardino et al., 2014). The maximum of $PM_{2.5}$, PM_{10}, and TPM were recorded in the Vulcano site (Vul 1), about 18 μg m^{-3}, 23 μg m^{-3}, 28 μg m^{-3} respectively (Fig. 2). These PM peaks corresponded to the greatest peaks of SO_2 and to the low values of NO_x, suggesting a contribution of volcanic emissions. Furthermore, other minor SO_2 peaks with possible volcanic influence were evident in the following stations: Campi Flegrei (Fleg 1), Stromboli (Str 2 and Str 3), and Panarea (Pan) (Fig. 2). In these sites, the $PM_{2.5}$, PM_{10}, and TPM values were moderately high.

Fig. 3 shows, as an example, the plots of the SO_2 peaks for two of the five stations, Vulcano 1 and Campi Flegrei 1, highlighting the wind direction by colour (see lateral legend), and joining the spatial information by the route picture (Fig. 1) had been possible to confirm that the origin of air mass recorded was linked to volcanic activity .

Additionally, the higher values of Radioactivity showed that the air mass was coming from the land where the volcanoes are located.

The Rn concentration in air ranged from about 1 Bq m^{-3} to 7kBq m^{-3}, while the Rn concentration in water ranged from about 16 Bq m^{-3} to 640 Bq m^{-3}. The higher values of Rn in water were recorded in the bubbles of Panarea and Vulcano.

Table 1. Sites of the performed route with corresponding acronyms, start and end time, and geographical coordinates (Latitude and Longitude)

Site	*Acronym*	*Start Day*	*Start Time*	*End Day*	*End Time*	*Latitude (N)*	*Longitude (E)*
Acireale	Acir	20/08/2017	19:55	21/08/2017	19:26	37°35'01.74"	15°14'24.75"
Aci Castello	Acic	21/08/2017	21:20	22/08/2017	20:34	37°32'35.44"	15°10'48.53"
Marsili	Mars	23/08/2017	11:21	24/08/2017	10:35	39°12'55.72"	14°26'06.25"
Ischia	Isc	24/08/2017	18:50	25/08/2017	17:36	40°41'38.78"	13°54'10.51"
Campi Flegrei 1	Fleg 1	25/08/2017	23:00	26/08/2017	21:19	40°48'28.88"	14°08'18.06"
Campi Flegrei 2	Fleg 2	26/08/2017	21:40	27/08/2017	22:10	40°47'19.18"	14°06'18.11"
Stromboli 1	Str 1	28/08/2017	17:05	29/08/2017	16:51	38°48'24.90"	15°11'18.82"
Stromboli 2	Str 2	29/08/2017	18:15	30/08/2017	17:07	38°38'18.82"	15°06'15.72"
Stromboli 3	Str 3	30/08/2017	18:24	31/08/2017	17:00	38°48'7.17"	15°10'54.85"
Panarea	Pan	31/08/2017	18:20	09/01/2017	18:16	38°38'16.66"	15°06'17.81"
Vulcano 1	Vul 1	09/01/2017	23:50	09/02/2017	19:10	38°25'05.13"	14°55'38.39"
Lipari	Lip	09/02/2017	20:00	09/03/2017	19:56	38°27'47.03"	14°57'39.27"
Vulcano 2	Vul 2	09/04/2017	09:30	09/05/2017	14:05	38°23'53.45"	15°00'12.77"

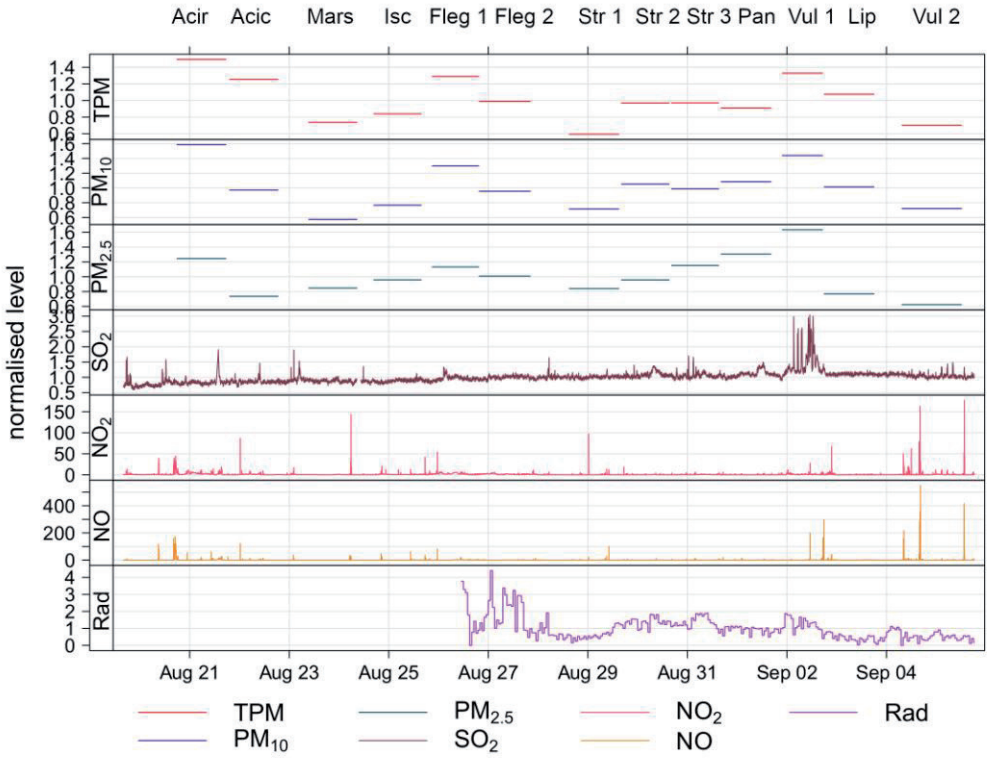

Fig. 2. Temporal trend of normalized TPM, PM_{10}, $PM_{2.5}$, SO_2, NO_2, NO, and radioactivity recorded during the cruise campaign

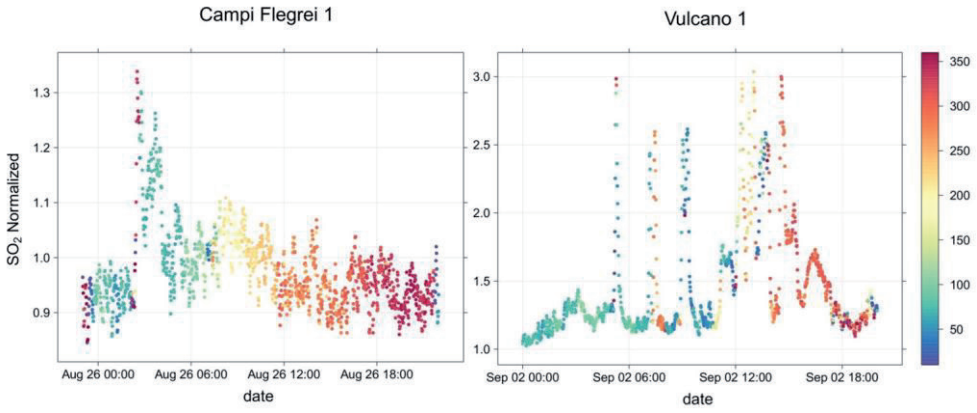

Fig. 3. Temporal trend of SO_2 normalized concentrations recorded during the stations: Fleg1, and Vul1, with the wind direction in degree are indicated by the colour (see lateral legend)

4. Conclusions

This campaign aimed the investigation of active volcanoes in the Mediterranean basin, like the Etna, the Phlegraean Fields, and the Aeolian Islands. The volcanic ashes released during the eruption or degassing were recorded as PM in the three size ($PM_{2.5}$, PM_{10}, and TPM). Through the evaluating of ancillary parameters, as SO_2, Radioactivity, and NO_x, had been possible to deduce the volcanic source. We highlighted some evidences of its possible influence in 4 sites: Phlegraean Fields, Stromboli, Panarea, and Vulcano (referred as Fleg1, Str2, Str3, Pan, and Vul1). Further confirmation would be obtained by the chemical elements of ICP-MS analysis of the particulate filters. Indeed, we attend a higher contribution of the chemical element considered marker of volcanoes. Furthermore, other measurements on field near volcanoes could quantify their direct emissions.

5. Acknowledgements

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