A field survey in Potenza (southern Italy) for developing and testing an innovative strategy of air pollution control on a local scale

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Abstract

Climate change and air pollution, both on a global and local scale, are two interrelated environmental policy problems, but usually they are studied separately with very different approaches. In a novel context, in which climate change and air quality become two related aspects of the same problem, we believe that it is necessary to carry out novel local strategies for Air Quality Monitoring Networks' (AQMNs) innovation, not only applying analytical optimization procedures of the existing networks, but also introducing advanced in situ devices and using data by remote investigations. Advanced instrumentation allows to evaluate the concentration of specific pollutants and to better characterize the local weather conditions. Remote observations (satellite data and vertical profiles of atmospheric variables) may improve the network effectiveness. In this study we present experimental data observed in the urban area of Potenza (Basilicata, southern Italy) during a field survey. In the same sampling period, we compare data atmospheric pollutants concentrations by AQM network of Potenza with data collected in our experimental site and with a satellite map of CO_2. Despite the observation scales being very different, the results are encouraging and we believe that other efforts have to be made; the short-term benefits obtaining from air pollution control and innovation may be as effective as the long-term benefits obtainable through strategic climate change measures. So it is important to develop and to support local integrated strategies, for mitigating air pollution and climate change contemporaneously.
Keywords: air pollution, AQMN, climate change, in situ data acquisition, remote sensing data.

1 Introduction

Climate change and air pollution are two interrelated environmental policy problems [1–6], but usually they are studied separately with very different approaches. Air quality is considered as a local environmental problem. Municipalities are devoted to control levels of atmospheric pollutants, applying national normative with the support of specific local authorities. The monitoring program is based on in situ devices organized in regional networks (Air Quality Monitoring Network AQMN). Sampling sites involves urban areas, industrial sites and background sites. Different atmospheric pollutants (NO_x, O_3, CO, PM) show different standard levels and the exceedance of these standards determines alarm conditions for the public health. Particularly the two air pollutants of most concern for public health are O_3 and PM. Only in recent years, in order to improve the forecasting methods and to better understand the emissions patterns of atmospheric pollution, also data coming from remote observations are taken into account [7, 8].

Contemporaneously many studies are devoted to climate changes and to their effects on ecosystems at different spatial scales. Many reviews are recently published in different contexts [9, 10].

In our opinion specific relevance has to be recognized to studies concerning novel combined strategies for climate change and air quality. In fact significant synergies and co-benefits are possible through a concerted consideration of air quality and climate change policies. Cost-benefit approach was applied for examining jointly air quality management plan and greenhouse gas reduction strategies. For example, in Seoul [11], the correlation of cost-effectiveness analysis indicated that fuel switching and CNG bus operation are the most cost effective option to reduce NO_x, PM_{10} and CO_2 emissions at the same time. Based on cost effectiveness and co-benefit analysis, this study developed an alternative scenario of emission reduction measures through optimization in order to achieve both air quality improvements and CO_2 reduction targets at the minimum cost. A different study puts in evidence that synergies and trade-off between climate change and air pollution may to be related with choice of the fuel and the energy conversion process. CO_2 emission reduction in the power and heat sector may influence the emission of SO_2, NO_x, PM, VOC and NH_3 [12].

In this novel context, in which climate change and air quality become two related aspects of the same problem, the climate characterization at local scale takes on a fundamental role. Climate change may deeply impact air quality levels because the changes in the meteorological conditions will induce changes on the transport, dispersion and transformation of air pollutants. In a modelling approach a global-regional climate-air pollution modelling system (GRE-CAPS) has been developed, coupling an existing general circulation model/chemical transport model (GCM/CTM), a regional meteorological model, and a regional chemical transport model [3]. In all cases, at local scale, it is important to take into account that changes in climate affect air quality by varying ventilation rates (wind speed, mixing depth, convection, frontal passages), precipitation scavenging, dry deposition, chemical production and loss rates, natural emissions, and background concentrations. In fact the potential importance of this effect may be appreciated by considering the observed inter-annual variability in air quality.

In this study, experimental data observed in the urban area of Potenza (Basilicata, southern Italy) during a field survey is presented. In the same sampling period data atmospheric pollutants concentrations by AQM network of Potenza with data collected in our experimental site (CO_2 concentration and H_2O content at soil level, horizontal profiles of gaseous species) and with a satellite map of CO_2 are compared.

2 Methods and data

For this experimental filed survey in situ observations (measures of CO_2 and H_2O and horizontal profiles of gaseous species), remote observations (CO_2 satellite map) and measures of atmospheric pollutants concentrations by an AQM network were collected and compared. In the following paragraphs the experimental test site is shortly described and collected data shown.

2.1 Experimental equipment

2.1.1 CO_2 and H_2O spectroscopic measures

CO_2 and H_2O in situ measures were carried out by means of an IMA-3000B analyzer system. The gas analyzer system is composed of: an infrared ray-light source, a multi-step cell, a detector, electronics for control and data storage. An infrared ray light is sent through a chopper modulator at 900 Hz to multi-step cell. The infrared light is detected with a Pb-Se sensor on the opposite side. A processor digitalizes the signal, stores and processes the data, after the signal is amplified. The instrument works in absorption selecting particular light wavelengths depending on the gas. The relation between absorbed light and gas concentration follows the Lambert-Beer law. In this field survey, the analyzer was positioned at soil level, in the parking area of the campus. CO_2 and water vapour were measured at intervals of 5 s during the day, with an accuracy of 2%.

2.1.2 Horizontal profiles of gaseous species by a DOAS system

Horizontal profiles of atmospheric gaseous pollutants were obtained with a Differential Optic Absorption Spectrometry (DOAS). It operates using the integration of Lambert-Beer law. The amount of absorbed light is related to the number of gas molecules in the ray path. The system is composed of two parts, emitter station and reflector mirror; a computer manages the system and calculates the concentrations in various wavelengths for the different gases. During the field survey the instrument worked in active configuration, deriving the gas density on a horizontal optical path of 200 m; it was positioned to 20 m from the ground level on the roof of a campus building; the sampling time was fixed at 3 minutes. Profiles of NO_2 N_2O O_3 SO_2 C_6H_5-CH_3 and CH_2O were acquired.

2.2 Data by Potenza Air Quality Monitoring Network

AQM network in Potenza city is run by ARPAB (Basilicata Environmental Regional Agency) that manages 15 stations located throughout the entire Basilicata region. Only the four monitoring stations located in the Potenza urban area (PZ1 – Contrada Rossellino, PZ2 – Viale Firenze, PZ3 – Viale dell' UNICEF, PZ4 – Via S. Luca Branca) were selected. Particularly PZ1 and P4 are located in sub-urban and in residential areas, on the contrary PZ2 and PZ3 are located in areas with high volume of traffic. For this study, hourly concentration data of CO in all the four stations; NO_2, SO_2, and O_3, in PZ1 and PZ4; $C_6H_5CH_3$ and C_6H_6 in PZ3 and PZ4 at the regional database were extracted for 25 November 2009.

2.3 CO_2 map by satellite data

AIRS sensor acquired CO_2 data from the satellite platform Acqua. AIRS measures diurnal and nocturnal distributions of CO_2 (ppmv) in atmospheric region (3–13 km), with a resolution of 90x90 km at nadir. In this paper we present the AIRS-CO_2 map for the Mediterranean basin, on 25 November 2009.

3 Results

Temporal trend (sampling period 10:00 am – 16:00 pm, $\Delta t = 5$ s) of CO_2 and H_2O concentrations are shown in figure 1: for CO_2 the mean value (with standard deviation) is 121 ± 6 mg/m^3, (CV% = 5%), for H_2O is 7327 ± 262 mg/m^3, (CV% = 3.6%). In figure 1 we may note that CO_2 and H_2O show a marked opposite behaviour. In the first part of the observation period, H_2O is low and CO_2 is high, but in the following hours their behaviour is reversed.

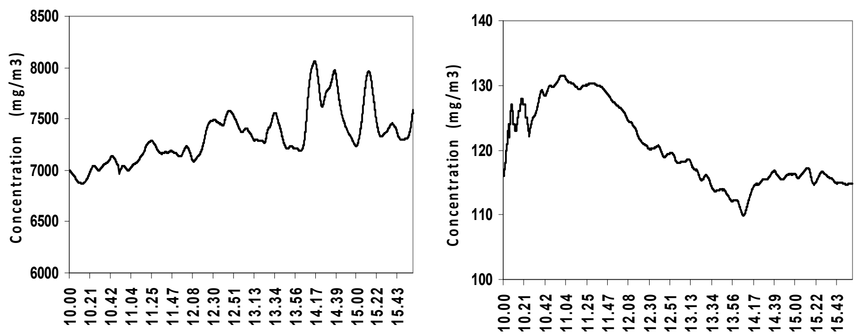

Figure 1: Temporal trends of H_2O (left), and CO_2 (right) concentrations (sampling period 10:00– 16:00 hrs).

In the investigated period, differences in external factors are evident both for the traffic volume and for the meteorological conditions. During the period 10:00–12:00 hrs, the traffic volume is high and CO_2 show values above the average; in the following hours the traffic decreases and also CO_2 decreases. Instead the vapour content seems to follow the behaviour of solar radiance and the observed values of H_2O are higher after 12:00.

DOAS data for NO_2, N_2O, O_3, SO_2,C_6H_5-CH_3 and CH_2O (sampling period 10:00–17:00 hrs, Δt = 180 s) are shown in figure 2. For simplifying the DOAS data discussion, hourly mean values are summarized in table 1.

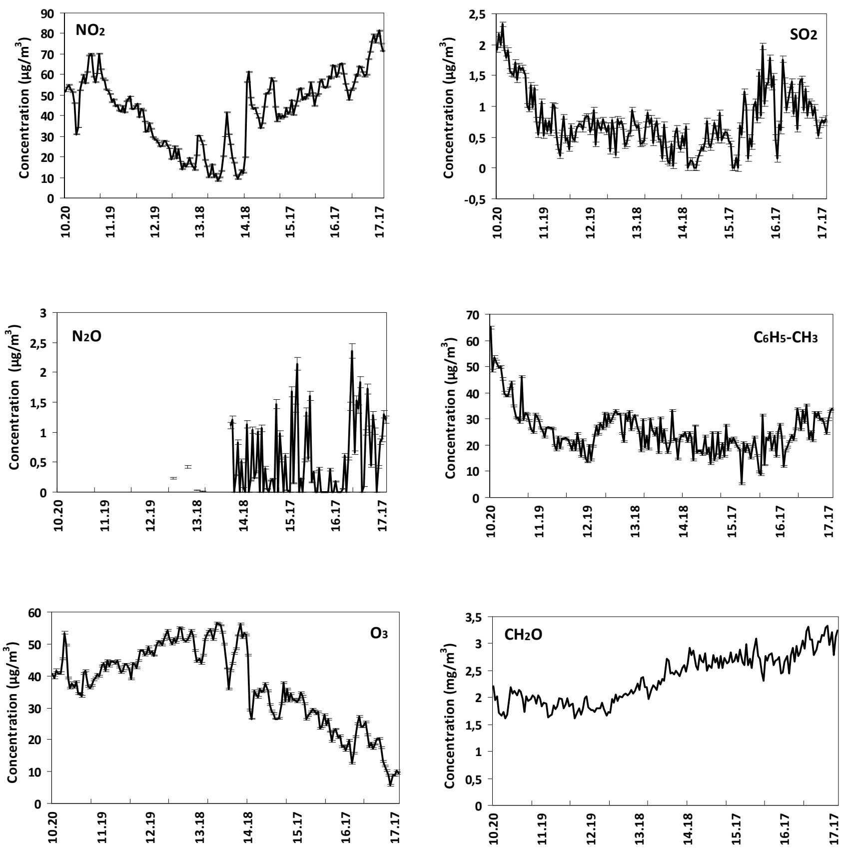

Figure 2: Temporal trend of the concentration of pollutants observed by DOAS system in Potenza campus (sampling period 10:00–17:00 hrs).

In figures 3–5 hourly concentrations of the compounds monitored by Potenza AQM network for 25 November 2009 are shown.

Comparing AQMN and DOAS data (NO_2(DOAS) = 42.3 µg/m^3 and NO_2(AQMN) = 27.1 µg/m^3; O_3(DOAS) = 36.9 µg/m^3 and O_3(AQMN) = 52.7 µg/m^3; SO_2(DOAS) = 0.8 µg/m^3 and SO_2(AQMN) = 5.7 µg/m^3; $C_6H_5CH_3$(DOAS) = 25.4 µg/m^3 and $C_6H_5CH_3$(AQMN) = 6.6 µg/m^3) we may

Table 1: Hourly mean values (with standard deviation) of DOAS data.

	NO_2	N_2O	SO_2	O_3	CH_2O	$C_6H_5CH_3$
	μg/m³	*μg/m³*	*μg/m³*	*μg/m³*	*mg/m³*	*μg/m³*
10:00–11:00	56±9		1.4±0.5	40±4	1.9±0.2	39±10
11:00–12:00	41±6		0.6±0.2	44±2	1.8±0.1	22±4
12:00–13:00	22±5	0.1±0.2	0.6±0.2	51±3	1.9±0.2	28±5
13:00–14:00	18±8	0.5±0.5	0.5±0.2	50±5	2.4±0.2	23±5
14:00–15:00	45±7	0.4±0.5	0.4±0.2	32±3	2.7±0.1	20±4
15:00–16:00	52±6	0.4±0.6	0.8±0.6	25±5	2.7±0.2	19±6
16:00–17:00	64±9	0.8±0.7	1.0±0.3	17±6	3.0±0.2	27±6

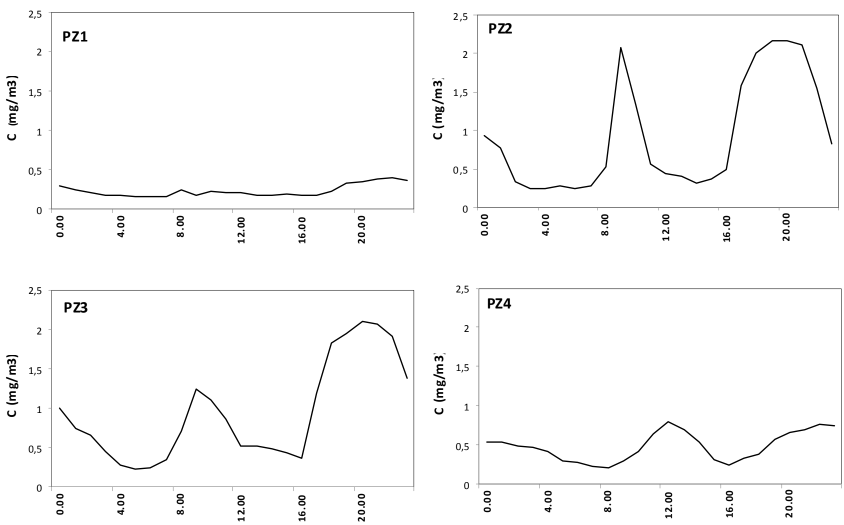

Figure 3: CO concentrations in four monitoring sites (sampling period 00:00–23:00 hrs).

note that DOAS and AQMN concentrations are very different. The specific characteristics of each sampling site and the specific physical-chemical properties of each pollutant introduce unavoidable variations for evaluating quantitatively the air quality.

More interesting is the comparison among the temporal patterns: there seems to be a delay between the two systems. For ozone, DOAS system keeps track of the maximum values about 2 hours before the ground system. DOAS system, operating at altitudes where the air is well mixed, gives data that best represent the average trend of a pollutant in a specific area.

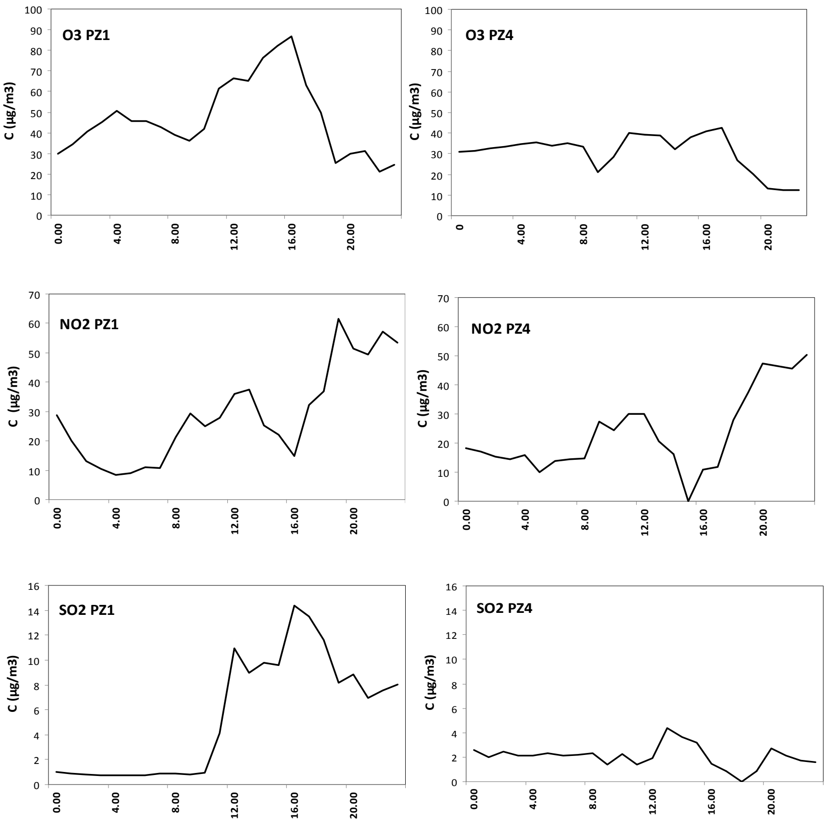

Figure 4: O_3, NO_2 and SO_2 concentrations in two monitoring sites of Potenza AQMN (sampling period 00:00–23:00 hrs).

Finally, for in situ AQMN data, we would note that there are significant statistical correlations among data measured in different monitoring stations [13]. For example, in the data shown in this study, it is evident that CO levels show significant correlations between PZ1/PZ4 sites and PZ2/PZ3 sites.

In the last step, we obtain a satellite map of CO_2 for 25 November 2009 (Figure 6), processing HDF data made available by JPL-NASA. The values of CO_2 over the Mediterranean basin and over the island regions are between 385–395 ppm with an increase from southern regions to northern regions; there are some areas (Aegean Sea, Balearic Islands, Istanbul area and Adana region in Turkey) with levels of CO_2 higher than 400 ppm. A level of 395 ppm compares to southern Italy.

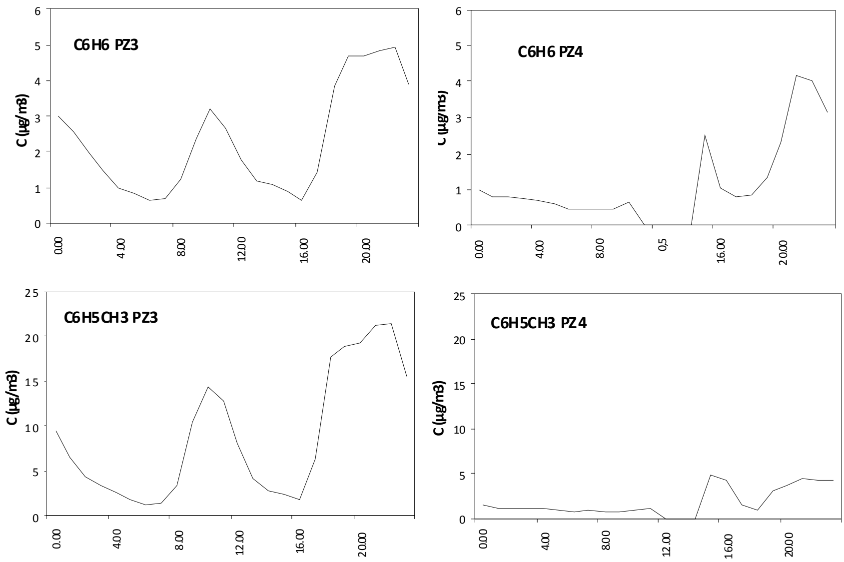

Figure 5: Benzene and toluene concentrations in two monitoring sites of Potenza AQMN (sampling period 00:00–23:00 hrs).

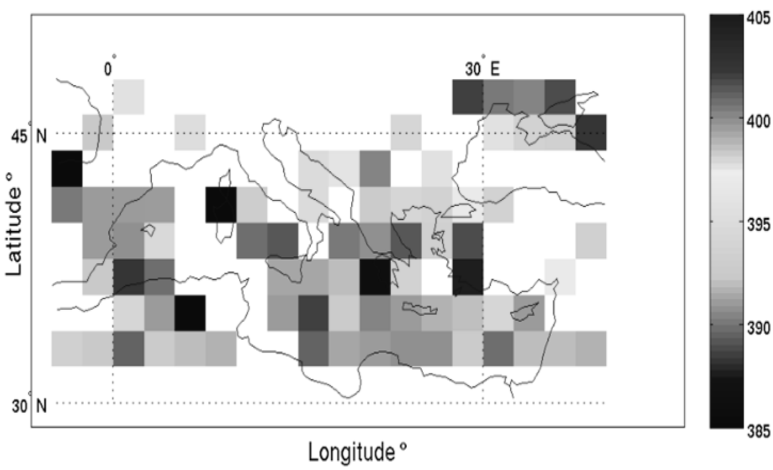

Figure 6: CO_2 map by AIRS data (25 November 2009).

4 Discussion and final remarks

The data shown in this study represent a limited test case in which data in situ and data obtained by remote sensing are compared. Particularly, the current observations of air pollution carried out in AQMN with data collected with different equipments are compared. At the same time, the possibility for measuring other pollutants, as CO_2, that are not closely related to air quality but that may give indications about local climatic changes are explored.

From data collected in this field survey, we may highlight the following observations maybe made. Spectrometer in situ data may give useful information about not only specific sources but also the influence of meteorological parameters. Similarly, DOAS data, although they cannot replace the measures of air pollutants concentrations, may give interesting data on their temporal behavior. Furthermore, in many cases, the analysis of data collected in AQMN put in evidence the presence of significant correlation, suggesting that it is possible to rationalize and optimize the number of devices and their locations.

In conclusion, it is possible to carry out local strategies for AQMNs' innovation, not only applying analytical optimization procedures of the existing networks, but also introducing advanced in situ devices and using data obtained by remote investigations. Advanced instrumentation allows to evaluate the concentration of other pollutants (CO_2 or organic compounds) and to better characterize the local weather conditions. Remote observations (satellite data and profiles of atmospheric variables) may improve the network effectiveness. In this way it is possible also to improve the availability of data on local climatic changes and on the effects, at the local scale, of climate change strategies.

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