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$PM_{2.5}$ DISPERSION IN VENICE AREA: A MODEL VALIDATION

Eliana Pecorari[1], Stefania Squizzato[1], Mauro Masiol[1], Flavia Visin[1], Giancarlo Rampazzo[1] and Bruno Pavoni[1]

[1]Department of Environmental Science, Informatics and Statistics, University Ca' Foscari Venice, Calle Larga Santa Marta 2137, Dorsoduro 30121 Venice, Italy.

A multidisciplinary project was developed with the aim of better understand $PM_{2.5}$ primary sources and secondary aerosol formation and compositions. A model system was used to simulate four periods during different seasons in 2009 for which both organic and inorganic measured data were available. Input data were estimated and formatted as requested by models. Measured and predicted data were compared for the three stations and during different seasons in order to test model performance.

Key words: *mathematical, model, model validation, air pollution, $PM_{2.5}$.*

INTRODUCTION

Several studies have emphasized PM_{10} roles in air pollutionbut not more has been investigated respect to $PM_{2.5}$ role despite the new received European directive (Directive 2008/50/EC). The finest fractions formation and the relations between its behavior respect to the specific local environment is still not clear. An important role is especially assumed by meteorological conditions that strongly affect secondary pollutants formation. This phenomena complexity, that involves both emission and meteorological aspects, become very hard to study with only measurements devices. The use of mathematical models, despite their limitations, enables to estimate regions of different sizes and to provide information when there is a shortage of data in non-controlled areas. In order to best simulate pollutants dispersion, an exhaustive emission dataset is necessary to best describe local situations.Moreover measurements become essential to model validation allowing the comparison between measured and calculated data (Willmot, 1981; Juda, 1986; Weil et al. 1992; Hanna et al. 1993; Kousa et al., 2001; Kauhaniemi et al., 2008; Banerjee, 2011).

A multidisciplinary project was developed with the aim of better understand $PM_{2.5}$ primary sources and secondary aerosol formation and compositions. An air dispersion model system was used to study both primary and secondary fine particles ($PM_{2.5}$) in the Venice area as complementary device to an experimental research carried out between January 2009 and February 2010.

Methodologies

A measurements campaign was carried out From 1^{sh} January 2009 to 31^{st} January 2010. Based on different environmental conditions, three sites of Venice have been selected: a semi rural coastal site, Punta Sabbioni; an urban site, Via Lissa – Mestre, an industrial site, Malcontenta - Porto Marghera (Figure 28).Samples were collected according to EN 14907:2005 using a low volume sampler (2.3 m^3 h^{-1}) on quartz fiber filters (Whatman QMA).

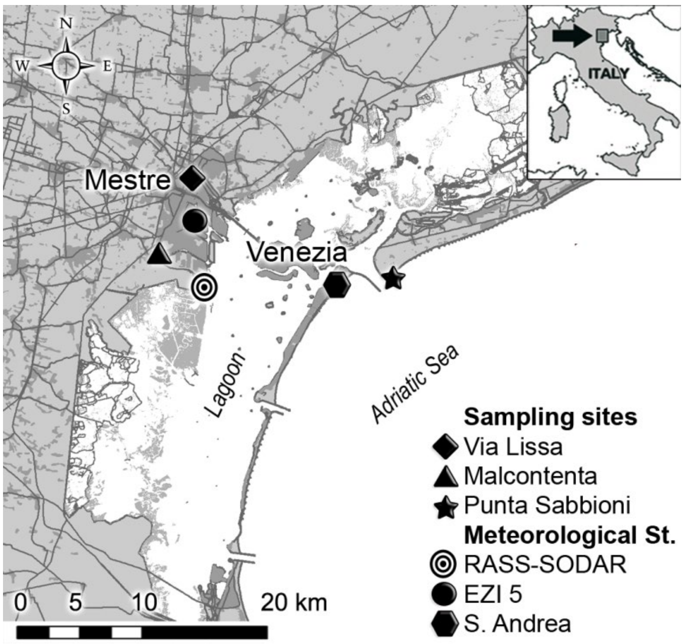

Figure 41. Project measurements and main surface and upper meteorological stations, Venice.

The modeling system used to simulate $PM_{2.5}$ dispersion is distributed by ARIANET S.p.A. and consists of three modules: a diagnostic meteorological model MINERVE (Desiato et al., 1998, Aria Technologies, 2001) coupled with a turbulence processor, SURFPRO, (D'Allura et al., 2004), an emission module, EMMA (Arianet, 2005) and an Eulerian photochemical-dispersion model Flexible Air quality Regional Model, FARM, (Gariazzo et al., 2007; Silibello et al., 2008).
MINERVE is a 3D wind field model for complex terrain; it produces a mass consistent wind field using data from a dispersed meteorological network. Temperature and humidity fields can also be interpolated. SURFPRO produces dry deposition velocities and turbulent diffusivities fields needed by the Eulerian model. FARM is a three-dimensional Eulerian model that accounts for transport, chemical conversion and deposition of atmospheric pollutants, originally derived from STEM (Sulfur Transport Eulerian Model, Carmichael et al., 1998).FARM was configured with two specific chemical mechanisms: the CMAQ *aero3* modal aerosol module (Binkowski, 1999) and a simplified bulk aerosol module (*aero0*), based on the approach adopted by the EMEP Eulerian Unified model (EMEP, 2003).

The modeling system has been applied over the study area considering the following four periods selected according to the data availability: 26/2/2009 – 16/3/2009 (spring period); 11/6/2009 – 16/7/2009 (summer period); 5/10/2009 – 31/10/2009 (autumn period) and 22/12/2009 – 31/12/2009 (winter period). Initial and Boundary conditions have been provided by national scale simulations performed by the Air Quality Forecasting System *Quale Aria* implemented by ARIANET (http://aria-net.eu/QualeAria/, Kukkonen *et al.*, 2011).

Meteorological data from 27 surface stations have been provided by ARPAV (Environmental Protection Agenciy of Veneto Region), EZI (Ente Zona Industriale) and other public agencies (Venice Water Authority, ISPRA, Centre for tide research).
Local wind fields have been adjusted by applying the MINERVE mass-consistent diagnostic model in order to improve the description of urban-scale winds. Upper data have been calculated integrating Rass/Sodar (Radio Acoustic Sound System/SOund Detection And Ranging) measurements data with RAOB (RAwinsonde OBservation) soundings from the nearest point available. Rass/Sodar instruments are controlled by Ente Zona Industriale and are situated near Malcontenta (Figure 28).

Two types of emission sources were considered, diffuse and punctual. As regard diffuse emissions starting point is mainly provided by national emission inventory (ISPRA, 2005) applying a top-down approach to compute provincial (NUTS3) estimates developed by ISPRA (Institute for Environmental Protection and Research). Pollutants have been spatialized at a municipal level using proxy variables.Some sectors, like ship movements and glassworks of Murano, that represent important sources in the area of Venice, were re-calculated, following European methodologiesEMEP/CORINAIR Emission Inventory Guidebook (EMEP, 2007) and ARPAV suggestions. To feed the dispersion model, yearly emissions were temporally and spatially disaggregated using as possible specific information related to the area. Space disaggregation is necessary to precisely allocate sectorial emissions according to the distribution of urban and forest areas. The dataset here presented refers to 2005 year and not to 2009 (measurements period). That depends on emission inventory availability that refers to 2005 for Venice area. Only industrialized emissions have been upgraded to 2009 year because situation changed a lot from 2005. A specific work has been conducted to calculate 2009 emissions for principle industrial sources in Venice area that have been considered as point source (*stacks*)with a *bottom-up* methodology.

Analysis and results

Model system results have been compared with measurements in order to evaluate model performance. Pollutants considered have been chosen respect to data analyzed: $PM_{2.5}$, secondary inorganic ions (NH_4^+, NO_3^-, SO_4^{2-}) and gas.Different approaches have been followed to best evaluate model prediction capacity.

FARM predicts very well $PM_{2.5}$ data, showing significant correlation between $PM_{2.5}$ measuredand $PM_{2.5}$ calculated in all three site (0.8 for urban site, 0.7 for industrial site and 0.6 for coastal site; $p < 0.5$) and during each period (0.7 in spring, 0.5 in summer, 0.6 in autumn and winter; with $p < 0.5$).As regard inorganic soluble part concentration (NH_4^+, NO_3^- and SO_4^{2-}), they are not well predicted as $PM_{2.5}$ data. Generally model tends to overestimate concentrations. Despite this, measured distribution and relations between the different ions are well represented by predictions. Measured and predicted gaseous pollutant concentrations are well correlated for all the periods and for the three station(Pecorari et al., submitted).

A first performance model analysis has been conducted using basic descriptive statistical analysis and a specific approach suggested by Weil et al. (1992), Hanna et al. (1993), and ASTM (2000). As regard $PM_{2.5}$ model seems to have a very good performance during all the periods and for all the three stations. Parameters are all included in the range suggested by Chang and Hanna (2004) (

Table 11) that confirm what presented before. As regard inorganic soluble part they don't fit performance range, but they don't exceed too much from that limits (

Table 11). Even though was not possible to control gas concentration for all the three stations, only industrial site has been considered to test gas performance model. Prediction gives very good results for NOx concentrations. SO_2 performance shows a good simulation for winter period, quite good for autumn period, while spring don't fit very well. SO_2 summer data was not available (Pecorari et al., submitted).

Table 11. Performance analysis for the three sampling sites and for the different periods (Pecorari, submitted)

	SRC	URB	IND	Spring	Summer	Autumn	Winter
$PM_{2.5}$							
FB	-0.1	-0.1	-0.2	0.1	-0.4	-0.3	0.0
MG	0.7	0.8	0.7	1.0	0.6	0.7	1.0
NMSE	0.3	0.3	0.2	0.3	0.4	0.2	0.1
VG	1.4	1.2	1.3	1.2	1.4	1.4	1.2
FAC2	0.8	0.9	0.8	0.9	0.8	0.8	1.0
NH_4^+							
FB	-0.6	-0.6	-0.9	-0.5	-1.0	-0.8	-0.7
MG	0.4	0.4	0.3	0.5	0.3	0.3	0.5
NMSE	0.8	0.8	1.4	0.6	1.6	1.0	0.9
VG	4.4	4.7	9.7	2.5	6.2	14.3	2.2
FAC2	0.5	0.3	0.2	0.4	0.5	0.3	0.6
NO_3^-							
FB	-0.4	-0.5	-0.8	0.0	-1.4	-0.8	-0.2
MG	0.5	0.3	0.2	0.9	0.2	0.3	1.0
NMSE	1.0	1.4	1.5	0.7	5.0	1.2	0.5
VG	4.4	24.7	28.1	1.9	63.9	15.0	1.8
FAC2	0.4	0.3	0.3	0.7	0.4	0.2	0.7
SO_4^{2-}							
FB	-0.7	-0.7	-0.9	-0.9	-0.6	-0.7	-1.1
MG	0.4	0.4	0.3	0.3	0.5	0.4	0.3
NMSE	1.1	1.0	1.5	1.5	0.8	1.0	2.7
VG	3.3	3.3	5.5	5.0	2.4	4.9	8.1
FAC2	0.5	0.4	0.2	0.2	1.3	0.4	0.2

Further a multivariatestatistical analysis has been performed to better understand $PM_{2.5}$spatial and temporal distribution taking into account meteorological influences and water soluble inorganic concentrations. A discriminant and a factorial analysis were used to compare model way of representing the phenomena with reality. The analysis were performed among the station and then respect to the different periods. As regards spatial distribution calculated data shows a less homogeneous scenario respect to measurements but it can predict some local peculiarity like pollutant behavior in coastal site (Figure 42). As regard seasonal analysis model shows a good prediction in pollutant discrimination while factorial analysis it is characterized by a not very good similarity between measured and calculated set of data.

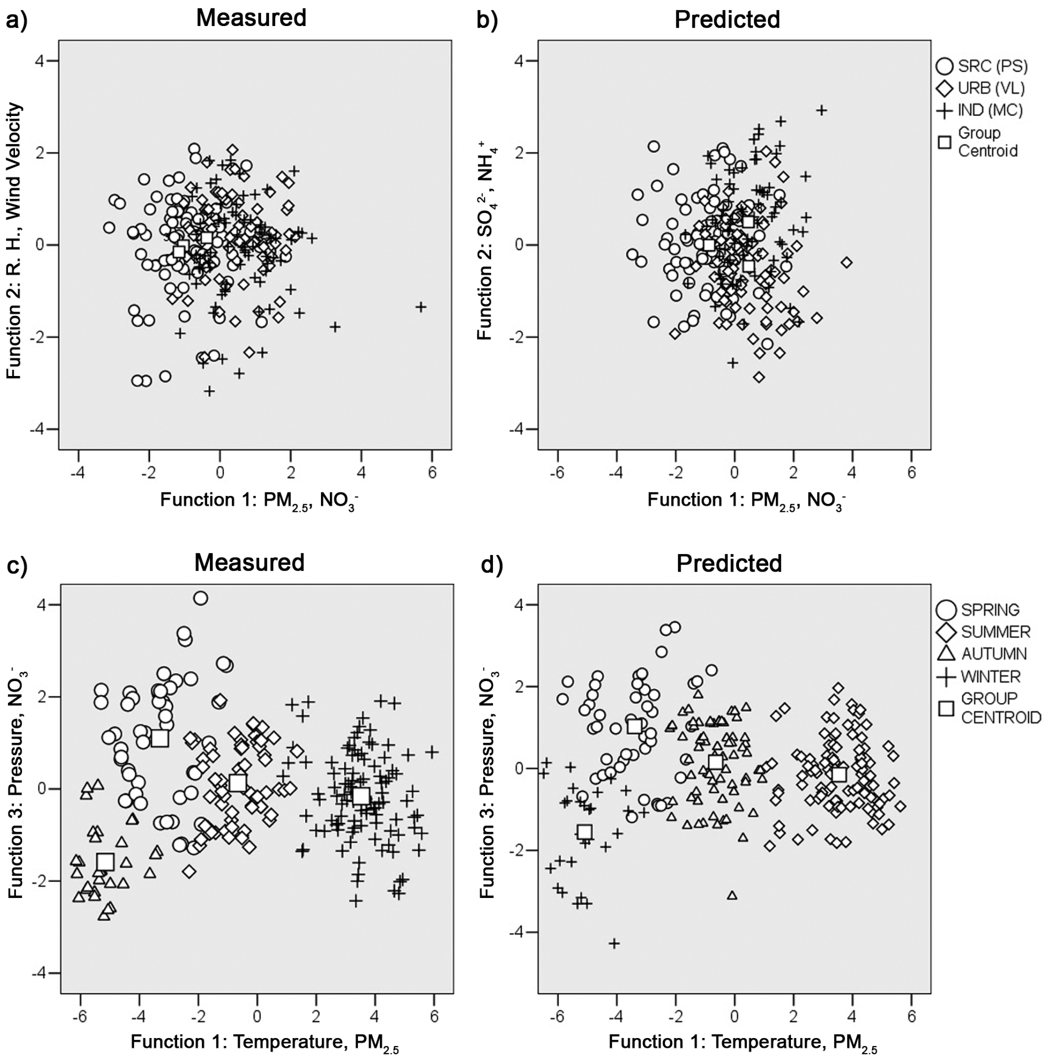

Figure 42. Canonical discriminant factor scatter plot for stations (a and b) and seasonal analysis (c and d) (Pecorari et al., submitted).

However general $PM_{2.5}$spatial and temporal distribution and reciprocal relations among the different pollutants concentrations are well predicted. Gas prediction shows a good description of the temporal and spatial distribution of the peak values and of the time at which they occurred.Organic fraction analysis is still in working progress so it hasn't been possible to test model performance with it. Model overestimation tendency can be due to a not precise emission input that referred to a previous period (2005) respect to measurements year (2009). Model results can also be influenced by the choice of the parameters that describe Venice environment.At the present time, an estimate of the 2009 emissions is in progress so that only application of the new inventory will allow more realistic model simulation. Moreover data from a meteorological measurements campaign will be soon available that will help to improve model input quality.

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