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# PMSS MICRO-SCALE SIMULATIONS OF POLLUTANTS EMITTED BY FIREPLACES LOCATED IN THE URBAN RESIDENTIAL AREA OF TORCHIAROLO (APULIA REGION, ITALY)

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**Abstract**

The atmospheric dispersion of pollutants emitted by fireplaces located in the urban residential area of a small town, Torchiarolo, in the south east of Apulia region (Italy), was simulated at micro-scale with the PMSS (Parallel Micro Swift Spray) model. Simulations were focused over a period of about 13 days during December 2016, when $PM_{10}$ hourly concentration value of 369µg/m$^3$ has been measured by local monitoring station, to investigate the influence of different local sources and the role of local meteorology on concentration distribution. Simulations were performed over a 2,4 km x 2,4 km horizontal domain with a 3 m horizontal resolution. The comparison of simulation results with measured concentration data shows the importance of micro-scale dispersion modeling to perform an accurate assessment of meteorological conditions effects on pollutants distribution, and the ability of PMSS in providing reliable simulation of atmospheric dispersion.

***Key words:*** *PMSS, Micro-Spray, Torchiarolo, biomass burning, residential heating*

## INTRODUCTION

Torchiarolo is a small town located in the southeast of the Apulia region, with a strong agricultural vocation. The wide availability of residues in agricultural activities, particularly referred to residues of the pruning of olive trees and of olive harvesting, encourages local population to use biomass as a fuel for domestic heating.

Although Torchiarolo is not far (6-7 km) from a large coal energy plant (ENEL Brindisi), the pollution caused by $PM_{10}$ and other pollutants associated with the biomass burning does not seem to arise from the power plant, but it rather shows a more significant contribution from the town itself. $PM_{10}$ concentrations, measured at fixed monitoring stations, show a typical seasonal pattern, with peaks evident in the winter months, and a high number of exceedances of the limit value set for the protection of human health (Giua R., et al., 2014). Since 2005 the $PM_{10}$ monitoring, at the urban air quality station, located at via Don Minzoni, showed very frequently a number of exceedances of the daily limit value (50 µg/m$^3$) higher than the one allowed (35) for a year.

The present study has been carried out in order to assess whether the monitoring station, located at via Don Minzoni, is placed in a concentration hotspot, such that the $PM_{10}$ measurements are not representative of the state of the air quality of the town, and to reconstruct ground concentrations distribution and consequently the impact of $PM_{10}$ and BaP concentrations, produced by biomass residential burning emissions.

These aspects were investigated using a microscale Lagrangian modeling system (Parallel Micro Swift Spray - PMSS), implemented with a spatial resolution of 3 m, to assess the direct impact of biomass residential combustion emissions during the period 1-13 December 2016, particularly critical for the numerous exceedances observed at the monitoring station.

**SET UP AND DESCRIPTION OF THE MODELING SYSTEM**

PMSS (Parallel Micro-Swift-Spray) is a modeling suite for primary pollutant transport and dispersion simulations; it is based on Pswift, a diagnostic meteorological preprocessor with null divergence condition, and Pspray, a lagrangian particle dispersion model, which can run in parallel mode (Oldrini et al., 2011). It can be used for both local scale and microscale simulations, with complex terrain or obstacles such as buildings directly taken into account (Tinarelli et al., 2013) (Tinarelli et al., 2016).

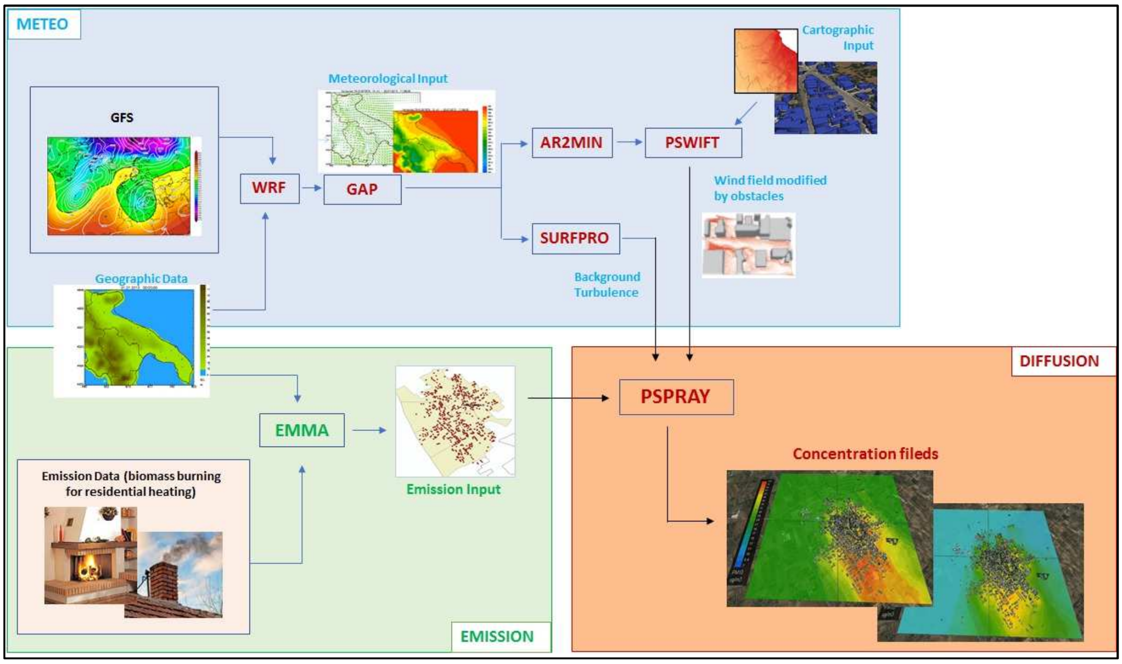


**Figure 1.** Scheme of the PMSS modeling chain used for simulations.

The modeling chain used for simulations consists of three main modules represented in Figure 1. Daily forecasts, performed by ARPA Puglia using the WRF model (Fedele F. et al., 2015) on a domain of 145 x 169 grid points with 4 km horizontal resolution, were used as meteorological input data. These data were processed to obtain atmospheric information on the background turbulence using the SurfPro preprocessor and to feed the Pswift processor to produce wind fields at high resolution taking into account the presence of urban buildings. These information, together with emission data, are the input for the Pspray dispersion model.

Emission input data were taken from a specific statistical survey among citizens, carried out adopting the CATI-CAWI (Computer Assisted Telephone Interviewing-Computer Assisted Web Interviewing) methodology. The total annual emission of $PM_{10}$ for Torchiarolo resulted of 44.6 tons per year and was equally divided by the number of chimneys detected in the town.
High resolution cartographic data, such as localization of 681 fireplaces (identified by photointerpretation of satellite image), 3D reproduction of buildings and high resolution reconstruction of local orography, were used to accurately reconstruct the emission distribution.

The domain used for dispersion simulations had an extension of 2.4 x 2.4 km$^2$, covering the whole urbanized area with 800 x 800 cells in the x and y directions with a 3 m horizontal resolution.
The domain was divided into 4 tiles (Figure 2) to speed up a parallel computation which was realized on a the RECAS HPC, a Data Center implemented by INFN (Istituto Nazionale di Fisica Nucleare) and Physics Department of Polytechnic and University of Bari (https://www.recas-bari.it/index.php/it/).

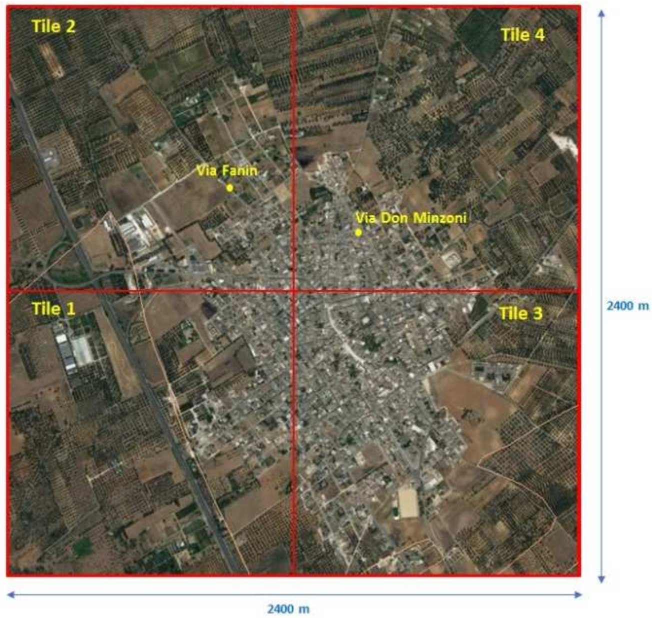


**Figure 2.** Computational domain, divided into four tiles, used for dispersion simulations.

## RESULTS AND DISCUSSION

In order to take into account the contribution of other sources and atmospheric processes not represented in the model, but which determine the background levels of $PM_{10}$ in the simulation area, modeled data have been added to the concentration values derived from a monitoring station (Lendinuso), managed by ARPA Puglia, located near the adriatic coast at a distance of about 4 km from the study area.

The comparison (Figure 3) between the time series of hourly $PM_{10}$ data measured by the two monitoring stations in Torchiarolo (located at via Don Minzoni and at via Fanin, see Figure 2) and the modeled data (including background) extracted at the equivalent grid points is more than satisfactory, highlighting the ability of the PMSS system to reconstruct the distribution of the pollutant within the simulation domain.

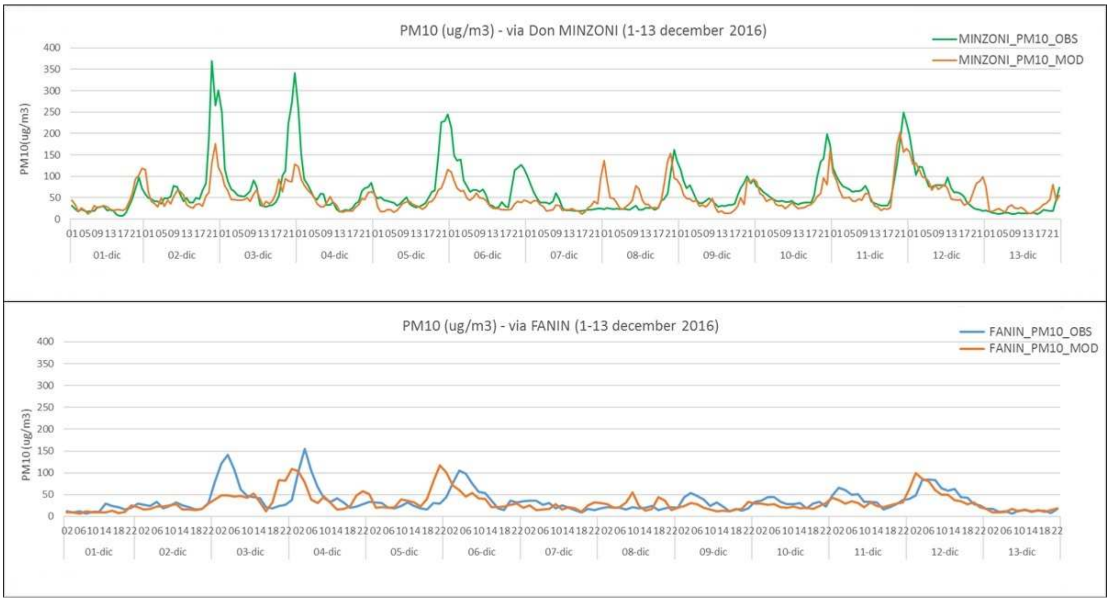


**Figure 3.** Comparison of the time series of $PM_{10}$ concentrations measured by the control unit at Don Minzoni (top) and Fanin (bottom) and the time series of the modeled concentrations (included background) extracted at the corresponding points grid, from 1 to 13 December 2016.

In particular, the comparison at the via Don Minzoni sampler shows that the model is able to reproduce quite precisely the peaks of concentration, with some differences in the amount of concentrations (slightly underestimated by the model), particularly on 2$^{th}$, 3$^{th}$ and 5$^{th}$ December. Such differences may be due to a variety of causes, such as the approximations made in the emission estimation attributed to each chimney, the intrinsic errors in sources identification that might have introduced an inaccuracy in the estimation of the number of chimneys, or the uncertainties of weather forecasts. The comparison of the hourly series of measured and modeled concentrations at the point corresponding to Fanin's station is very good too.

Table 1 summarizes a statistical evaluation of model performances. Essentially model results are consistent with the observations and performance indexes are quite good.

**Table 1.** PM10 forecast evaluation and skill scores analysis for MicroSPRAY model over the entire period considered for simulation (1-13 December 2016)

| **Station** | **Xmean obs (μg/m$^3$)** | **Xmean mod (μg/m$^3$)** | **R** | **BIAS (μg/m$^3$)** | **RMSE (μg/m$^3$)** | **NMSE** | **MFB** | **MFE** |
|---|---|---|---|---|---|---|---|---|
| Don Minzoni | 62,91 | 50,60 | 0,72 | -12,30 | 41,93 | 0,55 | -0,24 | 0,39 |
| Fanin | 34,83 | 31,35 | 0,54 | -3,48 | 23,29 | 0,50 | -0,06 | 0,21 |

Validation results show a negative bias, that is expected considering that Micro-SPRAY does not take into account secondary pollutants. A further evaluation of model results has been obtained by calculating indexes MBF and MFE, which are good indicators for $PM_{10}$ as suggested by Boylan and Russell (2006). Model performance criteria for $PM_{10}$ validation ($|MFB| \leq 0.6$, $MFE \leq 0.75$) is largely verified by both indexes.

Ground distribution maps of $PM_{10}$ and BaP average concentrations over the simulated period (Figure 4), show that this period (particularly critical from a meteorological point of view for the poor dispersion of pollutants placed on the ground) has been characterized by a generalized pollution situation, both for $PM_{10}$ and BaP, which has widely affected the whole urbanized area of Torchiarolo.

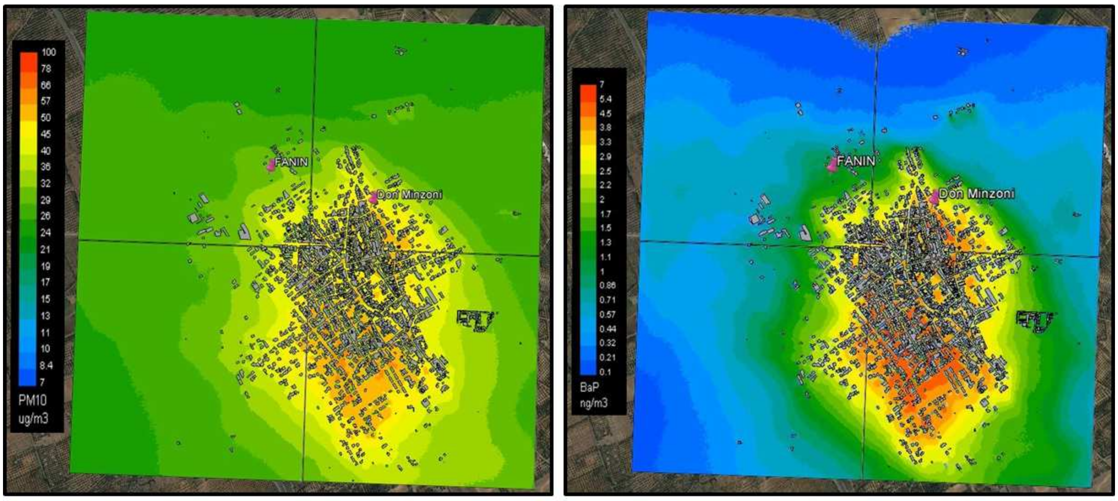


**Figure 4.** $PM_{10}$ (on the left) and BaP (on the right) map distribution of avarage concentrations, modeled on the entire period considered for simulation (1-13 December 2016)

The ground distribution of the $PM_{10}$ average concentration over the simulated period also shows that the monitoring station at Via Don Minzoni is located near a fairly wide area, characterized by concentrations between 50µg /m$^3$ and 57µg /m$^3$. Moreover, in the south-eastern part of the urban area of Torchiarolo (tile 3), there are largest areas with similar or even higher concentrations than those modeled at Via Don Minzoni.

These considerations lead to the conclusion that what is found by the monitoring station at the Don Minzoni site can be representative of what is happening in much of Torchiarolo's urbanized area. A more refined analysis of the model output obtained separating the contribution of emissions at different distances from the monitoring station shows also that closer emissions are responsible only of a minimal part of the total concentration, so the emissions coming from the entire town must be taken into account to reach the measured peaks.

The average BaP concentration map for the period from 1 to 13 December is similar to that of $PM_{10}$; even in this case the exceedance of the limit value (1 ng/m3) affects in general the entire urbanized area, with higher values located in the south part of the domain. From the maps, it is also evident a more pronunciated BaP impact over the urbanized area with respect to the surroundings compared to the PM10 that is affected by larger background values, setting in evidence more localized effects for the inhabitants due to this pollutant.

## CONCLUSIONS

In this modeling study, conducted with the PMSS microscale model, the direct impact of $PM_{10}$ and BaP emissions produced by the biomass burning for residential heating was reconstructed on a simulation domain covering the whole urbanized area of Torchiarolo with a 3m resolution and for a period of 13 days. The ground distribution concentrations maps of the statistical indicators contained in D.Lgvo 155/2010, provided by the PMSS microscale model for the simulated period, show a widespread pollution situation which interests all the urbanized area, indicating the biomass burning for residential heating as prevalent source of modeled exceedances of the daily limit value.
The analysis of these maps highlights how the monitoring site at via Don Minzoni does not actually constitute a precise hotspot, since the concentrations here modeled are very similar to those of other areas of the town. Therefore, it can be assumed that what is found at the "Don Minzoni" monitoring station can be representative of what is happening in other areas of Torchiarolo urbanized area, where the model also provides more critical issues.

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