# AIR QUALITY ASSESSMENT IN BOLOGNA BY AN URBAN DISPERSION MODEL

*Vanes Poluzzi[1], Linda Passoni[1], Marco Deserti[2], Michele Stortini[2], Enrico Minguzzi[2], Giovanni Bonafè[2]*

[1]Regional Agency for Prevention and Environment (ARPA) Bologna Provincial Department, Emilia Romagna, Italy
[2]Regional Agency for Prevention and Environment (ARPA), Hydrometeorological service (SIM), Bologna, Emilia Romagna, Italy

## INTRODUCTION

Modelling is one of main tools to evaluate air quality, integrating the monitorage techniques for determining the spatial variation in concentration as supported by European Environment Agency document "Guidance report on preliminary assessment under the EU Air Quality Directives".

Bologna, as most of the urban areas located in the Po Valley, is often affected by high pollution mainly by $PM_{10}$ and $NO_2$. These pollutants are produced by large scale chemical processes and by direct emissions inside the urban area. The urban pollution can be simulated combining the background concentration calculated by a chemical transport model, with the roadside concentration calculated by an urban dispersion model, which takes into account the pollution emitted by local sources.

## MODELLING METHODOLOGY

The urban dispersion model used is the Advanced Gaussian ADMS – Urban model (CERC, 2003), which treats industrial, domestic and road traffic emission sources in urban area and includes the OSPM street canyon model (Hertel et al, 1990), suitably adjusted to incorporate the meteorological input profiles. Furthermore, it includes a simple chemical reaction scheme for the photochemical cycle of nitrogen oxides and ozone, and another scheme for the sulphate chemistry.

The model was run to calculate the daily and hourly mean concentration respectively for $PM_{10}$ and $NO_2$ during a 1 year period (April 2003 ÷ March 2004). Furthermore, the model had provided the percentiles appropriate for calculate the exceedences established by EU Directive 99/30/EC. The simulation domain covers a district (2 km x 2 km) of the Bologna urban area. Output surface fields are calculated with a 50 m horizontal resolution.

Detailed traffic emissions on 213 road links were estimated on the basis of traffic flows (source: Bologna Municipality) and emissions factors. The vehicles were split into several categories, including cars, motorcycles and buses, considering several source of information such as the ACI (Automobile Club Italia) and the PSC (Bologna Municipality Structural Strategic Plan) data on circulating vehicles. The emission factors were taken from the Corinair 2000 for gases, and from the TNO (Netherlands Organisation for Applied Scientific Research) for $PM_{10}$ (cold starts, brake wear, tire wear and road abrasion). The emissions time-varying profiles were calculated from the Bologna PSC data.

The model was run using two different meteorological datasets. The first one is provided by the mass consistent meteorological pre-processor CALMET, operationally running at the ARPA Hydrometeorological service (Deserti et. al., 2001), which uses the meteorological data taken from surface and upper air stations in northern Italy. The other dataset, called LAMA, was provided by the non-hydrostatic meteorological model LM (Doms et al, 1999), with a continuos assimilation of surface and upper air stations over its domain, covering the whole italian peninsula, the Alps and part of the Mediterranean Sea.

The urban background concentrations were provided by the chemical transport model CHIMERE (Schmidt et al, 2001, Vautard et al, 2001) with a 50 km horizontal resolution, covering a large part of central and southern Europe. Data were provided by INERIS (Institut National de l'Environnement Industriel et des Risques).

(a) (b)

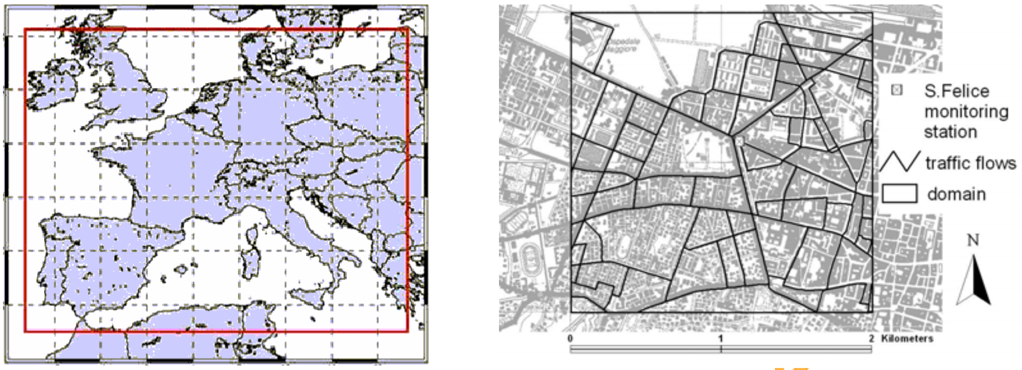


*Fig. 1; Domain of continental chemical transport model CHIMERE (a) and of the urban model ADMS-Urban (b).*

*Table 1. Emissions from road sources.*

| | **CO** t/y | **NOx** t/y | **VOC** t/y | **Benzene** (3% of VOC) t/y | **$PM_{10}$** t/y | **$NH_3$** t/y |
|---|---|---|---|---|---|---|
| Road sources (213 links) | 2352 | 166 | 370 | 11 | 16 | 4 |

**RESULTS**

The simulated pollutants concentrations were compared with the data measured by an air quality monitoring station located in the simulation domain (fig. 1b). Table 2 shows a good agreement between simulated and observed mean of $PM_{10}$, while $NO_2$ annual mean is slightly overestimated, but both these indexes are within the error range (30%) required by EU Directive 99/30/EC. The model is weaker in reproducing the peak concentrations (fig. 2, fig. 3); only the $PM_{10}$ 35$^{th}$ highest daily value satisfies the EU requirements with a modelling uncertainty within 50%, unlike the $NO_2$ 18$^{th}$ highest hourly value (tab. 2), which is overestimated.

*Table 2. Urban model results for the annual period.*

| **Receptor** | **$NO_2$** annual mean µg/m$^3$ | **$NO_2$** 18$^{th}$ highest hourly value µg/m$^3$ | **$PM_{10}$** annual mean µg/m$^3$ | **$PM_{10}$** 35$^{th}$ highest daily value µg/m$^3$ |
|---|---|---|---|---|
| *simulated*_S. Felice | 68 | 195 | 48 | 68 |
| *observed*_S.Felice | *52* | *123* | *42* | 73 |

Table 3 reports the mean values of pollution episodes (summer and winter) obtained with the meteorological datasets, CALMET and LAMA. The summer period was from 10 to 16 June 2003 (max observed value $O_3$ 250 µg/m$^3$, 11/06/03) and the winter period was from 12 to 19 February 2004 (max observed value $PM_{10}$ 164 µg/m$^3$, 26/02/2004). During the summer pollution episode the $PM_{10}$ daily concentration was in good agreement with observations, while it was underestimated during winter. On the other hand $NO_2$ results are in good agreement with observations during winter, when the daily cycle is quite well described (fig. 2), while the summer daily cycle is not well simulated. Concentrations calculated with LAMA meteorological input result higher than concentrations calculated with CALMET meteorological input, probably because mixing height and wind speed are often smaller in the first meteorological dataset than in the second one.
There is a good agreement between annual time series of simulated and observed concentrations of $PM_{10}$ (figure 3), except for the high observed peaks.

*Table 3. Urban model results for the pollution episodes (in square brackets results obtained with LAMA meteorological input).*

| **Averaging period** | **$NO_2$** simulated period mean µg/m$^3$ | **$NO_2$** observed period mean µg/m$^3$ | **$PM_{10}$** simulated period mean µg/m$^3$ | **$PM_{10}$** observed period mean µg/m$^3$ |
|---|---|---|---|---|
| summer episode (10 – 16 june 2003) | 102 [136] | *35* | 50 [69] | *32* |
| winter episode (12 – 19 february 2004) | 63 [71] | *65* | 55 [66] | *87* |

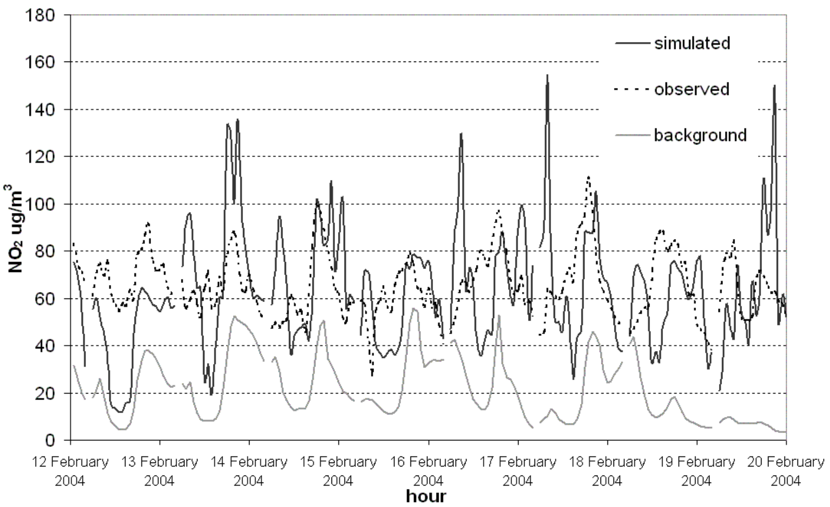


*Fig. 2; Time series of simulated and observed concentrations of $NO_2$ during winter pollution episode.*

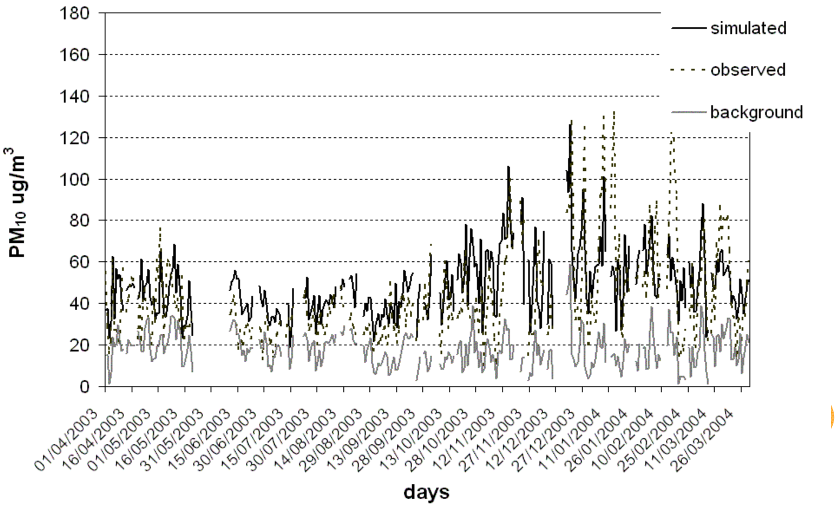


*Fig .3;Time series of simulated and observed concentrations of PM10.*

The simulated annual average fields were evaluated in order to identify the parts of the domain where the air quality limits are exceeded (fig. 4). Hot spots are in the major streets and cross-roads, where the $NO_2$ and $PM_{10}$ annual average limit for health protection (40 µg/m$^3$, EU Directive 99/30/EC) are not respected. Pollution is more homogeneously distributed in the North eastern part of the domain because the roads are wider. Furthermore, the street canyon effect is more important in the South eastern side of the domain, where the narrow streets arrive in the historical centre of the town.

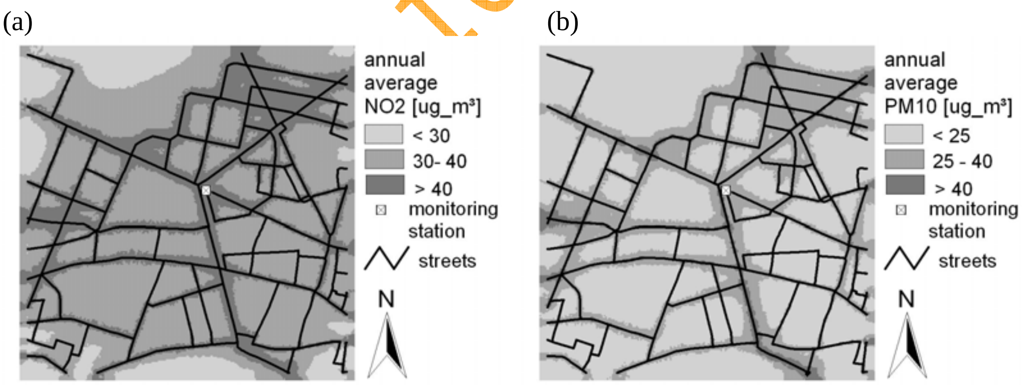


*Fig. 4; Spatial variation map of simulated annual average for $NO_2$ (a) and $PM_{10}$ (b) in the domain.*

**CONCLUSIONS**

Results show that the urban model, combined with the regional chemical transport model, performs quite well to assess long term averages of $PM_{10}$ and $NO_2$; on the other hand peak pollutions are poorly reproduced. Probably the chemical reactions scheme is not enough detailed to describe all the photochemical and thermodynamic processes that occurs in the critical episodes. However, the model provides more information than one coming from

monitoring station because it gives concentration data all over the domain. In fact, the results of the simulations tell us that high values of $NO_2$ and $PM_{10}$ can be found in many points of the analysed area. The simulation shows some hot spots near the edge of the domain; therefore future analysis could be extended in a wider zone.
Use of this modelling integrated system in the analysis of present and future scenarios can be a valuable support for the local administrations in applying EU directives on air quality.

**REFERENCES**

*CERC, 2000: ADMS 3 & ADMS-Urban 1.6 Technical Specification. User Guide. Cambridge.*

*CERC, 2003: ADMS-Urban User Guide (Version 2.0). Cambridge.*

*Deserti, M., Cacciamani, C., Golinelli, M., Kerschbaumer, A., Leoncini, G., Savoia, E., Selvini, A., Paccagnella, T., Tibaldi, S., 2001: Operational meteorological pre-processing at Emilia-Romagna ARPA Meteorological Service as a part of a decision support system for Air Quality Management. Proceedings of the Sixth Workshop on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Ed. Prof. A. Coppalle, Int. J. Environment and Pollution Vol.* ***16*** *Nos. 1 – 6.*

*Deserti, M., Lollobrigida, F., Angelino, E., Bonafè, G., Minguzzi, E., Stortini, M., Cascone, C., De Maria, R., Clemente, M., Mossetti, S., Angius, S., 2004: Modelling techniques for air quality assessment and management in Italy: the work of the National Topic Center. Proceedings of the 9th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Garmisch-Partenkirchen, Germania, 1-4 giugno 2004, 197-201.*

*Doms, G., Schättler, U., 1999: The nonhydrostatic limited-area model LM, part1: scientific documentation. R&D Dep. of DWD, 169p.*

*Hertel, O., Berkowicz, R. and Larssen, S., 1990: The Operational Street Pollution Model (OSPM). 18th International meeting of NATO/CCMS on Air Polution Modelling and its Application. Vancouver, Canada, 1990. pp741-749.*

*Schmidt, H., Derognat, C., Vautard, R., Beekmann, M., 2001: A comparison of simulated and observed ozone mixing ratios for the summer of 1998 in Western Europe. Atmospheric Environment,* ***35****, 6277-6297.*

*Vautard, R., Beekmann, M., Roux, J., Gombert, D., 2001: Validation of a hybrid forecasting system for the ozone concentrations over the Paris area. Atmospheric Environment,* ***35****, 2449-2461.*