AIR POLLUTION DISPERSION WITHIN AN URBAN ENVIRONMENT

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INTRODUCTION

The progress on understanding of urban meteorology and numerical fluid mechanics have provides a valid aid to improve strategies for environmental management in large cities. As is well known, in large cities the urban background concentration plays a fundamental role in the whole balance of the pollution. Sometimes the background concentration prevails with respect to that associated to the local emissions (*Cosemans, G. et al., 2005*). Also, the background concentration cannot be evaluated by few monitoring stations because it is not homogeneous within the city. In general, it is calculated by mesoscale models which are not well suited for the estimation of such inhomogeneities (see for example *Mensink, C. et al., 2005*). In this contest, the authors have developed a forecasting system able to supply short term prediction of pollutant concentration and to provide a better understanding of long term effects of scenarios changes of vehicular mobility as well. In the present work it is assumed that the concentration in each street canyon are composed by three different contributions: the first one is associated with the emissions external to the city (regional background), the second one with the surrounding streets (urban background), while the third one is due to local effect, i.e., the street canyon contribution. The study area for the model application is the urban area of Rome and its surroundings (~20x20 km^2), including the G.R.A. (Figure 1a), a ring road encircling Rome (Figure 1b). Starting from meteorological data and road traffic emissions referred to the year 2002, the model ADMS-Urban has been applied to forecast the Carbon monoxide (CO) concentrations. The results have been compared with the observations taken in 9 monitoring stations located within the study area (Figure 1b).

THE MODELLING APPROACH

Starting from previous researches on the habits of the Rome inhabitants, the Mobility Agency for the City of Rome (STA) estimated the emissions in the Rome area for the peak hour of a typical working day (*Atzori, A.M. et al.*, 2004). The contribution of the single roads was spread on areal sources. These authors also estimated the cycle of the mobility factor for a typical working day (Figure 2). This factor is defined as the ratio between the number of vehicular displacements in the whole urban area in each one of the 24 hours of the day and that corresponding to the peak hour. In the present work all the typical working days of the year 2002 have been analyzed. In order to discard unwanted events of anomalous traffic conditions, only Tuesdays, Wednesdays and Thursdays far from non-working days have been considered in the emission data set. Additional restrictions have been applied for summer days, rainy days and episodes of low wind speed (<0.8 m/s). The complete cycle of emissions for all the sources has been obtained by multiplying the peak hour strength of the areal sources by the mobility factor at each hour. Because of its strong correlation with the road traffic, in this preliminary study the carbon monoxide (CO) has been chosen as setting pollutant. The numerical model ADMS-Urban has been utilized for the analysis. This code is a version of the Atmospheric Dispersion Modeling System (ADMS) developed by the Cambridge Environmental Research Consultants (CERC) to evaluate dispersion in complex urban problems (*McHugh, C.A. et al.*, 1997). The model is based on the Gaussian solution of the diffusion equation in the cases of point, line, area, volume and grid pollutant sources. In order to calculate dispersion from road traffic sources in urban areas a street canyon model is integrated in the system. Differently from other Gaussian models based on the Pasquill stability parameter, ADMS-Urban utilizes parameterizations of the boundary layer structure based both on the Monin-Obukhov length and the boundary layer height. This approach is defined in terms of measurable physical parameters and generally gives a more accurate prediction of the pollutant diffusion. The meteorological data have been taken from the station of Ciampino Airport, which characterizes the urban area better than other airport stations located within the Roman area (*Leuzzi, G.*, 2002). At each hour of the selected days wind velocity, temperature and cloud cover have been entered into the model. For a further site characterisation a surface roughness of 1.0 m and a minimum positive Monin-Obukhov length of 100 m have been set. The emission data set consists of 1623 road sources corresponding to the main roads located within the "Railway ring" (Figure 1b) and to 20 road sources located outside the ring. 85 area sources outside the railway ring have been also considered in the simulations. For lack of an adequate estimation of the buildings height, the option "canyon" was activated only for the roads close to the monitoring stations.

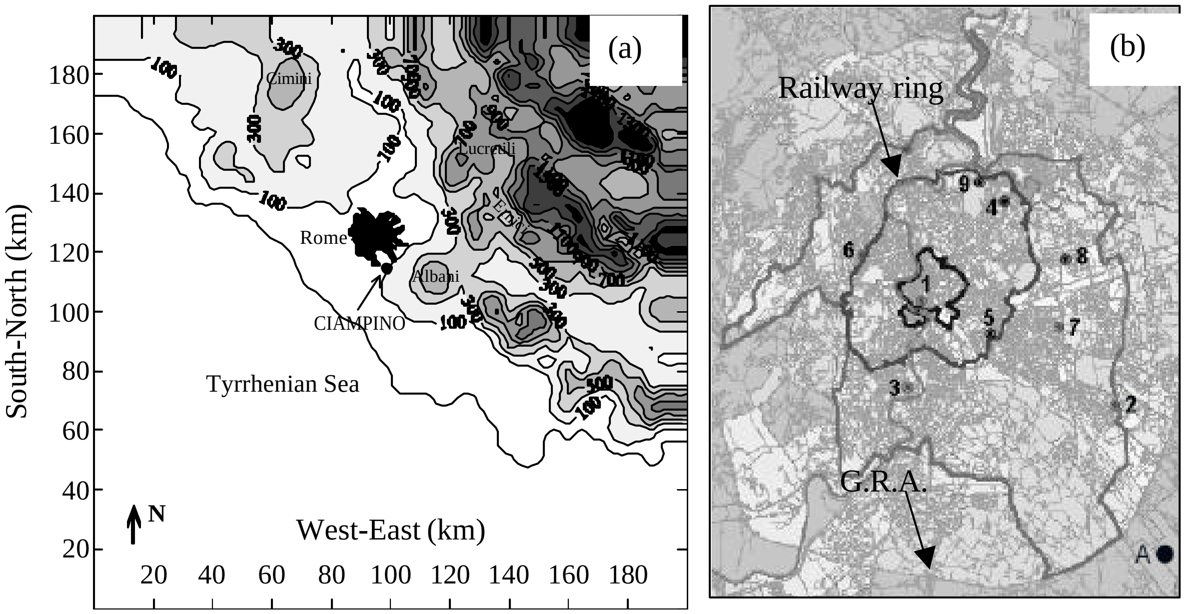

Fig. 1; (a) Topography of the Lazio region. (b) Map of the studied area; the locations of Ciampino Airport (A) and of the meteorological stations are also included: (1) Arenula, (2) Cinecittà, (3) Fermi, (4) Libia, (5) Magna Grecia, (6) Montezemolo, (7) Preneste, (8) Tiburtina and (9) Villa Ada.

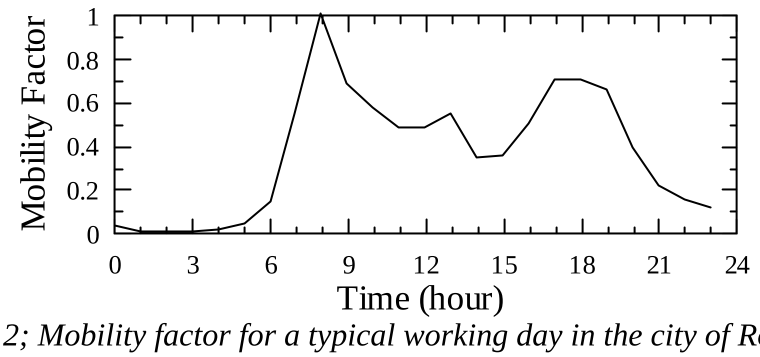

Fig. 2; Mobility factor for a typical working day in the city of Rome.

RESULTS

The model has been run starting at 00 Local Standard Time (LST) for each of the selected days with the corresponding meteorological data file taken at Ciampino Airport. As an example, in Figure 3 the CO concentration simulated at 3 m above ground level in the whole studied domain on 12 March 2002 is depicted. On that day a breeze event occurred. Note that Rome is located in a relatively flat area of the Lazio region, about 25 km inland from the shoreline (Figure 1a) and it is prone to the formation of sea and land breeze flows. At 08 LST (Figure 3a) the residual land breeze advected the pollutant toward the southwestern suburban areas. In such conditions the boundary layer was thermally stable and could not efficiently diffuse the emissions, which, in turn, reached the peak level. Subsequently, the sea breeze grew until the hottest hours of the day. At that time period the pollutant concentration decreased because both of the pollutant emission rate reduction and of the simultaneous increase in wind speed as well as convective turbulence activity. The sea breeze decreased continuously during the afternoon, while the emission rate increased again reaching the second peak level at 18 LST (Figure 2).

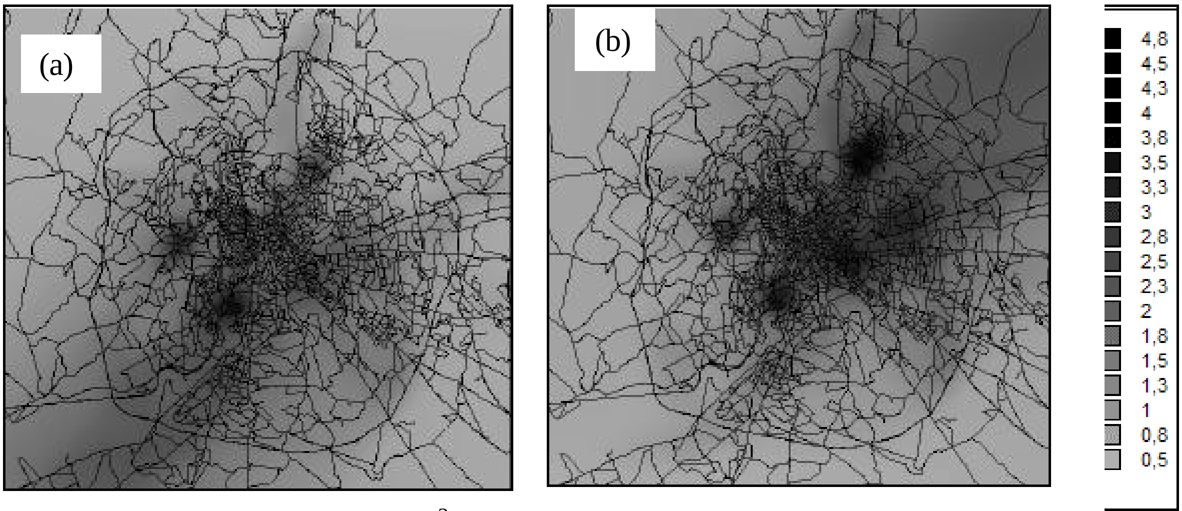

Fig. 3; CO concentrations (mg m^{-3}) calculated by ADMS-Urban at 3 m above ground level at 08 LST (a) and at 18 LST (b) on 12 March 2002.

The corresponding concentration field is shown in Figure 3b. The plume is directed northward advected by the residual sea breeze. The computed concentrations have been compared with those measured by the monitoring stations of Rome Municipality. As mentioned above, the spreading of road traffic emissions on areal sources procedure permits to evaluate urban background concentrations only. On the other hand, it takes no account of the pollution due to local traffic. As a consequence, only the urban background concentrations can be properly evaluated at the stations located outside the Railway Ring with the adopted set-up of ADMS-Urban. Based on a preliminary analysis on the measurements of all the monitoring stations taken during the period of the day without emissions (i.e., nighttime), an average concentration of 0.5 mg/m^3 has been calculated. That value has been considered as the regional background concentration. Thus, it has been added to all the concentrations calculated by ADMS-Urban.

In Figure 4 the comparison between the computed and the observed concentrations averaged over all the selected days is depicted. In almost all the stations the two daily concentration maxima are reasonably calculated. Based on the Italian law, the stations are classified into three categories, namely, A, B and C, according to their lesser (category A) or greater (category C) exposure to local traffic. In general, the agreement between calculated and observed concentrations is quite satisfactory for the stations not exposed directly to traffic emissions (categories A and B). The best agreement occurs for the Cinecittà station, probably because of its vicinity with the Ciampino airport. As expected, because of the sources setting, the model predictions are less accurate for the stations of category C (high traffic exposure). The discrepancies should be related to the local traffic contribution. Confirmation of this hypothesis comes by analysing the errors of the 8 hour averages computed for all the selected cases, as summarized in Table 2. A quite good agreement occurs for Villa Ada (category A). The agreement is also satisfactory for the stations of Arenula, Cinecittà and Preneste (all of them are of B category), while at Fermi, Montezemolo and Tiburtina (category C) the model, as expected, underestimates the pollutant concentrations.

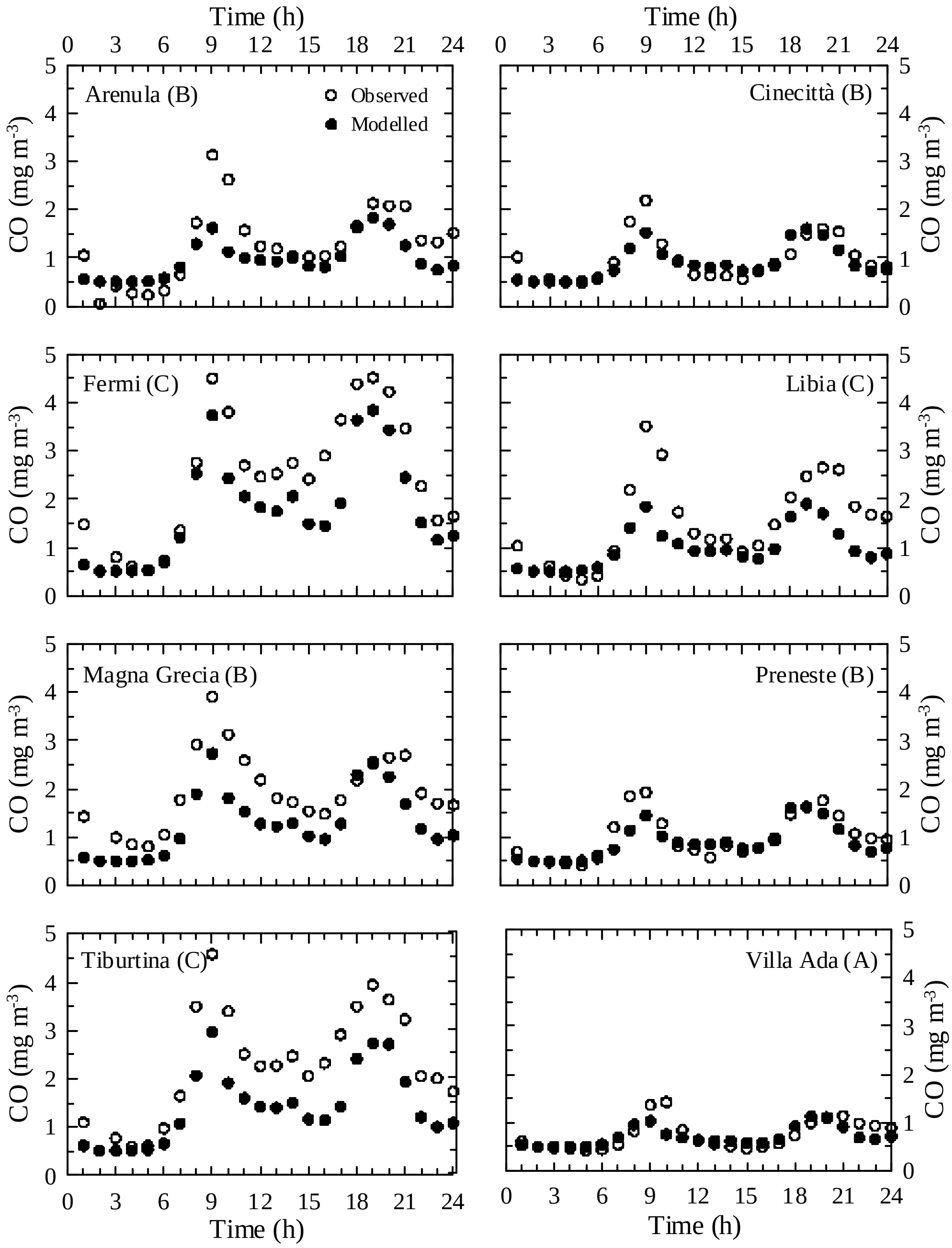

Fig. 4; Comparisons between modeled (full circles) and observed (open circles) CO concentration averaged over all the selected days. Letter between parenthesis indicates station category.

Table 1. Errors corresponding to the average day for the nine meteorological stations.

STATION (Category)	FRACTIONAL BIAS	INDEX OF AGREEMENT	CORRELATION INDEX	MOVING AVERAGE
Arenula (B)	-0.18	0.57	0.52	-0.54
Cinecittà (B)	0.24	0.91	0.94	-0.07
Fermi (C)	-0.08	0.66	0.55	-0.78
Libia (C)	-0.30	0.64	0.66	-0.78
Magna Grecia (B)	-0.33	0.69	0.77	-0.60
Montezemolo	-0.47	0.43	0.53	-1.66
Preneste (B)	0.12	0.77	0.67	-0.19
Tiburtina (C)	-0.31	0.80	0.84	-1.16
Villa Ada (A)	0.26	0.42	0.32	-0.10

CONCLUSIONS

The model ADMS-Urban has been utilised to evaluate the dispersion of pollutant emitted by the road traffic in the city of Rome during the typical working days of the year 2002. The emission data of have been provided by the STA (Mobility Agency for the City of Rome). The meteorological data have been measured at the Ciampino Airport. The computed concentrations have been compared with data observed by the monitoring stations of the Rome Municipality. Despite the uncertainness related to the actual emissions (see Figure 2), the modelled concentrations are in reasonably agreement with the observations for the stations located far from road traffic emission. As expected, because of the sources setting, a systematic underestimation occurs for the stations placed within heavy traffic zones. Finally, ADMS-Urban with the adopted set-up seems to give a satisfactory estimation of the urban background concentration.

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