AN APPLICATION OF CALPUFF AND CALINE MODELS ON AN URBAN AREA, COMPARISON BETWEEN THREE DIFFERENT APPROACHES

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ABSTRACT
CALPUFF lagrangian model has been applied with three different configurations in order to evaluate NOx and CO ground level concentrations over the urban area of Brescia in northern Italy.
The meteorological conditions were obtained from CALMET output. Stacks were treated as point sources while traffic emissions were treated as an emitting grid of volume sources, or as volume sources following the road network. The traffic model CALINE has been also applied. Model results have been compared with measured concentrations at an urban station to verify CALPUFF capability to reproduce urban pollutants behaviours in these different models configurations.

1. INTRODUCTION

In the frame of a model intercomparison exercise organised by the CTNACE (Italian National Topic Centre on Air, Climate and Emission) CALPUFF and CALINE models have been applied over the urban area of Brescia. This work aims at evaluating models performance in near-field urban applications involving complex meteorological conditions and three different approaches in setting up the simulation.
The domain, shown in Figure 1, covered 12x12 Km^2 of a plain area dominated to the east by a hill that reaches elevations of 900 meter a.s.l. Air circulation is characterised by calms, with 23% of calm hours in the year (wind speed lower than 0.5m/s) and weak winds regime. Hourly meteorological data were provided by CTNACE for the year 1999 at one ground level point. Data were obtained from a one-year CALMET application over a larger area of 300x300 km^2.
Emission data were provided for six industrial point sources emitting NOx (white circles), two emitting CO (white filled rhombs), and a network of 948 roads (black lines) including one highway. Traffic emissions were time-modulated, while industrial emissions where considered uniformly emitted in the year.
Measured NOx and CO concentrations were provided for one monitoring station located in the centre of the City (white cross).

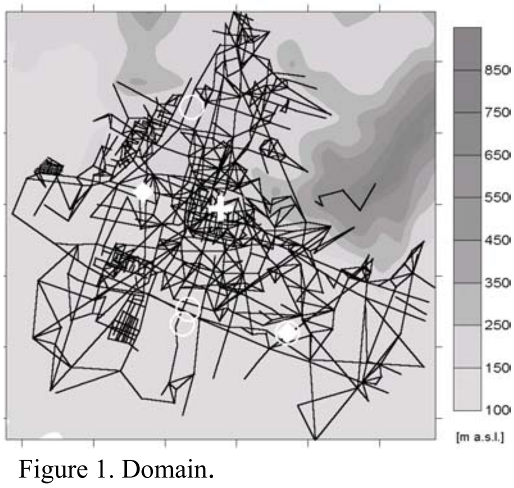


Figure 1. Domain.

Table 1. Total emission (Mg/y).

	Total	Industrial Point Sources	Traffic Road Network
NOx	5.328	3.048	2.280
CO	22.648	6.695	15.953

2. METHODOLOGY

Three models configurations have been considered. In the first (Cal_1), CALPUFF was used to simulate industrial point source, while traffic emissions were simulated as linear sources in CALINE model. In Cal_2 and Cal_3 configurations all sources were simulated with CALPUFF. In Cal_2 road transport emissions were splitted over a regular grid of 500x500 m^2 volume sources (Figure 2). In Cal_3 the road network was replaced by about 6.000 small volume sources following the road axes.
The models shared the same single ground point meteorological information (ISC-type). In Cal_3 case, also u*, L and sensible flux computed by CALMET (for a CTNACE choice only unstable and neutral conditions are considered), have been used in the simulation. In one simulation (Cal_3) the single point information has been integrated with wind and temperature profiles. These two facts, mainly not considering stable

conditions, makes the two approaches (Cal_1 and Cal_2 respect to Cal_3) much different. Besides, in Cal_1 and Cal_2, wind speed was set to a minimum of 0.5 m/s. Other differences between the set up are shown in Table2. Both pollutants have been considered non-reactive, dry deposition and wet depletion modules were disabled.

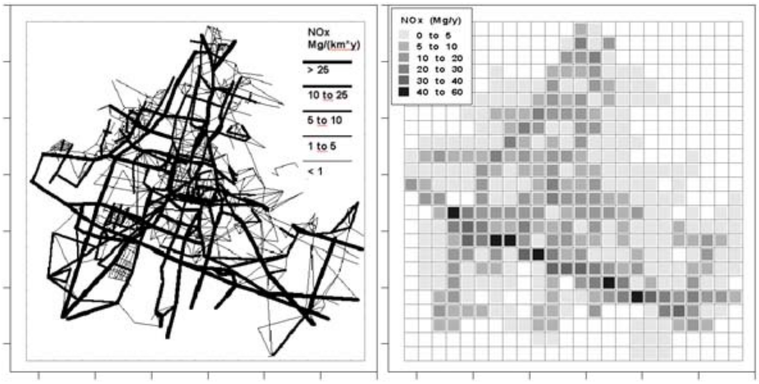


Figure 2. Traffic emission, line sources and regular grid of volume sources.

Table 2. Model configurations.

	Cal_1	Cal_2	Cal_3
meteorology data	ground point data	ground point data	ground point and profile data
turbulence	Mechanical turbulence vehicles induced and Pasquill-Smith disp. coeff.	McElroy-Pooler disp. coeff.	Similarity theory 1/L
stability	stability classes: A-F	stability classes: A-F	1/L always negative for CTNACE hypothesis
cell size (m)	400	500	1000
wind calm algorithm	wind minimum set up to 0.5 m/s	wind minimum set up to 0.5 m/s	Yes
complex terrain	No	Yes	No
dispersion of industrial emission	CALPUFF point source	CALPUFF point source	CALPUFF point source
dispersion of traffic emission	CALINE linear emission	CALPUFF grid of volume emission	CALPUFF “rectangle” volumes emission following roads
background conc.	No	No	No

3. RESULTS AND DISCUSSION

Hourly NOx and CO concentrations for year 1999 computed by the three models have been compared, in particular looking at: annual mean (and maximum) concentration maps and hourly concentration time series in correspondence of the monitoring station location.

Table 3 shows the values for statistics that have been selected to analyse time series data. Due to missing measured data and to too high values in provided CO emission data of the last quarter of the simulation, statistics have been computed on two subsets of hours: 5442 valid data for CO (62.1%) and 7698 valid data (87.9%) for NOx.

Bias shows an overall overestimation of observed concentrations for Cal_1 and Cal_2. Cal_3 approach seems to lead to underestimation of pollution level especially for NOx (probably due to the fact of not simulating stable conditions), while CO sample is almost unbiased.

Absolute Bias, Correlation Indexes and Root Mean Square Errors assume similar values for Cal_1 and Cal_2 and are slightly better for Cal_3 maybe due to the improved meteorological information used.

Scatter plots for hourly concentration percentiles for CO and NOx are presented in Figure 3. According to this analysis, Cal_3 is characterised by the lack of stable dynamic, which results in an increasing underestimation of concentrations for the last plotted percentiles (90^{th} and 99^{th}). Underestimation is smaller for Cal_2 percentiles whose scatter plots are almost aligned on the 1:1line. Cal_1 percentiles are close to Cal_2 ones except for the maximum value that overestimates the measured one by a factor of 1.8.

Table 3. Statistical analysis of hourly concentration time series.

	Pollutant	Cal_1	Cal_2	Cal_3
Average Normalised Bias	CO	0.45	0.50	-0.04
	NOx	0.25	0.42	-0.33
Average Normalised Absolute Bias	CO	1.06	1.00	0.65
	NOx	0.92	0.99	0.58
Correlation Index	CO	0.34	0.44	0.55
	NOx	0.25	0.31	0.45
Root Mean Square Error	CO	1.42	1.10	0.89
	NOx	0.17	0.16	0.15

* Statistics for CO are computed for the period 1st Jan-30th Sep

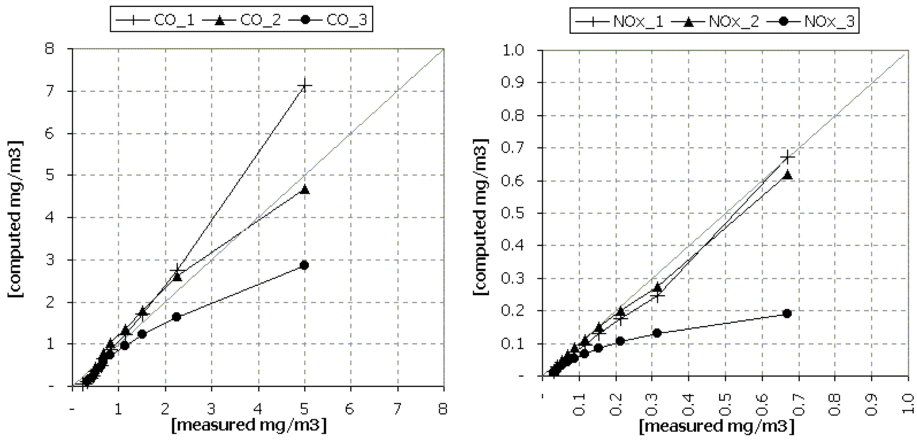
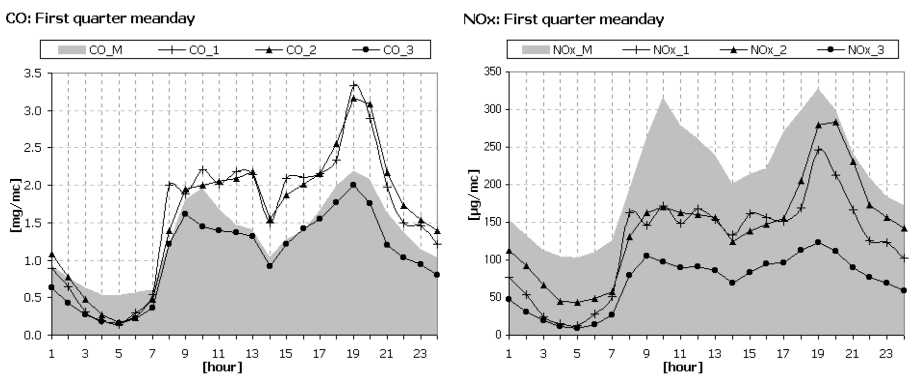


Figure 3. Percentiles scatter plots for CO and NOx hourly concentration.

1999 first and third quarter mean days (Figure 4) confirm the considerations above and highlights the model capability to reproduce the seasonal variation and daily behaviours of CO and NOx. While CO is mainly emitted by the sources here considered (even if a background might be considered to fill the gap of lack of boundary conditions and other emission sources), during wintertime NOx are emitted by residential combustion plants not considered here and they are imported by surrounding urban areas just outside the computational domain. These are the reasons why CO and NOx graphs are similar in the hot quarter, while all models underestimate NOx levels in the cold quarter.



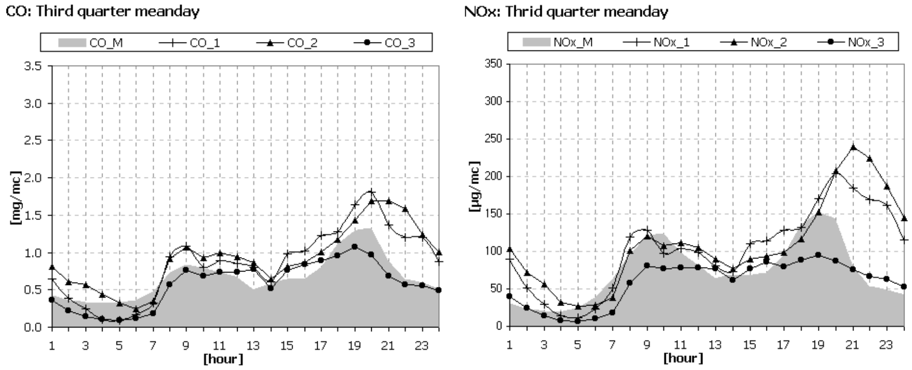


Figure 4. Mean temporal profile of CO and NOx concentrations measured (filled area) and simulated (dotted lines).

Figure 5 shows the maps of the mean annual concentration for nitrogen oxides calculated on a regular receptor grid. Grid steps have been set equal to 400m in Cal_1, 500m in Cal_2 and 1000m in Cal_3.
Maps show similar patterns but are different in values and gradients. Cal_1 map, obtained using CALINE to model traffic emissions, is the sharpest and keep in strong evidence the highways emissions. The grid of volume sources used in Cal_2 smoothes the pattern and spreads pollutant more uniformly over the domain; mean concentrations results higher than in the first case. Finally, with 1-km step size grid resolution, the main emissive structure is still recognisable even if values are significantly lower than in Cal_1 and Cal_2.

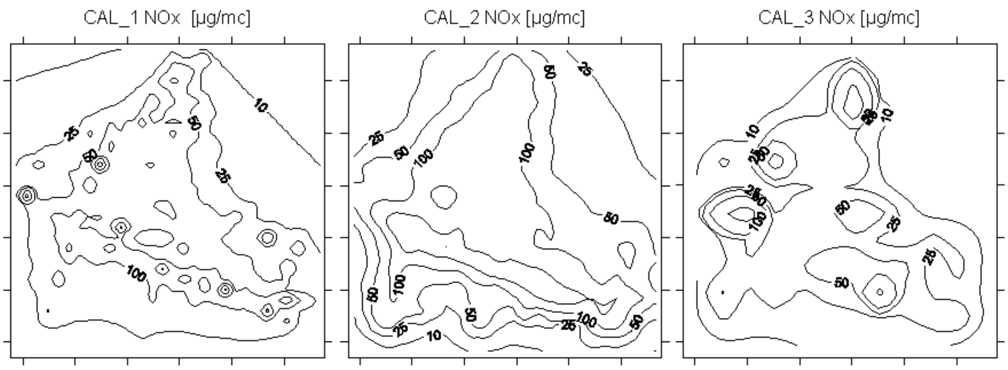


Figure 5. Mean annual concentration for NOx.

4. CONCLUSION

The results show that urban air quality modelling could be satisfactorily carried out with a lagrangian modelling approach and with simple meteorological information. Enhanced performance could be obtained with two or three (not considered in this intercomparison) dimensional meteorological input. The effect of considering stable conditions also in the third modelling approach could complete and enforce these conclusions.

5. ACKNOWLEDGEMENTS

The authors are grateful to the CTNACE (Italian National Topic Centre on Air, Climate and Emission) for providing the data used in this study. CESI contribution to this paper has been supported by the MICA (Italian Ministry of Industry, Trade and Handicraft) in the frame of Energy Research Program for the Italian Electric System (MICA Decree of February 28, 2003), Project on SCENARI. The Municipality of Milan has sustained Mobility and Environment Agency contribution.

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