A SENSITIVITY ANALYSIS OF ADMS-URBAN

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INTRODUCTION

Activities to test and improve atmospheric dispersion models are increasing in Europe. In order to evaluate environmental impact of vehicular traffic, Italian local authorities, acting in concert with other European countries, are beginning to utilise dispersion models. Algorithms based on simplified schemes of diffusion are particularly suitable for these applications. Despite its simplicity, ADMS-Urban is one of the most advanced models to calculate dispersion in the city as a whole.

The behaviour of ADMS-Urban has been studied extensively by several evaluations of long-term air pollution concentrations and comparisons with monitored data (e.g. *Carruthers, D. J. et al,* 1999 and *Owen, B. and Raper, D.W.*, 2001), while analyses of individual pollution episodes are more rare (*Arciszewska, C. and McClatchey, J.*, 2001). Local authorities should predict episodes in which pollutant concentrations overcome safety thresholds.

In this study a sensitivity analysis of ADMS-Urban (version 1.6) has been performed. In order to analyse single episodes, model concentrations were carried out under short-term averaging conditions. Particular attention has been devoted to meteorological input. Data of meteorological stations located in the city of Rome have been compared with those taken in its rural counterpart. These different input data have been furnished to ADMS-Urban and the results of the corresponding dispersion simulation have been compared. Finally, the model has been applied to a road with heavy traffic in the centre of Rome. Numerical results have been compared with pollutant concentrations measured by a monitoring station.

This study has been undertaken as part of a larger research project in collaboration with STA (Agenzia per la Mobilità del Comune di Roma).

THE MODEL

ADMS-Urban is a development of the Atmospheric Dispersion Modelling System (*Carruthers, D. J. et al*, 1994), including algorithms for the simulation of road sources. It has been produced by CERC (Cambridge Environmental Research Consultants) and can take account of chemical reactions, non-Gaussian distributions of concentrations, diffusion in street canyons or around buildings. Meteorological input are treated by an advanced pre-processor.

SENSITIVITY TO METEOROLOGICAL DATA

The model response for variations of all input parameters has been investigated, but only results related to variations of wind data have been reported in this paper.

Base case

The sensitivity analysis has been conducted starting from a base case (Table 1) and changing one parameter value at a time. Meteorological input can be furnished through different datasets. Speed and direction of the wind are always necessary, plus one of the following parameters: reciprocal of Monin-Obukhov length, surface sensible heat flux and cloud cover (together with time of day and time of year). Monin-Obukhov length and sensible heat flux are not routinely recorded at stations, therefore cloud cover has been utilised for all the simulations.

Table 1. Parameters of the base case

Wind speed (m/s)	Wind direction (degrees)	Cloud cover (oktas)	Julian day number	Local time (hours)	Boundary layer height (m)	Height of recorded wind (m)
1	0	4	161	10	800	2

The road source was 1 km long, 35 m wide and oriented in south-north direction. The road was lined on both sides by buildings of height 15 m, thus the street canyon module has been activated. Output concentrations have been calculated at a receptor point positioned at half-way, 15 m east of the road centerline and at a height of 3 m. This receptor corresponds to a hypothetical roadside monitoring station. The source emission rate was fixed to 1 g/km/s. The site location is defined by a latitude of 41°, a surface roughness of 1 m and a minimum Monin-Obukhov length of 30 m. The last two data are suggested by the model help for cities and large towns.

Results

The model response to the variations of each input parameter has been tested. The results related to wind parameters are reported in Figure 1.

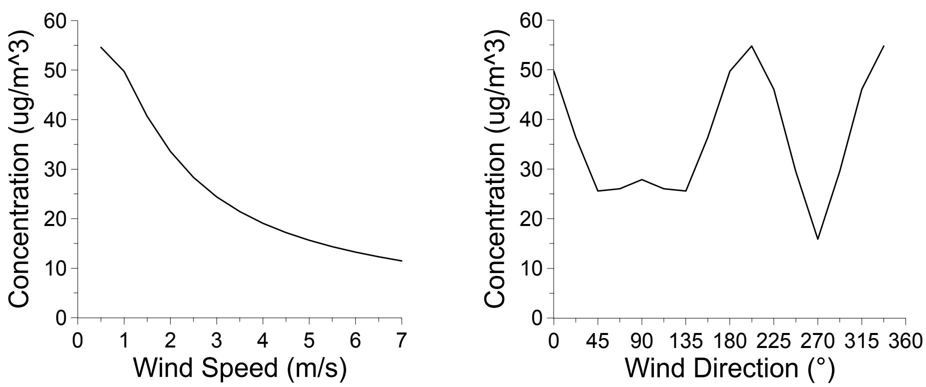

Figure 1. Pollutant concentration calculated by ADMS-Urban versus wind speed and wind direction, for a road source located in a street canyon.

All the parameters that are not in abscissa assume the base case values. The sensitivity can be associated to the slope of the diagrams. The model shows a high sensitivity at low wind speed. In this conditions the meteorological pre-processor introduces a threshold. All the wind velocities below 0.75 m/s are enhanced to this value and the corresponding wind directions are fixed to the first value for which the threshold was activated. The wind angle forcing may introduce unrealistic levels of concentration. The model is very sensible to wind direction variations (Figure 1), a difference of 45° around to 270° introduces an error of 200% on the concentration. Note that angle differences of this entity between urban meteorological stations are not rare.

SENSITIVITY TO SOURCES OF METEOROLOGICAL DATA

Wind data taken at stations within Rome area have been compared with data of rural stations located in the neighbourhood of the city. Data taken from these stations are alternatively furnished to ADMS-Urban. The corresponding effects on model output have been evaluated.

Comparison among data from different weather stations

In the city of Rome there are several weather stations. Most of them are roadside stations and are not representative of the whole dispersion area. In this study two urban stations located on the top of high buildings have been considered: S. Pietro in Vincoli (41°53'N-12°29'E) and Colli Aniene (41°54'N-12°34'E). The first one is situated in the centre of Rome, the anemometer is placed on a 6-metre mast. Colli Aniene station is located in a suburban area of Rome, the anemometer is installed on a 3-metre mast.

In addition to urban stations two rural stations have been analysed: Fiumicino (41°48'N-12°14'E) and Ciampino (41°47'N-12°35'E). They are rural synoptic stations of the Aeronautical Meteorological Service, placed in the homonymous airports of Rome. The anemometers are located on standard 10-metre masts.

Meteorological data were obtained for individual days in June 2002. The results of the comparisons of wind speeds and directions on 14 June are shown in Figure 2. Starting from 10.00 LST the effects of the sea breeze are evident: the wind turn to west and the magnitude grows to its maximum value. During the night the land breeze appears: wind turn to east and its magnitude grows again. In the Rome area, because of the vicinity between mountains and coastline, the effects of sea-land and valley-mountain circulation interact. Nocturnal breeze is not evident at every station. At Fiumicino the direction of the nocturnal wind is classified as variable, hence no data are available.

During night time and in early morning a strong spread of data has been observed for the various stations. On the contrary, after 12.00 LST, when the sea breeze grows, wind directions match pretty-good and the percentage differences between wind velocities decrease. Due to the lower mast height, the observed wind speeds at Colli Aniene are rather low. The example shown is for one single day, but a similar behaviour has been observed on the other days of June. Such conditions are very frequent during summer months in Italy, when strong synoptic winds are absent.

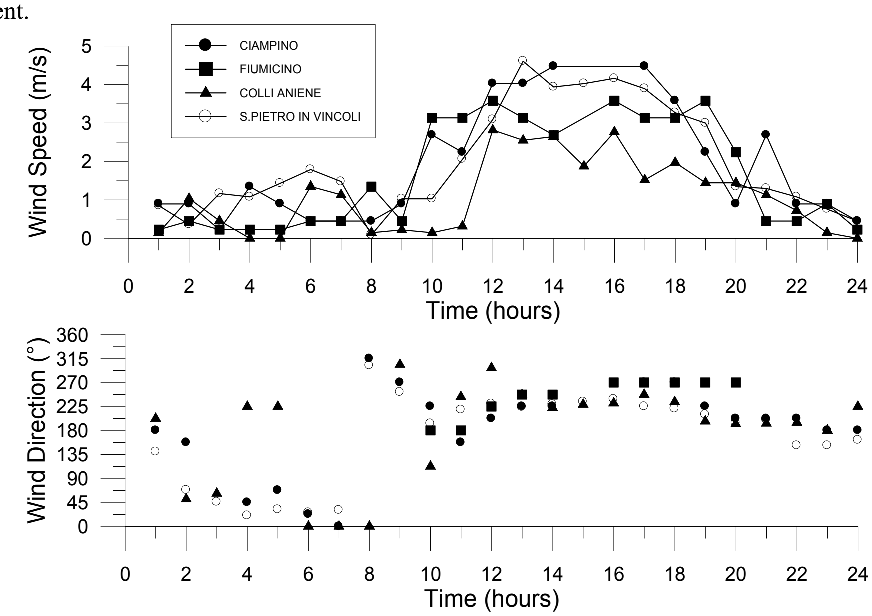

Figure 2. Comparisons among wind data taken at different weather stations on 14 June 2002.

Comparison among concentrations

Meteorological data, recorded during individual days of June at different stations, have been alternatively furnished as input to ADMS-Urban. In order to evaluate how the choice of the station affects the model output, resultant concentrations have been compared. The simulation of 14 June 2002 has been considered as an example. The wind input data have been described in the previous paragraph. Cloud amounts and temperatures at different stations have been assumed equal to those measured at Colli Aniene. The pollutant source and the other needed parameters are the same described in the previous section. The results for Fiumicino have been discarded because of the lack of wind direction data. The predicted concentrations have been shown in Figure 3.

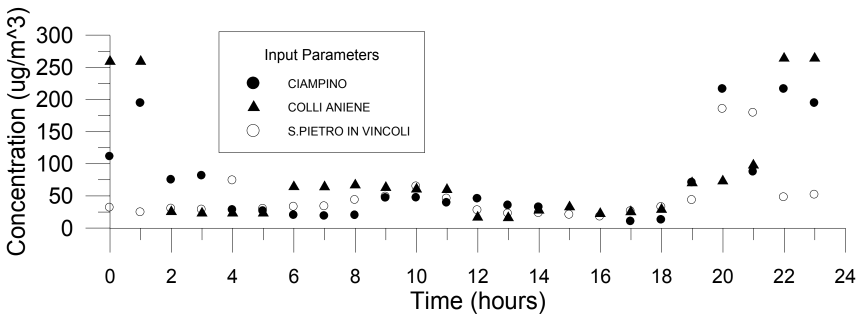

Figure 3. Comparisons among concentrations calculated by ADMS-Urban, making use of input wind data taken at different weather stations on 14 June 2002.

The spread of input data affects the calculated concentrations. During night time uncertainties in the wind data give more than a tenfold increase in output differences. Such a behaviour is due to a synergic effect of low wind speeds and angles of high sensitivity. As experienced in some other simulations, the freezing effect, exerted by the pre-processor threshold on wind angle, does not seem to improve the results. During the morning the increases of wind speed and angle matching reduce output differences.

A VALIDATION EXAMPLE

ADMS-Urban has been set up to simulate pollutant diffusion in a busy road, situated in a street canyon of Rome. Model runs were carried out for individual days in November and December 2001. Input meteorological data have been taken at a sub-urban station (Saredo 41°12’N-12°34’E). The wind was recorded 2 metre above the top of a building. Emission data have been furnished by STA. These input data and the CO concentrations on 27 November 2001 are reported in Figure 4.

The predicted concentrations have been compared with measurements taken at a roadside station in the same street of the source. On the whole the agreement is satisfactory, but at some hours the model predicts peaks of concentrations not confirmed by observations. As explained in previous sections, such a behaviour is due to low wind speed conditions and fluctuations of wind angles. Moreover the model, which is based on stationary diffusion hypotheses, follows instantaneously the emission forcing, leading to unrealistic peaks of concentrations. Analogous results have been obtained during the other days of the simulation. An improvement of the data agreement has been observed in presence of higher wind speeds.

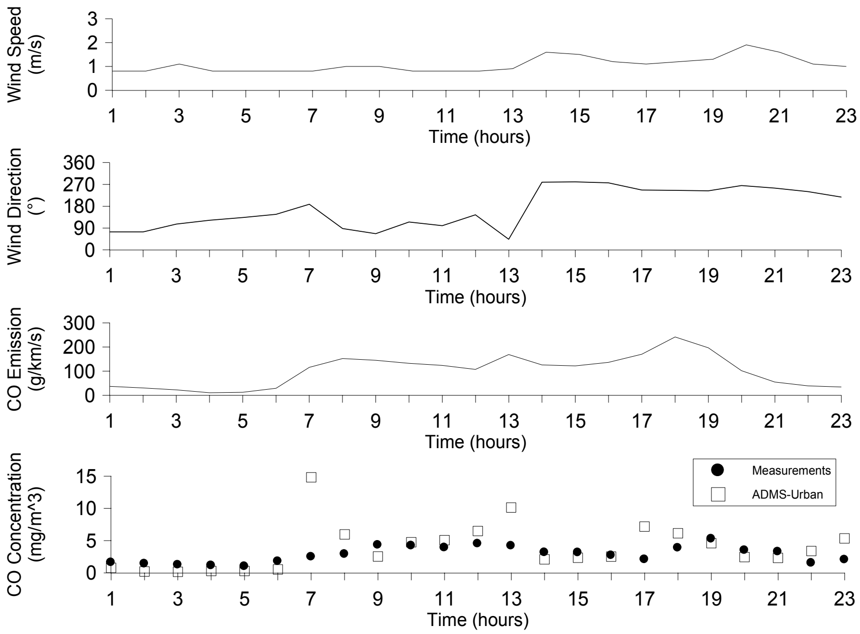

Figure 4. Comparison between measured and modelled CO concentrations on 27 November 2001. The corresponding wind and emission input data have been reported above.

CONCLUSIONS

A sensitivity analysis of ADMS-Urban to meteorological parameters has been carried out. Data taken at different weather stations of Rome, during a typical summer day, have been compared and furnished to the model. Finally, a validation example, under light wind conditions, has been shown. The sensitivity tests show that the predicted concentrations are very sensible to low wind speeds and wind angle changes. A wide spread of wind data has been observed during the night and in early morning at Rome weather stations, which produces large uncertainties in the output concentrations. The comparison with observed concentrations shows a sufficient agreement, with the exception of some peaks of predicted concentrations. The uncertainties experienced under light wind conditions might give unrealistic predictions of high pollution episodes.

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