AN AMBIENT AIR QUALITY MONITORING NETWORK FOR BUENOS AIRES CITY

Laura Venegas and Nicolás Mazzeo
National Scientific and Technological Research Council (CONICET)
Department of Atmospheric and Oceanic Sciences. Faculty of Sciences.
Univ. of Buenos Aires. Ciudad Universitaria. Pab. 2. 1428-Buenos Aires. Argentina.

INTRODUCTION

The placement of air monitoring stations in a network depends upon the nature of monitoring objectives. One formalized approach to station sitting involves the use of atmospheric dispersion models (*Seinfeld, J.*, 1972; *Noll, K. and S. Mitsutomi*, 1983; *Mazzeo, N. and L. Venegas*, 2000; *Venegas, L. and N. Mazzeo*, 2003). Once the estimated air quality for various averaging periods has been computed, different mathematical techniques can be used to select monitoring sites on some prioritised basis. At present, the city of Buenos Aires has not an air-quality monitoring network but the City Government is interested in installing one. The objectives of this study are: a) to design a multi-pollutant (NO_x (expressed as NO_2), CO and PM10) urban air quality monitoring network for Buenos Aires City to detect high concentrations and violations of a reference concentration (CR) and b) to evaluate the "representative spatial coverage" of the detected violations. The developed methodology is based on the analysis of the results of atmospheric dispersion models.

MODELS

We used the urban atmospheric dispersion model (DAUMOD) and the Industrial Source Complex Short Time 3 (ISCST3), to estimate NO_x (expressed as NO_2), CO and PM10 hourly background concentrations over the city. The DAUMOD model has been developed, described and evaluated in former papers (*Mazzeo, N.A. and L.E. Venegas*, 1991; *Venegas, L.E. and N.A. Mazzeo*, 2002, 2005). In this model the ground-level background air pollution concentration (C(x,z=0)) at each grid cell centre in which the urban area is divided is given by:

$$C(x, z = 0) = \frac{a\left[Q_0\, x^{b} + \sum_{i=1}^{N} (Q_i - Q_{i-1})(x - x_i)^{b}\right]}{\left(|A_1|\, k\, z_0^{b}\, u_*\right)} \qquad (1)$$

where the x axis extends horizontally in the direction of the mean wind; *a*, *b* and A_1 are parameters that depend on atmospheric stability, Q_i (i=0, 1, 2, …, N) is the emission strength of area sources in each of the square grid cell upwind, k is von Kárman´s constant, z_0 is the representative surface roughness length of the urban area and u_* is the representative friction velocity for the urban area. The DAUMOD model is applied to the area source emissions (domestic, commercial and small industries activities, terrestrial vehicles, aircrafts landing-taxing-taking off at the Domestic Airport) in the city. The model runs using hourly input data.

We applied the ISCST3 model (*U.S.EPA*, 1995; *Yegnan, A. et al.*, 2002) to the main point source emissions located in the city. According to the Argentine regulations, this model is still recommended by the Environmental Authority of Argentina to be applied to point source emissions. The basis of this model is the straight line, steady-state bi-Gaussian plume equation. The ISCST3 model accepts hourly meteorological data to define the conditions for plume rise, transport and diffusion.

Hourly concentrations calculated for each type of source (area and point sources) at each receptor are summed to obtain the air pollutant concentration at each receptor by the combined source emissions.

RESULTS AND DISCUSSION

Monitoring site selection

We ran both atmospheric dispersion models using one year (2003) of hourly meteorological data obtained at the Domestic Airport located in Buenos Aires city. The emission inventory of NO_x (expressed as NO_2), CO and PM10 for the city (*Mazzeo, N.A. and L.E. Venegas*, 2003; *Venegas, L.E. and P.B. Martin*, 2004) had a spatial resolution of 1km x 1km over the city and a typical diurnal variation. We considered as reference concentrations (CR) the 50% of the air quality standards in order to take into account the possible bias of the results of both models. Therefore, for NO_x (averaging time: 1 hour) CR= 0.20mg m^{-3}, for CO (averaging time: 1 hour) CR= 20.0mg m^{-3}, for CO (averaging time: 8 hours) CR= 5.0mg m^{-3} and for PM10 (averaging time: 24 hours) CR= 0.075mg m^{-3}.

We ran DAUMOD and ISCST3 to compute the horizontal distribution of background hourly NO_x, hourly and 8-hour CO and daily PM10 concentrations (C) in the urban area. As first step, we applied the network design methodology described in *Venegas, L.E. and N.A. Mazzeo* (2003) to determine the minimum number of sensors needed to register the occurrence of C>CR in the area, considering one air pollutant at a time. For each pollutant, the locations of the monitors were selected among the grid cells with C>CR. According to the network design methodology, the first monitoring site would be located in the grid cell with the highest score. All the cases with C>CR at this grid cell, were not included in the further analysis. Considering the remaining cases, the grid cells were ranked again in order to select the second site location. This procedure continued until last case was eliminated.

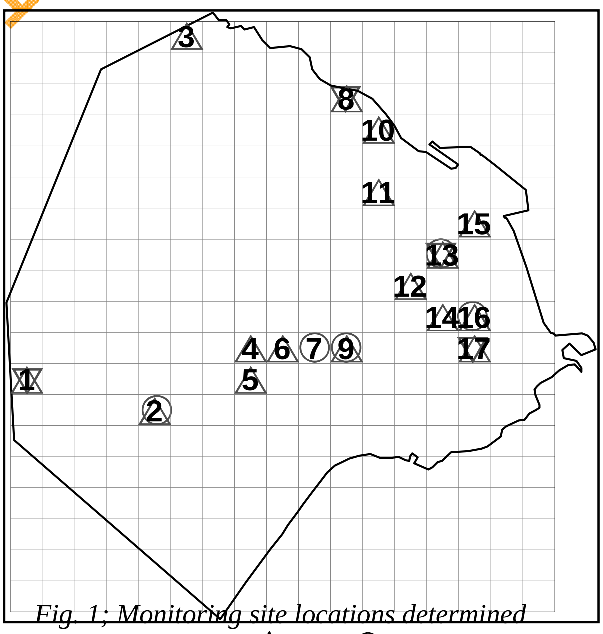

Fig. 1: Monitoring site locations determined in the first analysis. △ NO_x, ○ CO, ▽PM10

Analysing the pollutants separately, the network design methodology indicated that 16 sensors of NO_x, 4 sensors of CO and 4 sensors of PM10 would be required. With this number of sensors the efficiency of the network would be 100%. The monitoring sites obtained at this stage are shown in Figure 1. Only one site location (13) was common to the three pollutants.

Therefore, for practical reasons and limited resources, the second step was to do an optimisation analysis to pick up the most appropriate subset within the initial locations where to install different detection instruments together in the same place. Considering the efficiency of different network configurations to detect exceedances (see Table 1), the best scenario required 6 monitors of NO_x (efficiency: 94.2%), 4 monitors of CO (efficiency: 92.1%) and 4 monitors of PM10 (efficiency: 100%).

Table 1. Fraction (%) of the total exceedances C>CR, that different network configurations will be able to detect

Pollutant	NET 1 1, 2, 8, 9, 13, 16	NET 2 1, 2, 4, 8, 13, 16	NET 3 1, 2, 7, 8, 13, 16	NET 4 1, 7, 8, 12, 13, 16
NO_x (1h)	94.7%	94.2%	94.2%	95.8%
CO (1 h)	92.1%	89.5%	92.1%	89.5%
CO (8 h)	97.3%	97.3%	100.0%	100.0%
PM-10 (24 h)	100.0%	100.0%	100.0%	100.0%

The three pollutants would be measured at 2 sites, NO_x and CO at another 2 sites and NO_x and PM10 at the remaining 2 locations. The proposed network has the configuration shown in Figure 2.

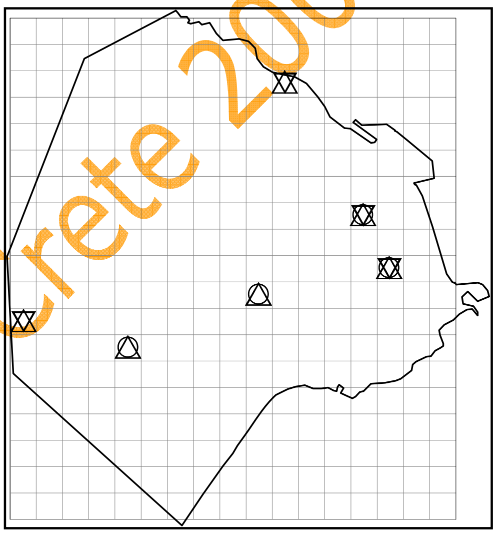

Fig. 2; Monitoring site locations proposed after an optimisation analysis. △ NO_x, ○ CO, ▽PM10

"Representative spatial coverage" of the detected violations

Once the network is operating, every time a monitor registers that C>CR at its site, we are interested to know where else in the city C could exceed CR, within a known probability. Considering one monitor at a time, we analysed all the estimated horizontal distributions of concentrations of one air pollutant, when C>CR at this site. For these N_T cases, we identified the other grid cells in the city where C was also greater than CR. For each grid cell in the city, we determined the number (n_i) (of the total exceedances N_T at the monitoring site under consideration) that also showed C>CR at the grid cell. From the horizontal distribution of the relative frequencies ($f_i(\%) = (n_i/N_T)*100$), we obtain the areas where concentration is expected to be greater than CR with a probability $f_i \geq 70\%$, $f_i \geq 80\%$ and $f_i \geq 90\%$ (see Figure 3), every time a monitor registers that C>CR. The extension of the "representative spatial coverage" of the detected violations ranges between the values included in Table 2.

Table 2. Areas where C>CR with a probability greater than 70%, 80%, 90% when C>CR at a monitoring site of the proposed network.

	Probability					
	70%		80%		90%	
Pollutant	Min. (km^2)	Max. (km^2)	Min. (km^2)	Max. (km^2)	Min. (km^2)	Max. (km^2)
NO_x	13.0	64.0	5.70	44.0	0.15	14.8
CO	0.2	9.4	0.08	4.0	0.02	0.43
PM10	5.7	39.7	0.57	23.3	0.03	7.00

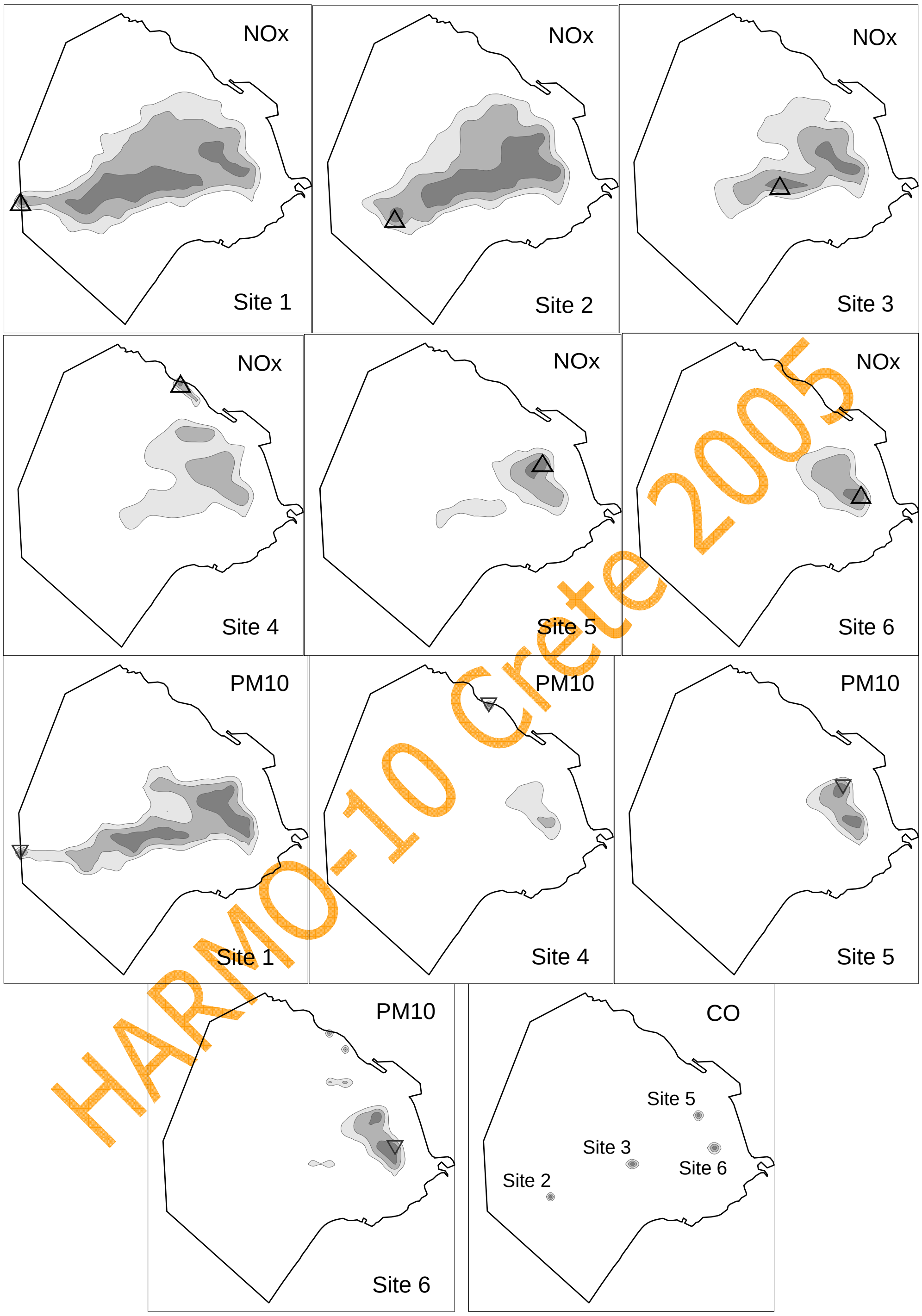

Fig. 3; Areas where air pollutant concentration is expected to be greater than CR with a probability greater than 70% (light grey), 80% (medium grey) and 90% (dark grey) every time the monitoring site indicated in each plot registers that C > CR.

CONCLUSIONS

In this paper, we design a multi-pollutant (NO_x, CO and PM10) monitoring network for Buenos Aires City to identify the occurrence of violations of reference concentrations (CR) assumed to be 50% of the air quality standards. We ran DAUMOD and ISCST3 atmospheric dispersion models to obtain the spatial distribution of background air pollutant concentrations in the city. After the analysis of the cases with exceedances of CR, we determined the minimum number of monitors needed to detect the occurrence of these violations. The optimisation analysis revealed that 6 monitoring sites located in the city would be able to detect these exceedances with efficiencies greater than 92%, depending on the air pollutant considered. The extension of "representative spatial coverage" of the detected violations varies between 0.2 and 62km^2.

ACKNOWLEDGEMENTS

This work was supported by Projects UBACYT-X060, FONCYT PICT2000 Nº 13-09544 and CONICET-PIP 6169. Meteorological data have kindly been supplied by the Argentine National Meteorological Service.

REFERENCES

Mazzeo, N.A. and L.E. Venegas, 1991: Air pollution model for an urban area, *Atmospheric Research*, **26**, 165-179.

Mazzeo N.A. and L.E. Venegas, 2000: Practical use of the ISCST3 model to select monitoring site locations for air pollution control, *International Journal of Environment & Pollution*, **14**, 246-259.

Mazzeo N.A. and L.E. Venegas, 2003: Carbon dioxide and nitrogen oxides emissions inventory for Buenos Aires city (Argentina), *Proceedings of the 4th International Conference on Urban Air Quality. Measurement, Modelling and Management*, Prague (Czech Republic), 25-27 March, 159-162.

Noll, K.E. and S. Mitsutomi, 1983: Design methodology for optimum dosage air monitoring site selection, *Atmospheric Environment*, **17**, 2583-2590.

Seinfeld, J.H. 1972: Optimal location of pollutant monitoring stations in an airshed, *Atmospheric Environment*, **6**, 847-858.

U.S.EPA, 1995: User's Guide for Industrial Source Complex (ISC3). U.S. Environmental Protection Agency, Office of Air Quality Panning and Standards Emissions, Monitoring and Analysis Divisions. Research Triangle Park, U.S.EPA-454/B-95-003.

Venegas, L.E. and P.B. Martin, 2004: Concentración de material particulado en la ciudad de Buenos Aires. *14th Congreso Argentino de Saneamiento y Medio Ambiente*. Buenos Aires, Argentina, 17-19 de noviembre de 2004, P-20, CDRom, (in Spanish).

Venegas, L.E. and N.A. Mazzeo, 2002: An evaluation of DAUMOD model in estimating urban background concentration, *Water, Air and Soil Pollution: Focus*, **2**, 433-443.

Venegas, L.E. and N.A. Mazzeo, 2003: Design methodology for background air pollution monitoring site selection in an urban area, *International Journal of Environment & Pollution*, **20**, 1-6, 185-195.

Venegas, L.E. and N.A. Mazzeo, 2005: Modelling of urban background pollution in Buenos Aires city (Argentina), *Environmental Modelling & Software*, (available on line)

Yegnan, A., D.G. Williamson and A.J. Graettinger, 2002: Uncertainty analysis in air dispersion modelling, *Environmental Modelling & Software*, **17**, 639-649.