INFLUENCE OF SURROUNDING AREAS AND WIND ON AIR QUALITY OF BUENOS AIRES CITY

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INTRODUCTION

Urban air pollution is a growing environmental problem in many countries. Emissions and ambient concentrations of pollutants in a major city can have widespread effects on the health of its inhabitants, urban and regional haze, and ecosystem degradation. Pollution emitted in a particular urban area as well as the advected by winds from outside constitute the most important components of air pollution in a city.

The city of Buenos Aires (CBA) has an extension of 203km^2 and 2776138 inhabitants. It is bounded by the de la Plata River at east and by the Greater Buenos Aires (GBA) at other directions. The length of de la Plata River is 320km and its width varies from 38km to 230km in the upper and lower regions, respectively. In front of the city the river is 42km wide. The GBA is an urban/sub-urban area with an extension of 3627km^2 and 8684437 inhabitants. Together the CBA and the GBA constitute the Metropolitan Area of Buenos Aires (MABA). The MABA is located on a flat terrain with height differences less than 30m.

This work studies how the heterogeneous areas that surround the city of Buenos Aires (CBA) affect air quality conditions in the urban area. Variations of the spatial distributions of NO_2 concentration in CBA due to wind direction are studied. Considering an emission inventory of NO_x from area sources located in the Metropolitan Area of Buenos Aires (MABA), the air quality in the city has been evaluated and analysed applying the urban atmospheric dispersion model DAUMOD.

ESTIMATION OF NO2 CONCENTRATIONS

The DAUMOD urban atmospheric dispersion model is an analytical steady-state model that can be used to estimate air pollutant concentrations due to area source emissions. This model has been described elsewhere (*Mazzeo and Venegas*, 1991; *Venegas and Mazzeo*, 2002, 2006) and evaluated with measurement data from different cities (*Mazzeo and Venegas*, 1991, 2004; *Venegas and Mazzeo*, 2002). At present, chemical transformations are not included in DAUMOD model. However, output concentrations of NO_2 are calculated on the basis of an empirical relationship between NO_2 and NO_x (*Derwent and Middleton*, 1996, *Dixon et al.*, 2001, *Middleton et al.*, 2007). The concentration of NO_2 is calculated using the polynomial expression (*Derwent and Middleton*, 1996, *CERC*, 2003):

$$[NO_2] = 2.166 - [NO_x]\,(1.236 - 3.348\,A + 1.933\,A^2 - 0.326\,A^3) \quad (1)$$

where $A = \log_{10}([NO_x])$ and concentrations are hourly-averaged concentrations in ppb.

An emission inventory of NO_x for the Metropolitan Area of Buenos Aires has been completed recently (*Pineda et al.*, 2007). The inventory includes NO_x emissions from: residence, commerce and small industry combustions, aircrafts LTO (landing/take-off) cycles at the domestic airport located in CBA and at the international airport situated in the GBA, and road traffic (cars, trucks, taxis, and buses). The inventory has a spatial resolution of 1 x 1 km and a typical daily variation. The spatial distribution of NO_x annual emission in the Metropolitan Area of Buenos Aires is presented in Figure 1.

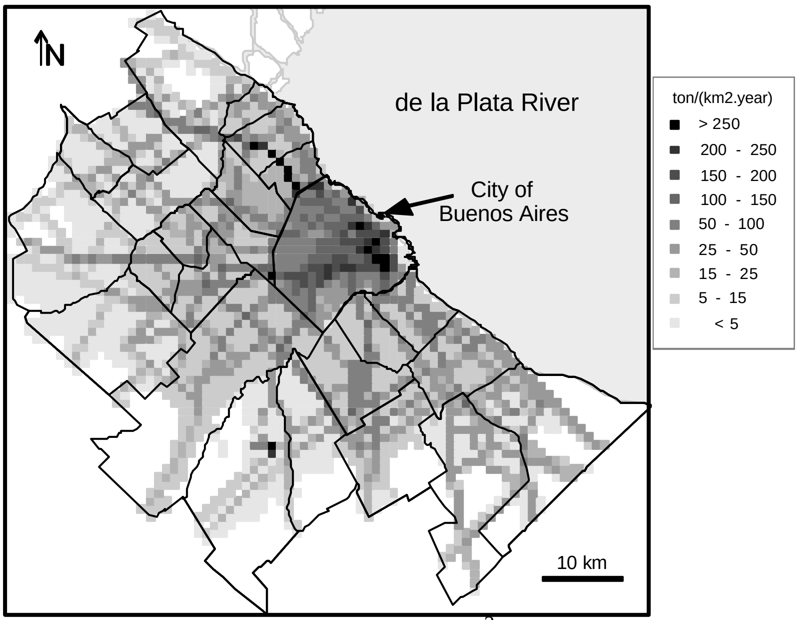

Fig.1; Annual emission rates [ton/(km^{2}year)] of NO_x from area sources in the Metropolitan Area of Buenos Aires. Grid resolution 1 x 1 km.

Hourly NO_2 concentrations in the city of Buenos Aires have been obtained applying the DAUMOD model considering three years of hourly meteorological data. Estimations obtained for 08:00PM (rush-hour) are considered for the analysis as they show the highest hourly concentration levels.

RESULTS AND ANALYSIS

Air quality estimations for 08:00PM reveal that NO_2 hourly concentrations may exceed the local Air Quality Standard (AQS= 0.376mg/m^3) in 4km^2 downtown of the city of Buenos Aires and that they may be greater than 0.5AQS, between (0.190-0.376)mg/m^3, in 48km^2 of the city. The spatial distributions of the number of 08:00PM hours in three years with these exceedences are shown in Figures 2 and 3, respectively.

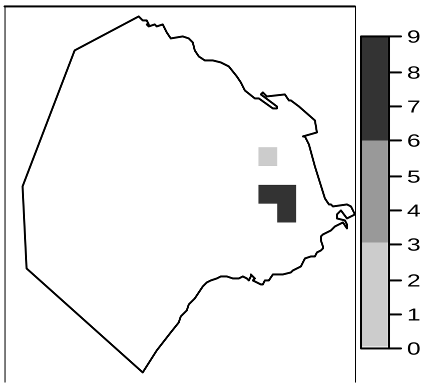

Fig. 2; Spatial distribution of 08:00PM hours with NO_2 hourly concentrations greater than 0.376 mg/m^3, in three years.

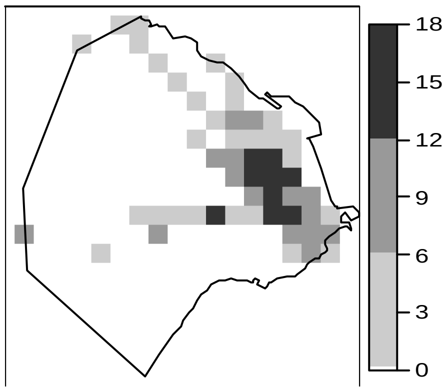

Fig. 3; Spatial distribution of 08:00PM hours with NO_2 hourly concentrations between (0.190-0.376) mg/m^3, in three years.

The influence of wind direction on the spatial distribution of NO_2 hourly concentrations in the city can be studied through model estimations for 16 wind directions (every 22.5º) and assuming rush-hour emissions, neutral atmospheric stability and a wind speed of 4m/s (the most frequent value of wind speed in the area). Some results are shown in Figure 4 to illustrate main features.

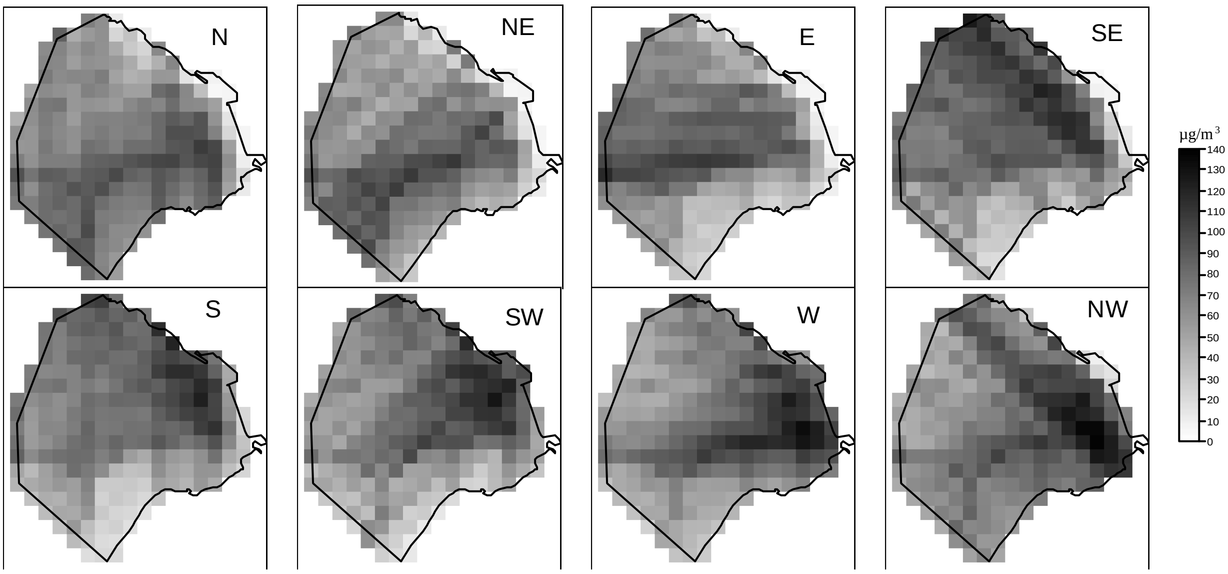

Fig. 4; Estimated NO_2 hourly concentrations assuming rush-hour emissions, neutral atmospheric stability, wind speed of 4m/s and wind direction indicated in each plot.

Results show that when wind blows from the wide river, concentration levels in the city not always decrease. For N, NNE, NE, ENE and E winds, concentrations near the coast are low and slowly increase with downwind distance. However, if wind blows from ESE, SE and SSE (also from the river) concentration values in the city are higher than in former cases. Highest concentration values occur for W, WNW, NW and NNW winds. In these cases, polluted air is blown towards the city from a freeway (with daily mean traffic flow of 270 thousand vehicles) that connects the Greater Buenos Aires with the NW part of the city.

Another important feature is that relative high concentration levels can be found at the centre of the city for all wind directions. Figure 5 shows the spatial distribution of the range ($C_{max.}$-C_{min}) of estimated NO_2 concentration values. Large concentration amplitudes (>60µg/m^3) can be observed in the coastal area (42km^2) and small ones (<30µg/m^3) in the centre of the city (16 km^2). This result shows that wind direction strongly affects NO_2 concentrations in the coastal area and it has very little influence in the central area of the city. There is a large urban area (145 km^2) where concentration amplitudes in these conditions varied between 30µg/m^3 and 60µg/m^3. The largest range of NO_2 hourly concentration in a grid cell is 100.5µg/m^3.

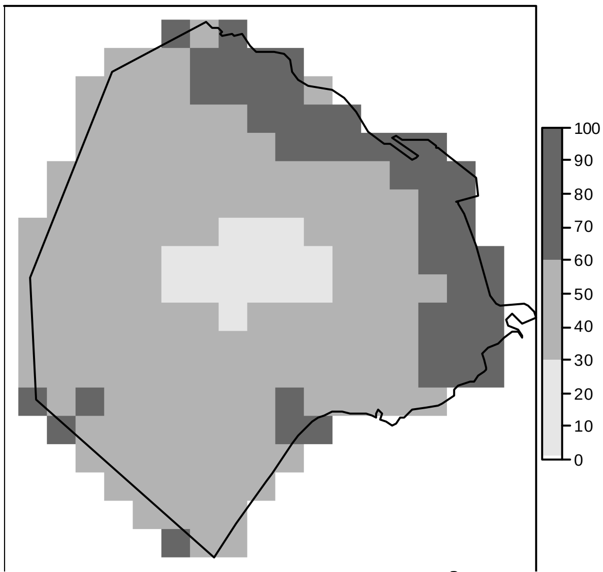

Fig. 5; Range (C_{max}-C_{min}) (µg/m^3) of NO_2 concentrations at rush-hour, estimated for 16 wind directions.

Also, model results for different wind directions, neutral atmospheric stability and the most probable wind speed for each wind direction (3m/s for NE, ENE, WNW and NW; 4m/s for N, NNE, E, SW, WSW, W and NNW; 5m/s for S and SSW; 7 m/s for ESE, SE and SSE) have been analysed. Horizontal distributions of NO_2 hourly concentration for eight wind directions are illustrated in Figure 6.

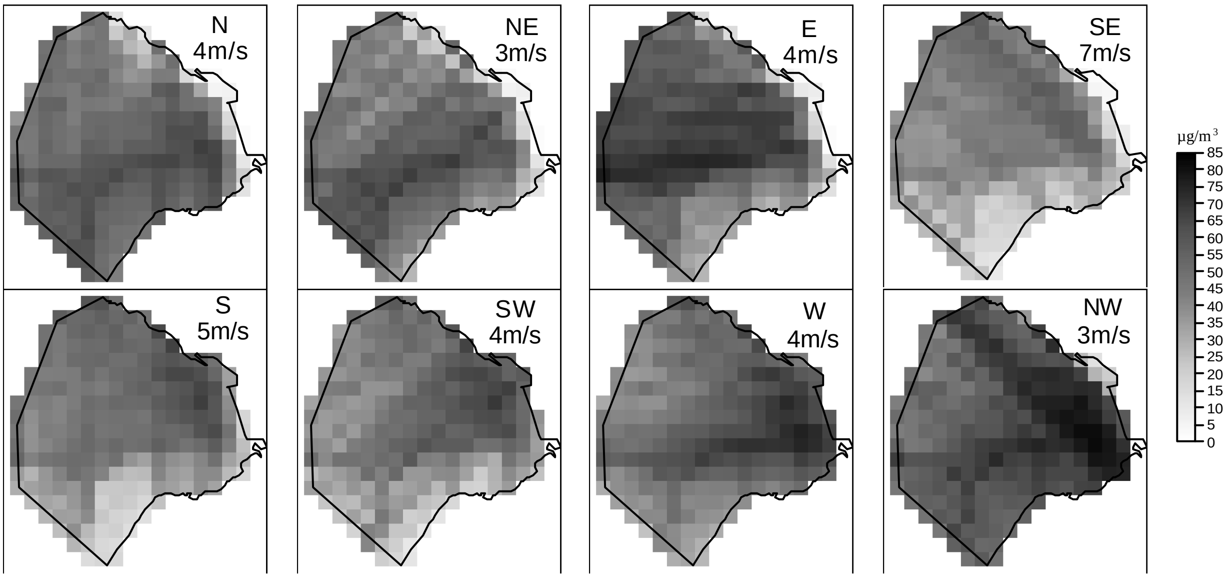

Fig. 6; Estimated NO_2 hourly concentrations assuming rush-hour emissions, neutral atmospheric stability and wind speed and wind direction indicated in each plot.

Higher concentration values (>80µg/m^3) result for wind directions WNW and NW with the lowest wind speed (3m/s) at downtown.

Wind rose of most probable wind speeds (3 – 7 m/s) at rush-hour (08:00PM) shows high frequency of winds from E (19.0%) and ESE (17.0%) and few cases with wind from WNW (2.0%) and W (3.1%) (Figure 7). Wind directions WNW (2.0%) and NW (5.7%), associated with the highest air pollution levels in the city may occur 28 days a year.

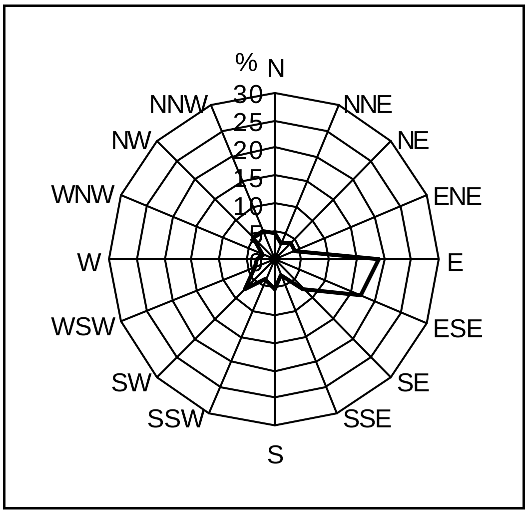

Fig. 7; Wind rose of most probable wind speeds at 08:00 PM

CONCLUSIONS

Air pollutants emissions in a city are one of the most important factors responsible for its air quality. However, emissions at surrounding areas may affect the air quality of the urban area. This is the case of the city of Buenos Aires (CBA). Buenos Aires is bounded by the wide de la Plata River at east and by urban districts of the Greater Buenos Aires (GBA) at other directions. The urban atmospheric dispersion model DAUMOD has been applied to the NO_x emissions in the Metropolitan Area of Buenos Aires considering three years of hourly meteorological data. Results for 08:00PM (rush-hour) reveal that NO_2 hourly concentrations may exceed the Air Quality Standard (0.376mg/m^3) in 4km^2 downtown and they may be between (0.190-0.376)mg/m^3 in 48km^2 of the city. The influence of the heterogeneous surrounding areas on the air quality of CBA has been studied on the basis of the variation of the spatial distribution of air pollutant concentrations due to wind direction variation.

Results show that concentrations levels in the city are not always low when wind blows from the wide river. For N, NNE, NE, ENE and E winds, concentrations near the coast are low and slowly increase with downwind distance. On the other hand, the highest concentration values can be found with W, WNW, NW or NNW winds, when polluted air is blown towards the city from a freeway located NW.

In the central area of the city, concentrations at rush-hour show little variation with wind direction. The largest variations of these hourly concentration values with wind direction are located on the coast, where the range of NO_2 hourly concentration estimations is greater than 60µg/m^3 and may reach 100.5µg/m^3.

Considering the most probable wind speed for each wind direction, the highest NO_2 concentrations have been obtained at downtown, for wind directions WNW and NW and a wind speed of 3m/s. These conditions may occur 28 days a year.

ACKNOWLEDGEMENTS
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