HIGH RESOLUTION MAPS OF ANNUAL NO_X AND NO_2 CONCENTRATIONS IN AN INFLUENCED RURAL AREA USING A DETERMINISTIC MODELLING METHOD

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INTRODUCTION

The application of Directive 1999/30/EC on Ambient Air Quality Assessment and Management requires the assessment of air quality all over the territory included rural areas. In these area we have generally a few number of monitoring stations because of the low density of emission sources. Therefore we have to used numerical tools to generate concentrations fields in these areas and to determine maps of average annual values. The main goal is to select the most operational technique using Eulerian transport numerical model to determine, with a miminum of data, the yearly concentration field, and to evaluate this model in front of geostatistical or statistical techniques. To reach this goal we have to evaluate the influence of input meteorological data sets. different kinds of data sets have been used: Chronological and statistical. The last ones are obtained by extracting a limited number of meteorological conditions which are supposed to be representative of the whole year. We used two methods to extract such data, the hierarchical clustering and the statistical wind rose. Afterwards we have alsoto evaluate the good parameters for the boundaries conditions. The deterministic model has been used to map annual NO_x and NO_2 concentrations. To conclude we compare deterministic model with statistical and geostatistical ones.

METHODOLOGY OF YEARLY MAP CALCULATION

Overview of study area

Located in the south of Paris, the study area cover 66 x 66 km² mainly in rural field between Paris and Orléans (Fig. 1). This study area has a temperate climate. The predominant wind directions are northeast and southwest. The study domain is influenced by both outer distant sources like the Parisian conurbation, and local inner sources like motorways .

Dispersion model and Boundary conditions

Simulations were performed with the 3D transport Eulerian model TRANSCHIM[1]. TRANSCHIM is an air quality model which second order scheme in horizontal direction and semi-implicit scheme in vertical direction. The horizontal resolution is 1 km and the vertical one 10 m. In this study the model was used without chemistry (i.e., no photo-oxydant mechanism). Surface concentrations data of CHIMERE continental[2] *provided* the boundary conditions. Since the CHIMERE horizontal resolution is larger than the one use in TRANSCHIM, CHIMERE data were interpolated on the TRANSHIM grid.

At first the model was calibrated with two nitrogen dioxide diffusive tube sampling measurement campaigns (15 days each) carried out over the 4356 km² of the domain. The spatial resolution of sampling was 11 km and 5,5 km when refined. These campaigns have

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[2] http://euler.lmd.polytechnique.fr/chimere/

been used to check the model result accuracy and good agreement have been found between calculated and measured values.

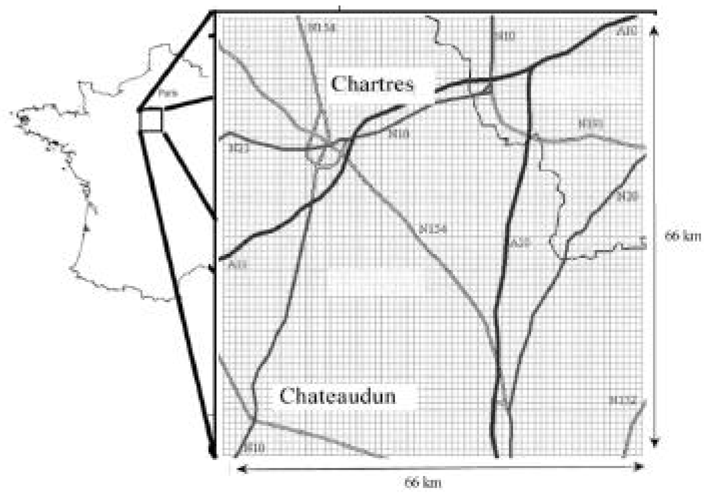

Fig. 1; Overview of the study area

Emission inventory

We used two types of annual NO_x emissions inventories: (1) a local inventory at 1x1 km² resolution; (2) the large scale EMEP inventory at 50x50 km² resolution. We need to aggregate these two different information in order to cover all the domain (Fig. 2). The motorway traffic and the city of Chartres account for the major part the emissions. We build two inventories, one for cold period and an other without domestic heating for warm period.

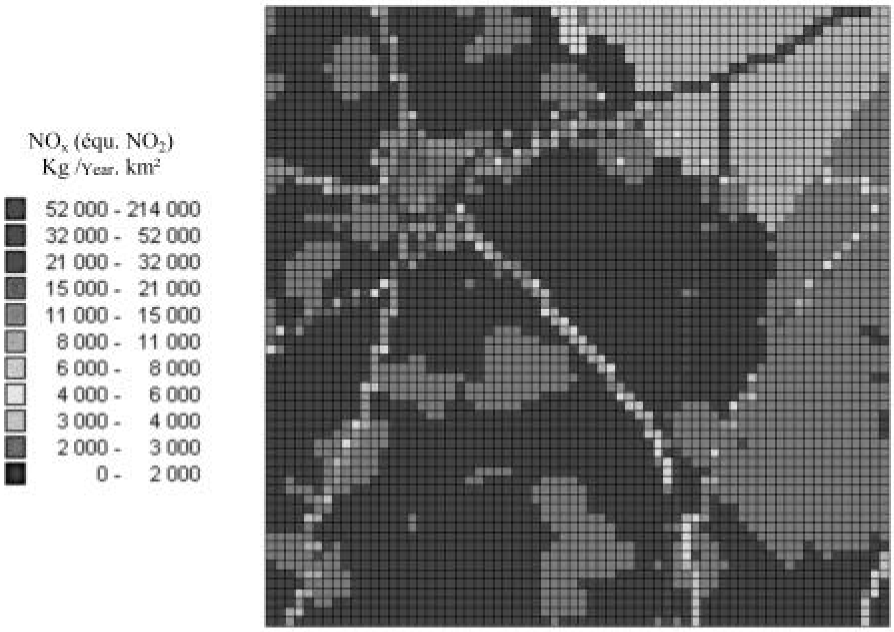

Fig.2; NO_X emission distribution in 2002.

Meteorological data

Vertical profiles of ARPEGE[3] *provided* meteorological data. ARPEGE data were interpolated in the calculated domain. In order to determine yearly maps, we used different methods: the TRANSCHIM model is provided with all the ARPEGE data (chronological

[3] Météo France. www.meteofrance.com

data), or data representing a limited number of meteorological conditions, scenarios, which are extracted from the ARPEGE chronological data over one year. It is assumed these scenarios are representative of conditions occurring over one year. Two methods have been used to extract such data, the hierarchical clustering and the statistical wind rose. We have to evaluate the influence of these two approaches on the pollutant yearly maps.

Chronological data:
We used one year of ARPEGE data (10/04/2003 to 09/04/2004) with a 3 hour time step and averaged on four different locations in the domain. The available parameters are the pressure, temperature, wind speed and direction from 10 to 1500 m high.

Hierarchical clustering:
From one year of ARPEGE data (10/04/2003 to 09/04/2004) we defined different classes using hierarchical clustering technique (*Sirois*, 1999).These classes correspond to typical meteorological situations occurring over the domain, ex: Strong south wind (dir : 181°, u= 8,2 m/s) or low north wind (dir : 47°, u=2,5 m/s). We chose a clustering level providing 64 classes.

Statistical wind rose:
The last method used to determine meteorological situation was the wind rose. We decide to use the same total number of classes as in the previous method. So from the French Met office Data, 16 classes of wind direction (every 22.5 degres) and 4 speed classes (<2 m/s, 2-5, 5-8, >8 m/s) were defined.

NOX AND NO2 YEARLY RESULTS

Maps of annual mean concentrations of NO_x and NO_2 were calculated using chronological data, both for boundary conditions and meteorology. The results obtained with this sequential method were compared with measurements at three monitoring stations - two urban, one rural (represented by symbols on fig. 3)– and showed good agreement with the quality objective (50% of uncertainty) fixed by the Directive for the modeling of annual NO_x and NO_2 concentrations (Fig. 3). Model provide a NO_2 annual mean average value of 17.06 µg/m3 in the domain, and the influence of the major sources (motorway and city area) was truly depict by the simulation, as shown in fig.3.

Maps of annual mean concentrations of NO_x and NO_2 were calculated with the scenario approach using the two statistical methods to classify meteorological data. The statistical wind rose method results show good agreement with those obtained by the sequential method all over the domain. The statistical scores, bias, correlation coefficient, root mean square error and normalized mean square error as defined in reference (Kumar and Vashisth, 1999 ; Kumar and Sharan, 1996 ; Kumar et al., 1999 ; Hanna et al.,1991 ; Hanna, 1988 ; Hanna and Heinhold, 1985) have been calculated and they are very close (Table 1). We obtains differences lower than 10% between calculated fields obtained with the sequential and statistical approaches. Obviously the statistical techniques are the quickest in time calculations.

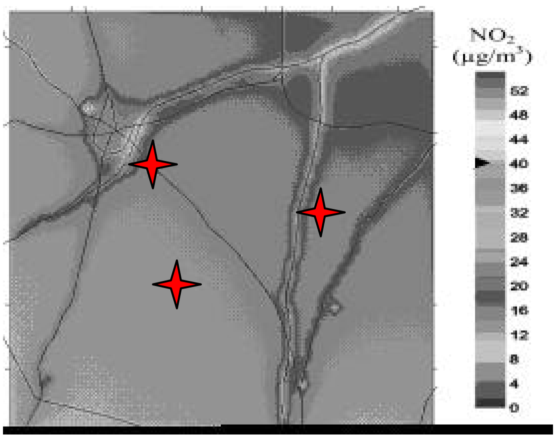

Fig. 3; Yearly concentration distribution in area. The symbols represent the locations of the monitoring stations used for comparison

Table 1. Statistical scores: calculated using values at three locations in the domain as in figure 3

	Chronological data	Wind rose	Clustering
Bias (µ/m3)	0.13	0.16	0.15
R^2	0.98	0.97	0.96
RMSE (µ/m3)	0.71	0.72	0.73
NMSE	0.0016	0.0017	0.0019

COMPARISON OF MAPPING TECHNIQUES

To evaluate the performance of deterministic model, we compared the previous calculated annual maps with two others approaches.

Geostatistic approach: The geostatistical mapping algorithm, called kriging, is based on the specific spatial behaviour of the mapped pollutant via a spatial correlation function calculated from the sample measurements (Chauvet, 1993). This method need to define a variogram, which is a function describing the degree of spatial dependency of the phenomena .We used the variogram in the kriging of the yearly maps. The geostatistical approach needs numerous measures (up than 30) to have a good representation of the concentration field. We realised two measuring campaigns (over 100 NO2 passive sampling in each campaign) in july 2002 and april 2003. The average maps was used to described the anual NO2 field of concentration.
Stedman approach: This is an empirical approach, in which the NO2 concentration was determined from NO2 rural concentration (*Stedman J.R*, 1995) by equation (1) :

$$\text{Conc(NO2)} = \text{Conc(NO2)rural} + \text{k.Emission(NO2)} \quad (1)$$

The NO2 concentration in every points of the domain was linked with rural NO2 concentration measure with the equation (1) With this equation, the concentration at a location in the domaine is determined knowing the rural concentration and the local NO2 emissions. The advantage of such method is that there exists everywhere a monitoring network providing the average rural concentrations and the emission inventories are at this time available.We compare the relevancy of a high resolution spatial approach of the modeling methods with the other methods (Table 2) This approach seem to be a good way to generate mean annual concentration field on slightly exposed territory. The others techniques seems to smooth the concentration field and the hot spot are not clearly described.

	Min (µg/m3)	Max (µg/m3)	Average (µg/m3)	Standard deviation (µg/m3)
Transchim model	14.52	49.45	17.06	2.69
Geostatistic	6.49	27.84	12.86	3.30
Calcul Stedman	7.69	22.52	12.41	2.70

Table 2. Comparison of NO2 calculation on the area with different methods

CONCLUSION

The aim of this study is to demonstrate the accuracy of using numerical operational model to describe the air quality all over the territory including rural areas. In these area we have a few number of monitoring stations, therefore we have to used mapping tools to generate maps of average annual values. The main goal is to select the most operational technique using a minimum of data. The study shows what we can use an Eulerian model with meteorological data provided by the weather forecast national organisms to generate annual concentration maps of NO2 on rural zone influenced by urban zones. The result show also an uncertainty lower than the air quality guideline. A better resolution of concentration gradients is achieved with the eulerian transport model than for the others methods (statistics, and geostatistics).

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