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Using different spatial scale measurements in a geostatistically based approach for mapping atmospheric nitrogen dioxide concentrations. Application to the French Centre region.

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Abstract:

Passive sampling surveys followed by geostatistical data analysis have become a common and efficient way of mapping background concentrations at regional and urban scale. Traffic related pollution is also a matter of concern as regards people exposure but since it acts at shorter spatiotemporal scales, it is usually not integrated in the same maps. However, to provide more comprehensive information to the authorities and the public, the organisms responsible for air quality monitoring are searching for innovative ways of representing background and roadside concentrations together. A methodology based on geostatistics and the examination of the relationships between season averaged nitrogen dioxide concentrations and auxiliary variables is proposed in this study. It is applied to data collected in the French Centre region.

Keywords: nitrogen dioxide, traffic related pollution, geostatistics, auxiliary variables.

1. Introduction

Maps showing concentrations of pollutants are an efficient way of informing policy makers and the public about air quality. Geostatistical methods are now commonly applied to represent past and current pollution situations at the city or the region scale (Rouil & Malherbe, 2003). Input data are usually obtained from passive diffusion tube surveys which enable a wide sampling coverage. In common practice, only urban, suburban or rural background sites are selected for interpolation ; industry or traffic related air pollution is rather the subject of specific studies. Resulting background pollution maps generally offer a correct view of the spatial distribution of concentrations but do not precisely account for concentration gradients near major sources. In particular, they can underestimate pollution levels along busy roads.

To get a more accurate picture of the situation and supply more comprehensive information about air quality, the French organisms in charge of air quality monitoring (the AASQAs) are wondering on how various spatial scale measurements could be treated together. Therefore, this study is aimed at integrating NO₂ background and

proximity related data into a single map. This pilot project results from a collaboration between INERIS and the regional AASQA LIG'AIR.

In that context LIG'AIR carried out two annual sampling programs in the region Centre : 1) from April 2003 to March 2004, samplers were installed at 19 sites across the region within a few meters from the main road intersections ; 2) from January 2005 to December 2005, samplers were set up at 49 locations in urban background areas and small towns. In both surveys, passive diffusion tubes were exposed for monthly periods, providing twelve records at each site.

2. Methodology

The developed approach is based on a detailed analysis of background and roadside NO₂ measurements and of the correlation between concentrations and auxiliary variables. It involves four steps: 1) Available secondary information is processed to find out explanatory variables for NO₂ background concentrations. 2) Using those variables, regional NO₂ background concentrations are calculated on a 5-kilometer resolution grid by kriging with external drift (or linear regression and kriging of residuals). Data under direct influence of traffic are not incorporated at this stage since their spatial representativeness is much lower than the grid mesh size. 3) Background concentrations are estimated at the roadside sampling points and compared to the measured values. The difference between the two is modelled by a statistical relationship, with NO_x emissions as a predictor. 4) The estimation grid is refined along the major roads. In the smaller cells, background concentrations are corrected by an additional term driven from the previously fitted model.

3. Results

The four-step methodology was applied to average winter 2005 data with help of the geostatistical software package Isatis (Géovariances).

3.1 Looking for explanatory variables

Auxiliary information includes : the regional inventory of NO_x emissions established by LIG'AIR on a 1 km x 1 km grid; the geographical distribution of 44 land cover classes (CORINE land cover database, IFEN) and sub-communal population data (INSEE). Data processing programs have been developed in a geographical information system (ArcView, ESRI, 9.0) to calculate various density variables within radius of 500 m, 1 km, 2 km, 5 km and 10 km around the 49 background sites : land cover rate [%] per CORINE class; NO_x emission density [kg/m²]; population density [#inhabitants/km²]. NO₂ background concentrations are linearly correlated with the log-transformed urbanisation rate, NO_x emission density and population density.

Whatever the variable, the correlation coefficient increases, then decreases, with the calculation radius, showing a maximum at 2 km for the urbanisation rate and NO_x emission density (correlation of 0.87 and 0.90 respectively) and 5 km for population density (correlation of 0.88). Such results highlight the efficiency of GIS tools to process secondary information and demonstrate the relevance of a detailed correlation

analysis. Without any treatment (i.e. when the value of the closest grid point is attributed to each sampling site) the correlation between NO₂ concentrations and the NO_x emission inventory drops to 0.58.

3.2 Mapping NO₂ background concentrations

An estimation grid of 5-km resolution is defined over the Centre region. Running the GIS programs, the three variables most correlated to NO₂ concentration levels are computed at the centre of each grid cell. As they are strongly correlated together, they are only used by one in the geostatistical model and the estimation.

Several methods are considered : ordinary kriging (OK), cokriging (CK), linear regression followed by kriging of residuals (RK), kriging with external drift (KED). They are compared by cross validation and their performance in urban environment is evaluated against data from monitoring stations. The last two methods, with a trend based on population or emission density, give the best results. RK or KED actually provide much more realistic maps than OK but the choice of the auxiliary variable proves determining (Figure 1).

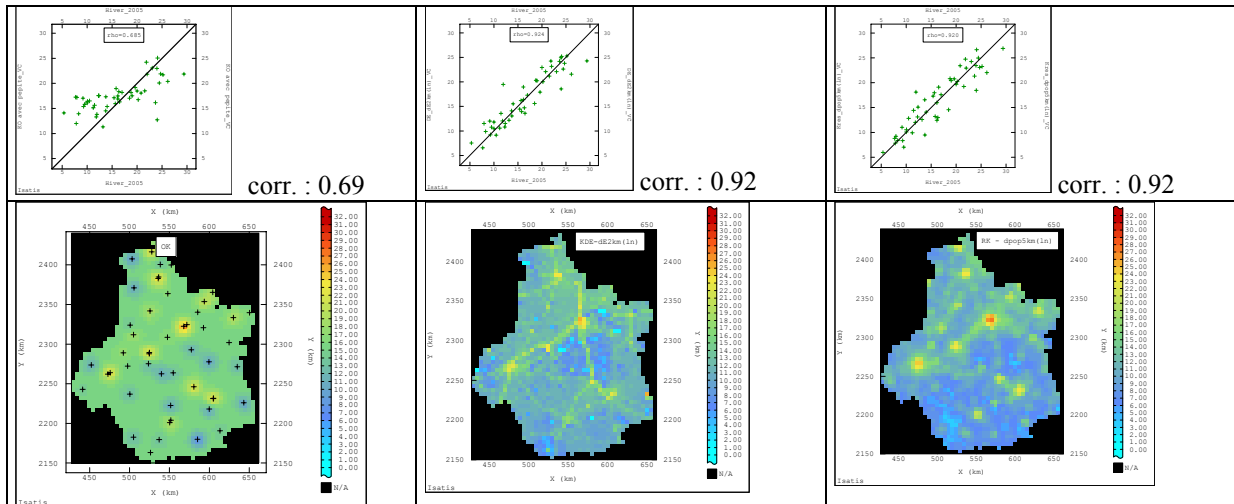


Figure 1 – From left to right: OK (black points: location of the sampling sites); KED using emission density within a 2-km radius; RK using population density within a 5-km radius. Above : Scatter plots between measurements and cross-validation estimates.

3.3 Modelling the difference between background and traffic-related NO₂ concentrations

Auxiliary variables are a valuable resource for representing the increase in concentrations near pollution sources but they are not sufficient to reproduce the measured levels. Background concentrations are estimated for winter 2005 at the 19 roadside sampling sites¹. The estimates are compared to the available measurements collected a year before. (We checked on the two roadside automatic monitoring stations that winter 2005 concentrations could reasonably be approximated by winter 2004 values). An underestimation (called Δ) ranging from 32% to 62% is observed. This gap

¹ As in the previous steps, emission and population densities are first computed at those sites.

can be interpreted as a concentration increment due to the local impact of the road (Stedman et al., 2001). It turns out to be correlated to the NO_x emission density within a 1-km radius (Figure 2). So it is modelled by a linear relationship: $\Delta = a.dE1km+b$ (1) where dE1km is the emission density expressed in kg/m².

3.4 Correcting the estimation along the major roads

A mesh size of 250 m is defined along the major roads using ArcView. As in step 2, density variables are calculated at the centre of each smaller cell. Because of high computing time, this is done only for a part of the region centred on the city of Blois. The higher resolution grid and the computed variables are then exported to Isatis. Roadside concentrations are finally obtained by adding the roadside increment derived from model (1) to background concentrations estimated by kriging (Figure 2).

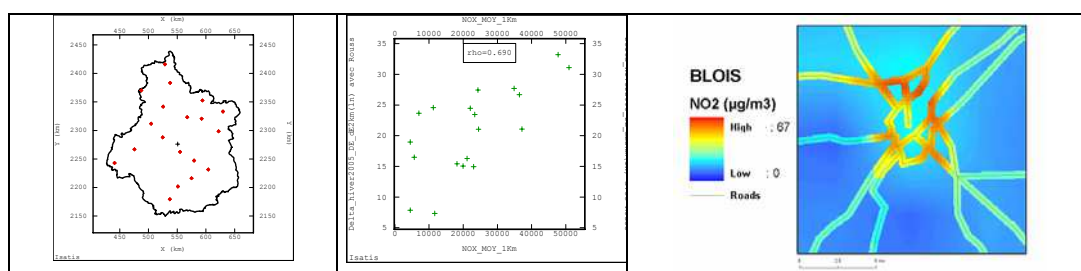


Figure 2 – From left to right: location of the 19 roadside sampling points; comparison between the estimated roadside increment and NO_x emission density within a 1km-radius; corrected NO₂ concentrations in the area of Blois.

4. Discussion

In this study, a methodology is proposed for taking advantage of different spatial scale measurements and auxiliary information and providing more comprehensive air quality maps. Though we were restricted by computing resources, the first results are promising and the approach is still being developed : application of the methodology to summer and annual data; extension to other parts of the region; improvement of the roadside increment model. Moreover, measurements currently conducted by LIG³Air at 11 roadside locations should deliver useful data for validation.

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