

Mapping air quality using a geostatistical approach: Application to a regional ozone measurement campaign in the North of France

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Abstract

During the summer 2000, six French associations certified for air quality monitoring (Associations Agréées de Surveillance de la Qualité de l'Air : AASQA) joined in to carry out a regional ozone measurement campaign using diffusive samplers. The goal of this campaign was to map the spatial distribution of ozone over several weeks applying geostatistical tools.

The analysis proceeded in several steps : first a statistical data analysis, then a variographic analysis so as to fit a variogram model and finally block-averaged estimation by kriging, taking the measurement error variance into account. 95% confidence intervals by conditional expectation were also computed to assess the spatial interpolation uncertainty.

The conclusion is that the variographic analysis reveals great differences in the spatial behaviour of ozone between rural, littoral and urban areas.

Introduction

In France the AASQAs (Air quality monitoring associations) are non-profit associations that have been certified by the Government for monitoring air quality, either at a local, departmental or regional level. Each AASQA has to equip its area with a network of fixed measurement stations, which fits the requirements of the European and national regulation on air quality. Monitoring strategy also includes measurement campaigns using mobile laboratories or passive diffusion samplers.

Tropospheric ozone is a secondary pollutant formed by photochemical reaction of primary pollutants known as precursors (nitrogen oxides (NO_x), carbon monox-

ide (CO) and non-methane volatile organic compounds (NMVCOs)) in the presence of sunlight. Since weather conditions (sunshine, high temperatures and low winds) play an important part in the formation of ozone, pollution episodes occur mainly in summer, in urban, periurban and rural areas. Air pollution by ozone can have effects on human health (particularly the respiratory tract) and vegetation (crops and trees).

The European and national legislation set thresholds for ozone concentrations in the air to protect human health and vegetation, as well as a population information threshold and a population warning (alert) threshold:

- ❖ Population information threshold: $180 \mu\text{g}/\text{m}^3$ for the mean value over one hour.
- ❖ Protection of human health: $110 \mu\text{g}/\text{m}^3$ for the mean value over eight hours.
- ❖ Protection of vegetation threshold: $200 \mu\text{g}/\text{m}^3$ for the mean value over one hour and $65 \mu\text{g}/\text{m}^3$ for the mean value over 24 hours.
- ❖ Population alert threshold: $360 \mu\text{g}/\text{m}^3$ for the mean over one hours.

For a better understanding of the ozone pollution and for more complete information of the public, five AASQAs joined in to carry out a regional ozone measurement campaign using diffusive samplers during summer 2000.

The study region is located in the North of France (Nord-Pas-De-Calais, Picardie, Normandie and Ile de France regions) and extends over approximately 560 ha. It is most rural type but includes several large urban areas.

The ozone measurement campaign was conducted from June 26 to September 4, 2000 (10 weeks). It provided weekly integrated ozone concentrations at more than 200 sampling sites in rural, suburban, urban and littoral zones. To calculate the variance of the measurement error, two or three diffusive samplers were installed at each site. The week from June 26 to July 3 is selected as an example to show the application of geostatistical techniques.

Materials and methods

Variographic analysis and variogram modelling are conducted distinguishing the different types of sampling sites.

Since the variance of the measurement error is known for each data, this term is added in the kriging system and kriging with measurement error is performed.

It is possible to provide a measurement of the uncertainty associated with the interpolated value using the kriging variance and the confidence intervals. The kriging variance represents the possible scattering of the real but unknown concentration around the estimated value. The width of the confidence interval gives us some idea about how uncertain we are about the ozone concentration.

The confidence intervals are calculated by conditional expectation assuming ozone concentrations follow a multigaussian distribution.

Results and discussion

Littoral data (mean grades: $92 \mu\text{g}/\text{m}^3$) are very few, so the spatial structure of the pollution phenomenon cannot be precisely described in this part of the domain. However their numerical values can be used in kriging (Figure 1).

If all the data are used for computing the experimental variogram, one gets a linear (Figure 2), therefore non stationary variogram : this behaviour is caused by the influence of the littoral data (Figure 3).

Sampling density is higher in urban and suburban zones (mean concentrations around $50 \mu\text{g}/\text{m}^3$), making it possible to model the small scale variability of ozone (less than thirty kilometres, Figure 4) and map concentrations in those areas.

Rural data (mean grades: $61 \mu\text{g}/\text{m}^3$) are well distributed in space, they represent a stationary phenomenon with a range comprised between 100 and 150 km (Figure 5).

The selected isotropic model is made of a nugget effect and two Gaussian structures of range 26 km and 136 km, see Figures 4 and 5 (NB: the nugget effect was adjusted when fitting the model. However, it was not used in kriging and the variance of the measurement error was provided instead for each data).

The estimates are between 32 and $101 \mu\text{g}/\text{m}^3$ (mean: $60 \mu\text{g}/\text{m}^3$, Figure 6). Ozone concentrations are higher on the littoral and lower in the urban areas (Paris, Lille, Rouen, Le Havre, Amiens, Dunkerque, ...). This can be explained by the destruction of ozone in presence of nitrogen oxides, pollutants mainly resulting from traffic, heating and some industries.

The lower confidence limits are between 32 and $84 \mu\text{g}/\text{m}^3$ (mean: $50 \mu\text{g}/\text{m}^3$) and the upper confidence limits are between 40 and $121 \mu\text{g}/\text{m}^3$ (mean: $73 \mu\text{g}/\text{m}^3$, Figure 7).

As expected kriging variance decreases with sampling density (cities).

The width of the confidence intervals is consistent with the kriging variance being larger in the less sampled areas. It also increases in regions of higher concentrations (littoral). If the threshold value set for the protection of vegetation over 24 hours ($65 \mu\text{g}/\text{m}^3$) is taken into account, the greatest number of exceedances could be recorded on the littoral and in

the East of Paris (upper confidence limits between 90 and 120 $\mu\text{g}/\text{m}^3$). This assumption should be verified on data recorded by the permanent stations of the monitoring network.

Conclusion

The spatial variability of ozone concentrations depends on the type of area (littoral, rural, suburban, urban). When mapping at a regional scale, the data used in the variographic analysis should be considered carefully. In this study, rural data were selected to calculate the experimental variogram, urban and suburban measurements being useful for getting information on small scale variability.

Confidence intervals calculated by conditional expectation provide additional information on spatial uncertainty and possible threshold exceedances.

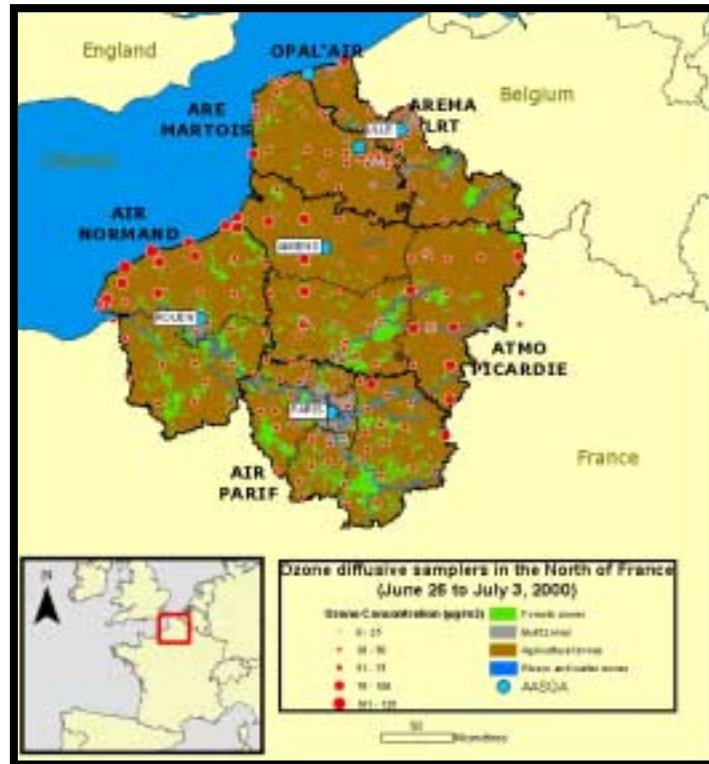


Fig. 1.: Ozone diffusive samplers in the North of France (June 26 to July 3, 2000).

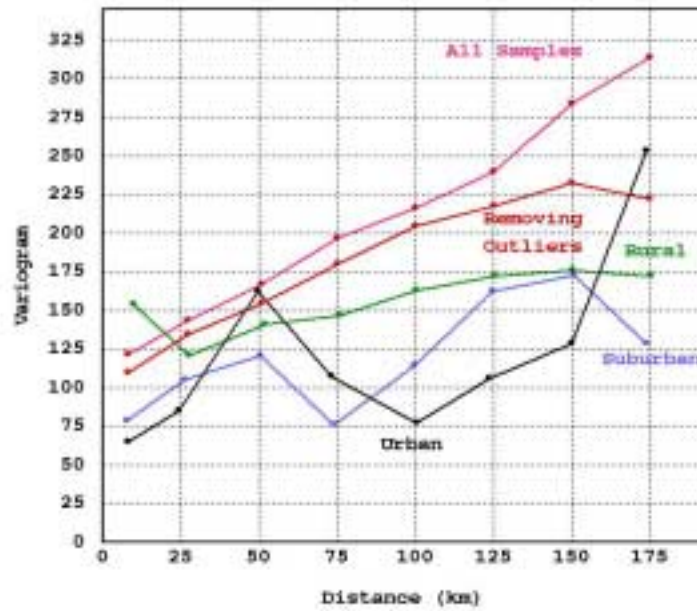


Fig. 2.: Experimental variograms for each type of sampling sites and for all samplers with or without outliers.

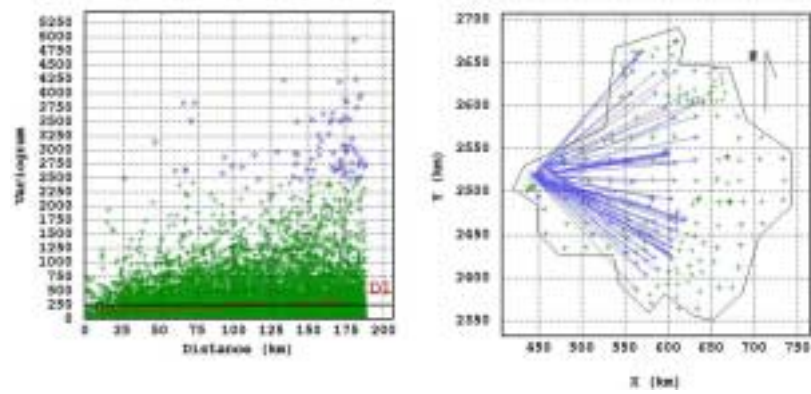


Fig. 3.: Variogram cloud, basemap and the effect of the outliers

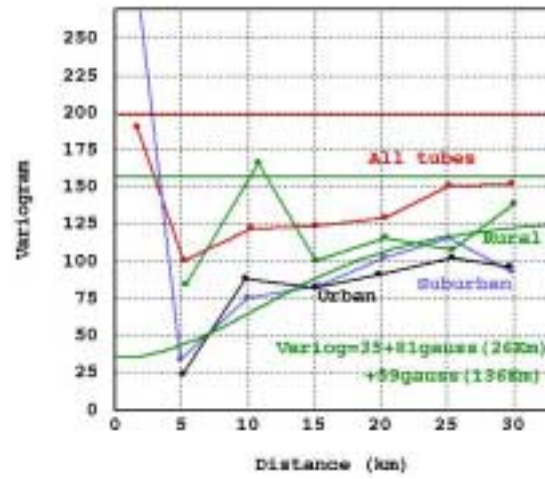


Fig. 4.: Variogram model (0-30Km)

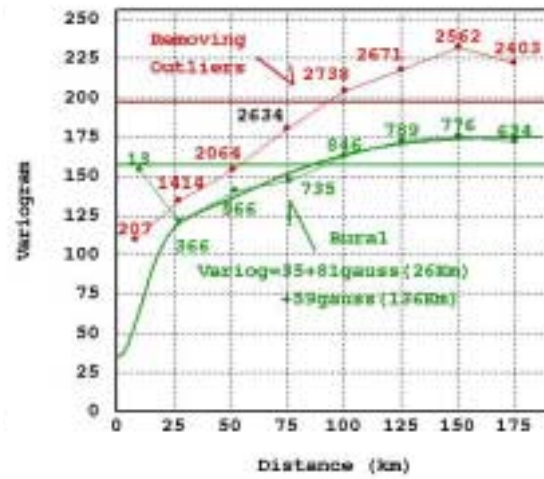


Fig. 5.: Variogram model (0-175Km)

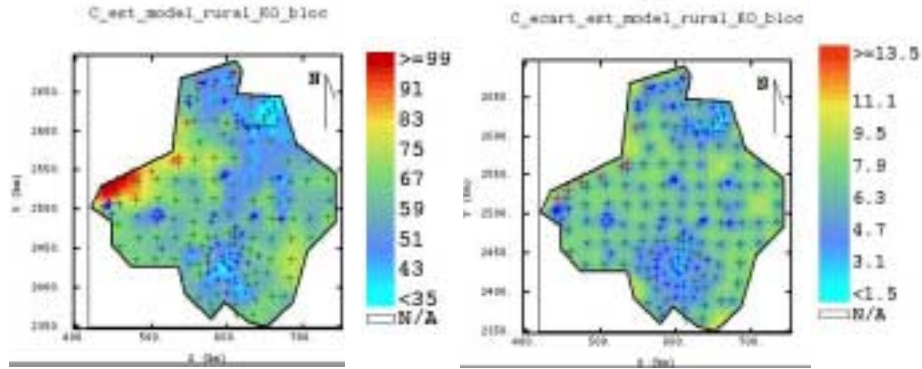


Fig. 6.: Ordinary kriging estimates and kriging variance (with variance measurement error)

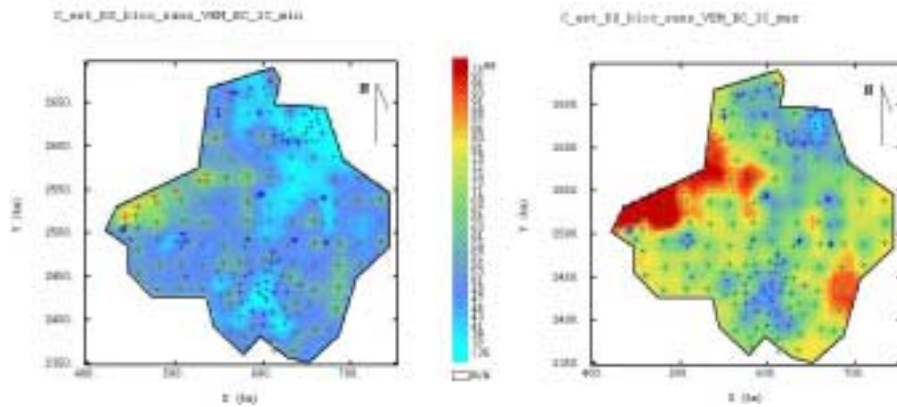


Fig. 7.: Low and high limits of the confidence intervals calculated by conditional expectation

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