Using systematic diffusive sampling campaigns and geostatistics to map air pollution in Portugal

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Abstract

In the context of the European Framework Directive (96/62/EC) preliminary assessment and the definition of zones, diffusive sampling campaigns applied for the first time at a country level were performed with the main objective to evaluate background concentrations throughout the country aiming both to complement monitoring stations results and to analyse spatial distribution patterns of sulphur dioxide, nitrogen dioxide, and ozone under different meteorological conditions. The first campaign occurred during Summer period (July 2000) and the second in Springtime, a colder period (May 2001). Samplers were distributed throughout background locations only using a systematic grid of 20x20 Km. The monitoring equipment used was Radiello®. Fondazione Salvatore Maugeri in Padua, Italy performed the analysis. Passive samplers were exposed during one-week period.

The results of the campaigns were introduced in the ESRI Geographic Information System software ArcGIS and the extension Geostatistical Analyst was used to obtain distribution maps. Several interpolation methods available were tested. The selected method was the geostatistical interpolation method – kriging, because it relies on both statistical and deterministic methods to create a surface and assesses the uncertainty of the predictions. Both prediction and error maps are presented for the Summer and Spring campaigns.

The produced maps showed that the levels were low for both nitrogen dioxide and sulphur dioxide but high for ozone especially in inland areas, where currently no monitoring stations exist. In the case of nitrogen dioxide results are higher closer to urban areas. Road traffic levels are the main reason for these higher levels. Regarding sulphur dioxide levels, the industrial areas are quite well highlighted in the map. Finally, with respect to ozone concentrations the altitude and the precursors transport from coastal to inland areas seem to play an important role.

Introduction

The new air quality European Directives make a distinction between air quality assessment based on measurements alone, and assessment that uses measurements and other techniques, such as emission inventories, indicative measurement methods, and air quality modelling. The use of supplementary methods for legislative purposes was introduced because such techniques will give in combination with fixed measurements, considerably more information than measurements alone. That is applied to designate zones, to measure concentrations, to determine the spatial concentration distribution in zones, to analyse the causes of air pollution, ad human and ecosystem exposure and risk.

The interpolation methods which rely on the similarity of nearby sample points to create a surface, combined with indicative measurements campaigns using diffusive sampling can be a very useful tool for supplementary assessment of air quality in obtaining spatial concentration distribution in large zones where no continuous monitoring exists.

In the context of the European Framework Directive (96/62/EC) preliminary assessment, two measurement campaigns of the background levels of sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3) were performed. The main objective of these measurement campaigns was to evaluate the distribution of the pollutant levels in Portugal, in the background sites. These campaigns were crucial since the concentrations of the three pollutants were unknown in a large area of the country.

The option of using diffusive sampling to perform these campaigns was based on: a) the possibility of working in the same time scale for all the country, allowing a comparison of the air quality in different areas for the same period, and b) the spatial distribution that you can cover with this kind of equipment (Stevenson *et al*, 1999).

Both campaigns had the same configuration, except regarding the climate and weather conditions. The campaigns were performed in a period of two weeks each, period needed to place and collect all the diffusive tubes. The selected dates were:

→ Between July, 17th and July, 31st of 2000 for the first campaign (summer period);
→ Between May, 7th and May, 21st of 2001 for the second campaign (spring period).

The samples were exposed for one week. Spatially, a systematic sampling grid of 20 x 20 km^2 across Portugal Mainland was implemented leading us to a selection of a total number of 236 sampling locations– Figure 1.

Only background sites were selected since the purpose of the research was to try to obtain concentration maps for all the territory. It was, indeed, necessary to have locations that were the most representative sites for each cell. The Radiello ® diffusive sampling cartridges were used. Fondazione Salvatore Maugeri, in Padua - Italy, performed all the analyses for the campaigns described in this paper.

No duplicates or triplicates were typically installed, except on one sampling location where five tubes were installed. The purpose was to follow a minimum quality assurance / quality control evaluation of the collected samples. This location is Monte Velho, where the Portuguese official network has a background air quality monitoring station measuring the same pollutants sampled. It is important to note that one of the major objectives of the work is to get a relative difference between areas and an approximation of the exact concentration averages for each pollutant. Therefore, the accuracy and precision of diffuse sampling is fully compatible with these goals.

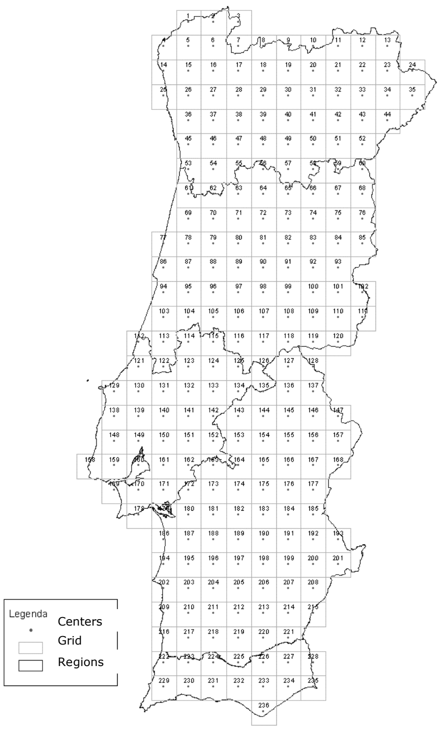

Fig. 1. Sampling locations adopted for Portugal Mainland

Methodology

The results of the campaigns were introduced in the ESRI Geographic Information System software ArcGIS and the extension Geostatistical Analyst was used to obtain distribution maps. Several interpolation methods available such as IDW (Inverse Distance Weighted) were tested. (Figure 2)

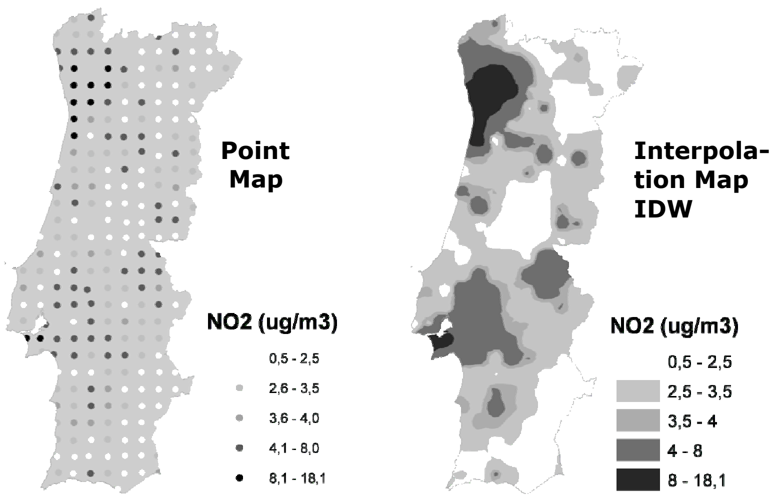

Fig. 2. Point and interpolation map (IDW)

The selected method was the geostatistical interpolation method – kriging, because it relies on both statistical and deterministic methods to create a surface and assesses the uncertainty of the predictions. Both prediction and error maps were performed for the Summer and Spring campaigns. (Figure 3)

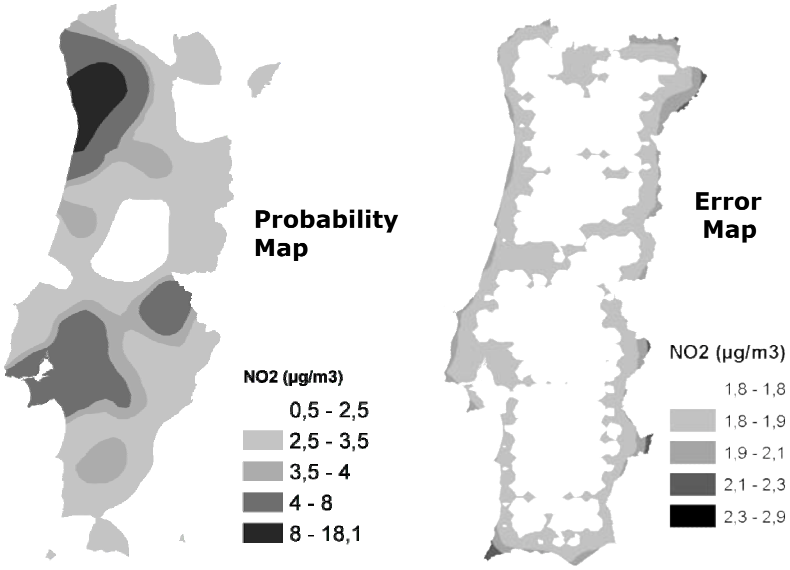

Fig. 3. Probability and error maps (Kriging)

The final distribution map produced for each pollutant uses the maximum value between campaigns. These maps represent the maximum probable value for each location. (Figure 4)

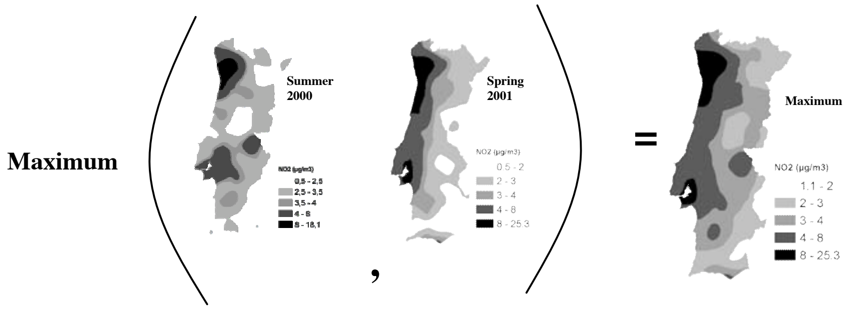

Fig. 3. – The maximum between campaigns to obtain the final maps

Maps representing the factors that influence air quality patterns were also produced for discussion purposes:

- Type and location of the major air pollution stationary sources;
- Population density and major agglomerations.
- Topography
- Meteorological conditions

Air quality managing zones were delimited based on administrative regions, pollutant background levels distribution maps, topography, climate and meteorological patterns, population density and land use.

Results and discussion

As we can see in Figure 5, relating NO_2 Maximum concentrations of 1st and 2a campaigns, population density and major industrial sources, NO_2 background results are generally low but are higher closer to urban areas (high population density) caused by high road traffic levels. The industrial point sources seams to have also some influence in the background concentrations of NO_2.

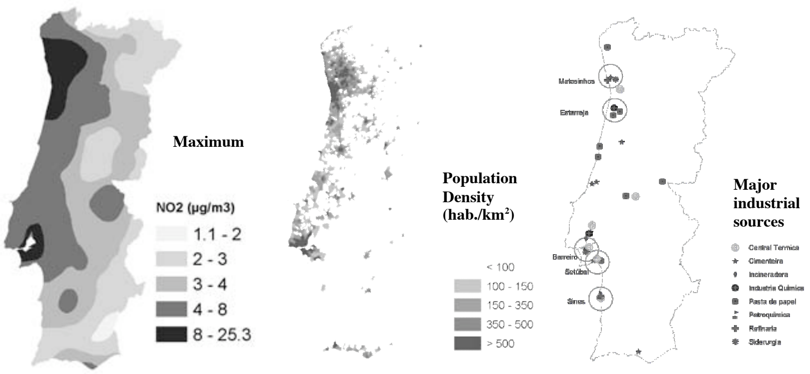

Fig. 4. NO_2 Maximum background concentrations of 1st and 2a campaigns, population density and major industrial sources

Figure 6, shows that background SO_2 levels are also low and the pattern of concentrations, can be explained looking to the location of the main sources of SO_2 and the wind regime in both campaigns.

Fig. 5. SO_2 Maximum background concentrations of 1st and 2a campaigns, wind roses and major industrial sources

Finally, the background concentration values found for O_3 are, in absolute values, as we can see in Figure 7, very high. Topography, wind direction, and the location of the main sources of ozone precursors (NOx and VOC´s) were the most relevant factors.

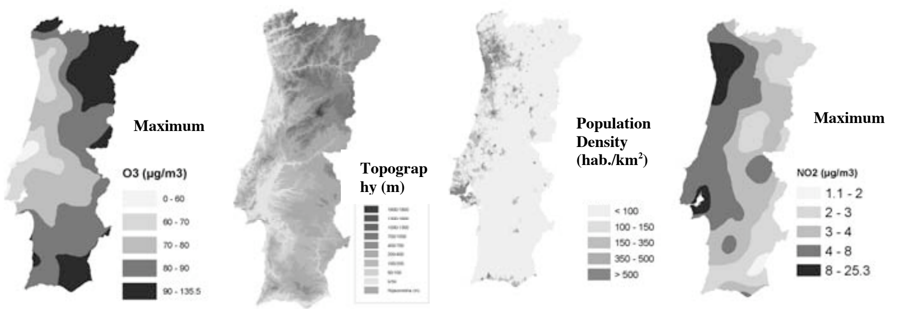

Fig. 6. O_3 Maximum background concentrations of 1st and 2a campaigns, topography, wind roses and major industrial sources

The final maps of pollutant background levels distribution obtained were very important in the definition of the 10 air quality managing zones delimited for Portuguese Continental Regions. Also important were regional and municipality administrative limits, topography, climate and meteorological patterns, population density and land use maps. (Figure 8)

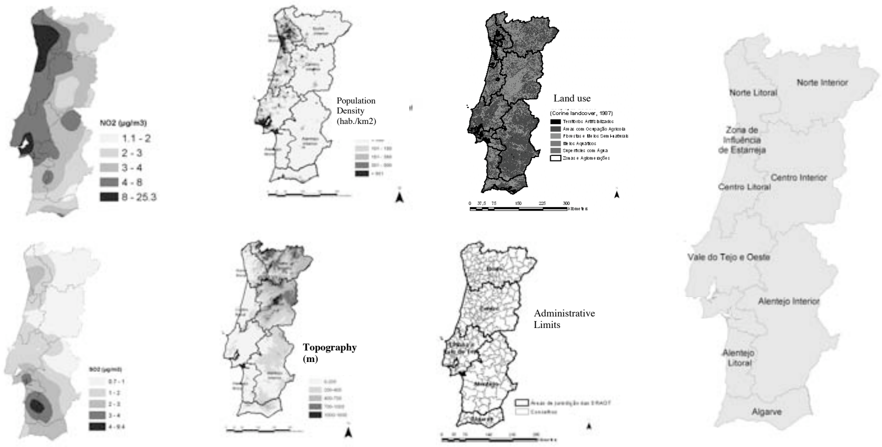

Fig. 7. Zones defined for Portugal, regional and municipality administrative limits, topography, climate and meteorological patterns, population density and land use maps

Conclusions

The geostatistical interpolation method - Kriging provides the possibility of obtaining probability and error maps which are very useful on the perception of patterns and the interpretation of data;

The use of diffusive sampling method within a systematic grid (20x20 Km2) combined with the geostatistical interpolation method Kriging as proved to be a low-cost and efficient way for mapping of SO_2, NO_2 and O_3 background levels in a country like Portugal;

Making maps of the potential factors that influence air quality such as wind roses of both campaigns, population density, major point industrial sources and topography was also helpful in the interpretation of campaign results;

The pollutant distribution maps produced were fundamental in the delimitation of the 10 zones for Portuguese Continental Regions. Also important were the administrative limits, topography, climate and meteorological patterns, population density and land use maps.

References

European Union (1996) *Council Directive 96/62/EC of 27 September 1996 on ambient air quality assess and management (“Framework Directive*). Official Journal of the European Communities N.er 296/55.

Ferreira, F.,Tente, H., Torres, P., Mesquita, S., Santos, E., Esgalhado, F., Jardim, D., (2001). *Background levels of Sulphur Dioxide, Nitrogen Dioxide and Ozone in Portugal,* International conference Measuring Air Pollutants by Diffusive Sampling, Montpellier, France, 26-28 September 2001.

Roth, C., Bournel-Bosson, C., (2001). *Mapping diffusive sampling results: Including Uncertainty and indirect information.* International conference Measuring Air Pollutants by Diffusive Sampling, Montpellier, France, 26-28 September 2001.

Van Aalst, R., Edwards, L., Pulles, T., De Saeger, E., Tombrou, M., Tonnesen, D., (1998). *Guidance Report on Preliminary Assessment under EC Air Quality Directives*, Copenhagen (Denmark), Environmental European Agency, Janeiro 1998.