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URBAN MORPHOLOGY, REMOTE SENSING AND POLLUTANTS DISTRIBUTION: AN APPLICATION TO THE CITY OF STRASBOURG, FRANCE.

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1. INTRODUCTION

This paper reflects the work achieved for demonstrating the potentialities of Earth Observation data for the knowledge of the atmospheric pollutants concentration fields over metropolitan's areas. Usual methods for deriving spatial information on the pollutant distribution over cities are interpolation (whatever the interpolator operator) or extrapolation. But these methods did not take into account morphological aspects and structural characteristics of city of interest. Hence, influences of urban forms on pollutant distribution are presently investigated in urban atmospheric pollution researches.
This multi-scale problem is generally studied on a single scale (local, meso or global) but seldom considering the total effect of network and urban units together. The interaction of several scales of pollutant observations (points-measurements, streets and urban area) is a particularity of the present work. This project is applied to the city of Strasbourg, France. Its objectives are to:

- precisely define the morphological elements which influence the pollutant distribution;
- spatialize the measurements with the help of satellite data, taking benefits from previous results.

This research project explores:

- the combination of different scales (from points-measurements to the complete urban community of Strasbourg);
- different methods (mathematical morphology, spatial analysis, interpolation, extrapolation, ...);
- different modeling approaches (from a single street to the total urban area);
- and different geographical and pollutants data sources (points-measurements, geographical databases, remotely sensed data).

The points-measurements sites were qualified according to morphological indicators and a representativity indicator of the sites defined. The geographical database (BD TOPO© IGN) was exploited for the extraction of parameters as inputs of the models of pollutants transport [1].

After presentation of the studied area, a method combining remotely sensed data, provided by the Landsat Thematic Mapper (TM) sensor, combined with the points-measurements, is presented, allowing the obtaining of a spatial distribution of pollutants over the city. This remotely sensed distribution is compared with usual methods (interpolation or extrapolation) used for the spatialization of pollutants. This comparison enhances the benefits of using satellite information for the description of pollutants over the city. A discussion on the results of this research project is proposed enhancing benefits of a multi-disciplinary, multi-scale, multi-sensor approach of air pollution.

2. DESCRIPTION OF THE AREA OF INTEREST AND DATASET

The city of Strasbourg is located in Eastern France at the border of Germany. L'Association pour la Surveillance et l'étude de la Pollution Atmosphérique en Alsace (ASPA) is the local organization in charge of the air quality measuring network in the city of Strasbourg and vicinity. A set of three Landsat TM quarter scene images was acquired in March 31, 1998, August 15 1998 and September 10, 1999. The Landsat TM sensor provides images with a 30m pixel and seven spectral bands from the blue to the thermal infrared spectral band. The thermal infrared band presents a spatial resolution of 120 m but interpolated to a pixel size of 30 m. These images were geometrically corrected to allow superimposition with the geographical database available over the area. Hence, the location of the measuring stations is easily achievable thanks to the geographical location achieved through GPS measurements. The pollution data corresponding to the overpass of the satellite were acquired by the measuring network and archived by the ASPA team.
Urban planners and public policy makers need tools for a comprehensive knowledge of the urban environment, for the forecasting of air pollution and for population information. Since 1996, in France, mayors in charge of large cities (over 100 000 inhabitants) must install a measuring network. This network is managed by local organization, such as ASPA. It is composed of static measuring stations and pollution data are collected in near real time. Collected data are used to compute an atmospheric pollution indicator (ATMO) aiming at informing local authorities as well as the population of atmospheric air quality. This indicator is calculated from NO2, SO2, O3 and particulate matter concentrations. This indicator is used as a warning for high-risk population. But this network is composed of a few measuring stations that are scarcely distributed over the city. Hence an accurate knowledge of the spatial distribution of atmospheric pollutants is currently inaccessible.

3. USUAL METHODS FOR MAPPING OF PARTICULATE MATTERS

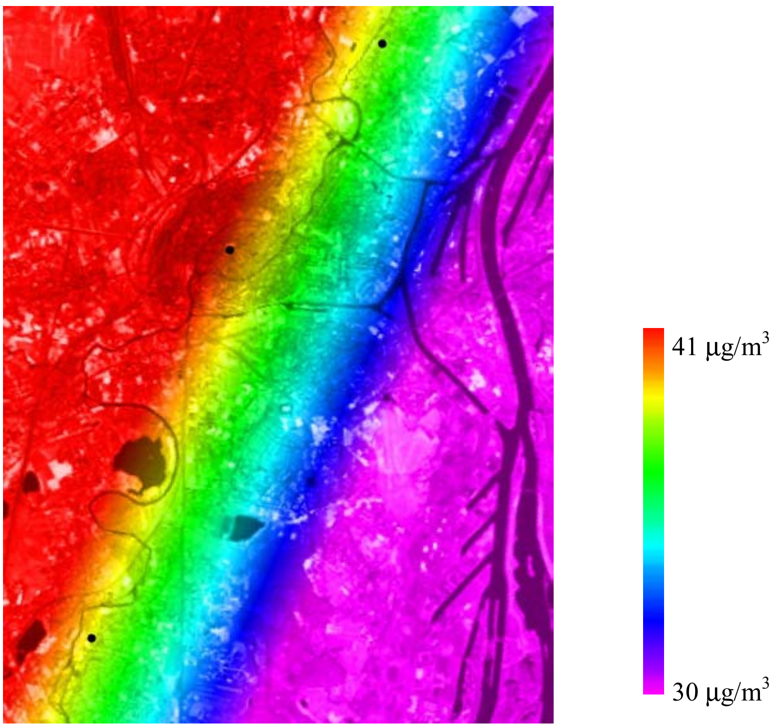

Figure 1. Extract of a map of PM10 for March 31, 1998 obtained from thin plates interpolation of the measurements (black dots)

Usual methods used for construction of maps of pollutants are interpolation/extrapolation techniques. Some are using kriging method [2], others recommend the use of thin plates interpolation method [3].

Figure 1 presents an example of a particulate matters (PM) map obtained with thin plates method from measures over the city of Strasbourg for March 31, 1998. In transparency is visualized the Landsat TM4 (blue) channel, showing the structure of the area. At this date only three measuring stations deliver information for PM. The accuracy of the method obtained depends on the accuracy of the measuring stations, if the measurement is representative of the neighborhood [4]. In fact the position of the instruments and the quantity of measuring stations greatly influence the mapping results. Some authors encounter even high variations of the pollutant concentrations from one side of a street to the other [5]. For a reasonable accuracy (5% of probability error) and top obtain concentration values with an error of 20 %, Sifakis [6] recommends 4 stations per 2.5 km². As the cost of a measuring station is very expensive, other solutions should be find. Using Earth observation data is one of the solutions

4. EARTH OBSERVATION DATA FOR IMPROVING PARTICULATE MAPPING

Several studies have shown the possible relationships between satellite data and air pollution ([4], [6], [7], [8], [9], [10]). Concerning the PM, a strong correlation was found by some of these authors with the thermal infrared image of Landsat (TM6). The proposed methodology is based on this assumption. But looking for correlation between three measuring stations and measurements acquired from satellite images is not mathematically convincing. Hence it is proposed to construct a multidimensional vector for each point of the image integrating several information. This vector is representative of the spectral information acquired by the satellite (it comprises the measurements done for each pixel in each spectral band except TM6) and of the morphological configuration of each pixel neighborhood (through a textural index or different other criteria as defined in [1]). This multidimensional vector can be understood as an identity card (ID) of each pixel in the image. The ID of each pixel is then compared to the ID of the pixel corresponding to the real measuring stations. When the IDs are similar, the value of the Landsat TM6 band is considered, and a pollutant value is allocated to this pixel according a relationship. This relationship is a regression computed from all the available images (in this case three) and the pollutant measurements of the stations. Figure 2 proposes a result of the application of such a methodology.

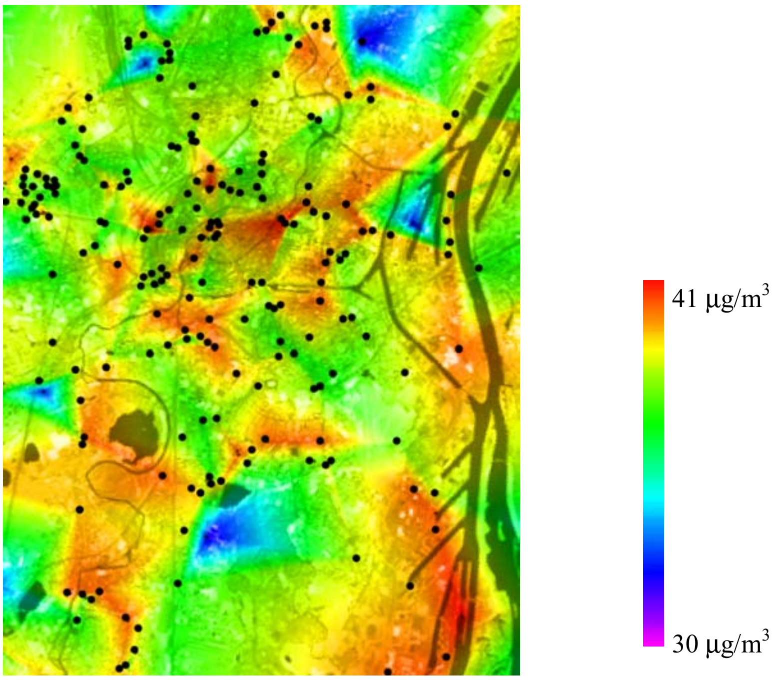

Figure 2. Extract of a map of PM 10 over Strasbourg derived from Landsat TM6 data. The black dots represent the virtual stations.

This methodology allows the creation of so-called "virtual stations" (black dots in Figure 2). It strongly improves the quantity of points of measures and allows the application of interpolation methods for computation of pollution distribution over the city. For this particular case, 4018 virtual stations were derived for the 180 km x 180 km of the Landsat image. The resulting image gives a more realistic view of the distribution of pollutants over the city. In order to validate the proposed approach, a ground-truth campaign will be organized in June 2002 combining acquisition of satellite data, around 20 measurement vans distributed over the city and an important concentration of measuring instruments (lidar, airborne instruments,...).

5. CONCLUSION

The use of remotely sensed data for mapping of pollutant concentration in towns brings a better spatialization of the phenomena under study. The results achieved for PM 10 mapping over Strasbourg will allow:

- a better location of the main pollution sources as well as their extension,
- the indication of areas where anti-pollution efforts should be carried out,
- the optimization of sitting for new measuring stations,
- a better understanding of the influence of local morphology over pollution,
- validation of numerical models dealing with local pollution.

The next step of this part of the project research is the establishment of mathematical relations between other pollutants, such as NOx, O3, SO2, with other spectral bands measured by satellites (SPOT, Landsat, ENVISAT, IRS, IKONOS,...) and improvement of the methodology for obtaining a more complete representation and understanding and to fight with efficiency air pollution in cities. The validation of this approach will be achieved through the ground-truth campaign organized within an inter regional research project of the INTERREG 3 program.

6. ACKNOWLEDGEMENTS

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