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MULTIRESOLUTION ANALYSIS FOR AIR POLLUTION MAPPING OVER A CITY – TYPICAL FIELDS METHOD

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ABSTRACT :

The sanitary impact of atmospheric pollution is becoming a major problem of public health in European cities. To estimate citizens exposure and take action accordingly, authorities in charge of monitoring air quality need to know the spatial distribution of pollutants concentration at any time and any place in the city.

Several data sets are available from local to regional scale. But either the resolution is too coarse to represent structures of the concentration field at the local scale and models do not cover the area of interest. The method proposed, the “typical fields method”, exploits all available data sets putting emphasis on scales and coherence between information. A typical field is defined as the ensemble of spatial structures of a field for all scales described and for a given meteorological situation.

1. INTRODUCTION

Atmospheric pollution becomes a critical factor of anticipated deaths. Car traffic is increasing continuously : the total number of cars increased of more than 90 % in 30 years (<http://cea.fr>). Atmospheric pollution hampers human breathing and impact on life quality. Studies suggest that current levels of particulate pollution in urban air associated not only with short-term, but also long-term increases in cardio respiratory morbidity and mortality (Nevalainen 1998). Authorities in charge of monitoring air quality have to take decisions in order to reduce pollution and to inform the population about its effects. To this aim, most large cities in Europe have acquired measuring networks for air quality monitoring and numerical models simulating physicochemical behaviour of pollutants for forecast and analysis.

A network is composed of static measuring stations, which continuously monitor air pollution at station location. Pollution data are collected in near real time and used to compute a global atmospheric pollution indicator. This indicator aims at informing local authorities, as well as the population. In answer to a high rating of the indicator, public authorities may take restrictive measures with car traffic essentially and with some air polluting companies. Air quality monitoring agencies are using forecast or meteorological models at large scale to map pollution. The CHIMERE model is largely used and gives fields of pollutants concentration over a country or Europe. Diffusion models as STREET or ADMS provide pollutants concentration at street scale.

However the real exposure of citizens to ambient pollution can neither be estimated with the present monitoring network nor with the different models. The costs of measuring station and of its maintenance limit the knowledge to specific sites of the town.

To evaluate the exposition to atmospheric pollution, an accurate knowledge of the spatial distribution of pollutants over the city is required. To perform it, maps are obtained either by spatial interpolation based on the set of measuring stations or physicochemical models. The network of measuring

stations is too sparse to give a satisfying result. The outputs of the models have a too coarse resolution (typically ~10 km) to represent structures of the concentration field at the local scale.

Our efforts are focussing on this problem of assessing the spatial distribution for scales ranging from 100 m to 10 km. This communication presents a method called “typical fields method”.

2. METHOD

The proposed method combines point measurements and different data sources such as outputs of meteorological models. In a few words, it exploits all available data sets at all scales. It also appeals to mathematical tools such as the multiresolution analysis and the wavelet transform. A typical field is defined as the ensemble of spatial structures of a field for all scales described and for a given meteorological situation.

A reusable library may thus be created which contains the set of typical fields for all typical meteorological situation. Given a map at broad scale ($R = 10$ km), ground measurements and a meteorological situation as inputs, a map of pollutant concentration is constructed at high resolution ($R = 60$ m) by the means of this library of typical fields.

This method originates from the work of Beyer *et al.* (1997) who created maps for the new European Solar Radiation Atlas (ESRA) and is connected to the ARSIS concept (Improvement of the spatial resolution by injection of structures) (Ranchin and Wald 2000), developed in the field of image processing.

STEP 1: EXTRACTION OF THE SET OF TYPICAL FIELDS WHICH DETERMINE A GIVEN METEOROLOGICAL SITUATION FOR A GIVEN AREA. CREATION OF A LIBRARY.

Initially, maps are available that provide a direct information on the spatial distribution of the pollutants. Examples are the emission register or vehicle traffic sectorisation. They are available at various scales. A multiresolution analysis is used and in particular an “à trous” (with holes) algorithm to extract typical fields at each scale. Mathematically, the typical fields are described by wavelet coefficients. Within this framework, the approximation of the concentration field at a given resolution is equivalent to pollution map. The wavelet coefficients are the differences between two consecutive approximations, $C_{j+1}(x,y) = f_j(x,y) - f_{j+1}(x,y)$ with C , the wavelet coefficient, f the approximation and j , the scale. These coefficients are normalized in order to be re-used for any level of pollution. They represent the ensemble of typical spatial structures of a pollution field for a given pollutant and a given meteorological situation. Thus, for a certain geographical area a library of typical fields is created and is easily re-usable.

STEP 2: CONSTRUCTION OF A POLLUTION MAP AT LOCAL SCALE.

By using the algorithm opposed to that used for the extraction of the typical fields, a multiresolution synthesis is carried out. Starting from coarse resolution, the appropriate typical fields are added to the coarse information at each scale. The iterative process is performed till the smallest scale is reached. The synthesis

$$\text{equation is written : } f_j(x,y) = f_{j+n}(x,y) + \sum_{k=1}^n C_{j+k}(x,y)$$

where n is the number of iterations. This map represents the concentration field over a city with a resolution of 60 meters in our example. The difference between the values obtained in this manner and those measured on ground is computed. A map of differences is obtained by interpolation and added to the 60 meters resolution map. The following diagram (figure 1) describes the creation of the library and the construction of the map.

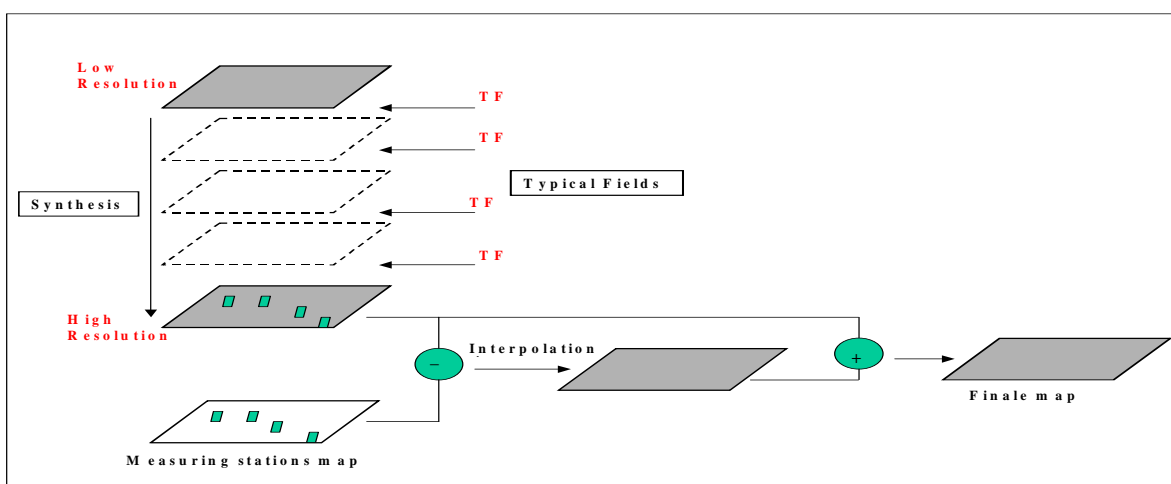


Figure 1 : Diagram of the creation of the library and construction of the map at high resolution.

3. RESULTS AND DISCUSSION

Here is presented the first implementation of the method for fine particles (PM) in order to show the feasibility of the method. Images at different scales are used. At large scale, i.e at low resolution, an image is extracted from a map with a resolution of about 15 km issued from the CHIMERE numerical model. This map is provided by a monitoring air quality organization (<http://www.prevoir.org>) and shows fields of pollutants concentrations over Europe. At higher resolution, the emission cadastral register provided by ASPA (Association for the Monitoring and the study of Air Pollution in Alsace) has a resolution of 1 km and describes the distribution of emission over the city of Strasbourg and surroundings. At even higher resolution, maps showing sectors of polluted areas are employed.

A multiresolution analysis is applied to each data set for resolution R less than 10 km (Fig. 2) to extract the typical fields at each scale. By carrying out the inverse algorithm and using the CHIMERE model as an input (Fig. 2, upper left), a map is synthesized at a resolution of 60 m (Fig. 2, bottom).

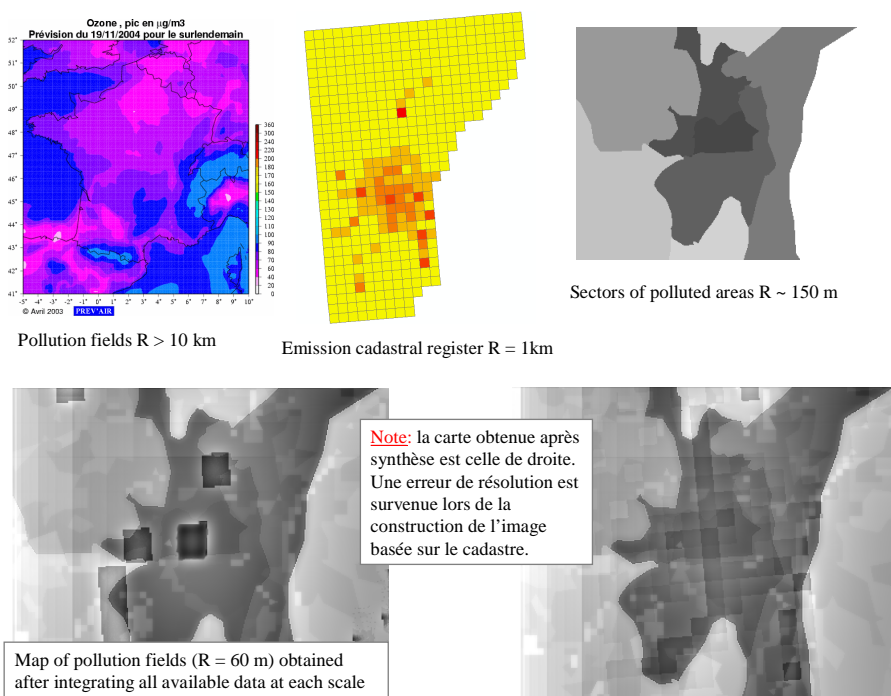


Figure 2 : Available data at different scales and final map at local scale.

Ground measurements are then introduced to improve the last map and adjust its levels to ground measurements. The difference between the estimated value and that measured at measuring stations is calculated. The differences are then spatially interpolated and this map of differences is added to the previous map. We have not yet studied the effects of the choice of the interpolation method.

The typical fields method can be used to replace the kriging interpolation method which does not introduce enough spatial variability. The typical fields method can integrate additional information : it is possible to introduce qualitative information in a quantitative way. By merging numerous information from various origins (qualitative information : epidemiology, pollution perception ; information coming from other spatial scales), the interpolation is refined and the pollution representation becomes more precise. This original approach presented here is connected with data fusion. However the manner of proceeding remains vague and must be precisely studied. It raises technical questions : how, for example, to translate the qualitative information into quantitative data with wavelet coefficients ?

The typical fields library is constantly available. It is assumed that the spatial pollutants distribution is the same for a given weather situation. Only the pollution level varies. Thus for each weather situation, the spatial pollutants distribution is characterized by a typical field. The usefulness of the typical fields library is certain : it easily constitutes a database available and exploitable without additional calculation. However, there are several difficulties in the determination of the number of characteristic weather situations, in the adequacy between the current weather situation and a typical situation. Moreover, the assumption according to which the spatial pollutants distribution is the same for a given situation remains to be validated.

4. CONCLUSIONS

On the one hand, the typical fields method proposed here makes it possible to obtain maps of air pollution at city scale and on the other hand to create a data bank which contains all the characteristics and structures of a pollutant concentration field for a given meteorological situation. This method involves mathematical tools such as multiresolution analysis and wavelet transform. The wavelet coefficients, extracted during the analysis, represent the ensemble of the typical spatial structures of a concentration field for a given meteorological situation independently of the pollution level. The method is still at the stage of development, but offers definitely promising prospects for results. We believe it deserves attention and we are focussing at demonstrating its feasibility and usefulness.

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