Preparation of a spatialised emission inventory as input for modelling

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ABSTRACT

A collaborative research project between the European Commission's Joint Research Centre and the Lombardy Region, both located in Northern Italy, aims to identify the best pollution reduction strategies in this area and to set a framework solving such complex problem for other areas in Europe. Advanced numerical air quality models (AQMs) have become an essential tool for analyzing the effect of the implementation of pollutant emission abatement strategies and for integrated assessment modelling. Therefore a spatialized atmospheric emission inventory for all major pollutants (CO, NOx, SO_2, PM_{10}, $PM_{2.5}$, NH_3 and VOC) and compatible with the requirements of a Eulerian chemical transport model (CTM) was elaborated for the whole area of Northern Italy merging all the available information collected from the institutions in charge of emission inventories at regional and national scale.

The methodology, the steps followed and the difficulties encountered to prepare a high quality spatialized emission inventory as input to AQMs are presented in this paper. A major challenge was to include, as much as possible, bottom-up emissions information elaborated by the regional authorities in Italy. Several problems of data collection, homogenization and merge had to be faced, considering that each region in Northern Italy is autonomously in charge of its own air quality plan and emission inventory and not all the local inventories were complete for the same reference year.

INTRODUCTION

The Po valley in the Northern Italy has been identified as a hot spot area where pollutant levels will remain problematic in spite of application of the current European legislation devoted to air pollution control even in the year 2020, or even beyond. This stresses the importance of local control measures to efficiently reduce the impact of air pollution. The Italian regions located in the Po valley area (Lombardy, Piedmont, Trentino Alto Adige, Veneto, Emilia Romagna, Friuli Venezia Giulia, Liguria, Valle D'Aosta and part of Tuscany) have designed regional air quality plans which include a series of control measures with the aim to abate air pollution levels. Within the frame of a collaborative research project between the European Commission's Joint Research Centre and the Lombardy Region an integrated air quality assessment over Lombardy and the whole Po valley has been initiated with the aim to assess the influence of local and regional emissions source on air quality levels. The methodology includes running an air quality modelling intercomparison exercise (POMI for PO valley Model Intercomparison). The application of advanced numerical air quality models (AQMs) over the Po Valley need as input accurate and spatially distributed atmospheric emission inventories.

Figure 1. The Po Valley area in Northern Italy and the POMI modelling domain. The boundaries of the Italian regions: the territorial and administrative units responsible for creation and maintenance of local emission inventories are shown as green lines.

The JRC had to acquire, collect and merge all the available data from the institutions officially charged and responsible of the emission inventory creation and maintenance, giving scientific support for improvement where necessary.

In order to get the highest accuracy without controlling the basic process of creation of the emission inventories it was necessary to collect as much information close to the bottom-up creation process as possible. This could be done only giving total priority to the regional emission inventories that are implemented mostly on the basis of bottom-up calculation procedures. We assume that, in particular for some sector and activity, the calculation of emissions done locally by the regions is more suitable to capture local information, characterizing the regional inventories with more accuracy than a pure top-down disaggregation of the national emission inventory, which has been a common practice in many modelling exercises in the past in Europe.

At present the local bottom up databases has not been fully implemented for all the regions of the Po Valley. Therefore the final inventory for the POMI exercise had to be completed merging different information and datasets supplied by different institutions in order to fill the missing information of the regional inventory. This was performed using emissions calculated by the national inventory and spatialized at the most suitable spatial scale.

Collecting and consolidating emissions data at the activity level from regional and national emission inventories (involving several regional institutions, the national environmental protection agency and the EMEP database) is a complex procedure due to the heterogeneity of the archives and data formats. This procedure has to be flexible enough to allow the implementation of the final emission database retrieving the appropriate information from all the original emission inventories by pollutant, sector, region and source geometry. Furthermore, the conversion of all emission data into a unique spatial database, the spatial allocation of national emission data to the municipal scale and the final spatialization onto a regular grid required building a common GIS framework containing all the spatial layers and information of administrative units, proxy variables, topography and land use.

MATERIAL AND METHODS

Emission inventories and data collection

European national and local authorities estimate pollutants emissions in a given area according to the EMEP/CORINAIR Emission Inventory Guidebook and report it up to now under the SNAP nomenclature (Selected Nomenclature for Air Pollution)[1]. Atmospheric emissions in Italy are estimated and reported with reference to spatial units which correspond to the national official administrative boundaries.

Depending on the spatial scale there are several institutions in charge of creation and maintenance of emission inventories for the Po Valley modelling domain. As a consequence, a number of emission inventories exist, each of these having a different domain and level of aggregation:

- INEMAR (INventario EMissioni ARia), – a database created for the implementation of high-quality regional emission inventory estimating the emissions of several pollutants (SO_2, NO_x, COVNM, CH_4, CO, CO_2, N_2O, NH_3, PM2.5, PM10, PTS and others) at municipal level for each emission activity and fuel type[2,3,4,5].
- National emission inventory - created and maintained by the Italian Institute for Environmental Protection and Research (ISPRA, ex APAT) – a database that collects all emission estimates of the major pollutants including GHG (green house gases), ozone precursors, benzene, PM, HM (heavy metal) and PAH (polycyclic aromatic hydrocarbon)[6]. The national inventory is reported to the European Commission at national aggregated level (NUTS0), but it is calculated at regional level and then disaggregated at the provincial level
- UNECE/EMEP European emission database. EMEP is the scientific program of the CLRTAP (Convention on Long-Range Transboundary Air Pollution) providing emissions for air quality modelling both as national total as well as gridded at 50 km resolution. The officially reported emissions available through the EMEP data portal include, on an annual basis, acidifying air pollutants, heavy metals, particulate matter and photochemical oxidants[7].

With the support of the institutions in charge of emission inventories, emission data at the local, Italian national and European scale were collected, homogenized and consolidated into a unique geodatabase covering the whole modelling domain (570x390 km^2) (see **Figure 2**). The procedure by which this was done is explained in the text below.

Emission data merge and consolidation

In order to follow the main purpose of building an emission inventory mostly based on local information, the consolidation procedure gave priority to the regional INEMAR databases.

Currently the INEMAR inventories for the base year relevant for the POMI modelling exercise (year 2005) are fully implemented in 3 Italian regions (Lombardy, Piedmont and Trentino Alto Adige) while they are still only partially implemented in other 3 regions of the Po Valley (Veneto, Emilia Romagna and Friuli Venezia Giulia). (**Figure 2)**.

However, in order to cover the whole POMI domain with the best compromise among completeness and accuracy, the final inventory for the AQMs exercise had to be built merging different information and datasets supplied by different institutions. The emissions which were replaced in the national emission inventory by regional emission calculation cover mostly the following sectors:

- point emissions (mainly SNAP 01 – combustion in energy and transformation systems, SNAP 04: Production processes and partially SNAP 03: Combustion in manufacturing industry)
- road transport emissions (SNAP 07)
- non industrial combustion, especially emissions coming from biomass and wood combustion (SNAP 02 non industrial combustion plants)

The proportions of emissions reported locally for the sectors mentioned above in the total Po Valley inventory are: 45% of SO_2, 80% of NO_x 88% of CO, 36% of COV and almost 65% of PM. These percentages show that, despite the incompleteness of local inventories in some regions, the total emissions of the domain are covered in large proportion by local inventories.

The spatial union of local inventories (INEMAR) with the national inventory disaggregated at municipal level has been for the first time in Italy realized within the experiment documented in this paper.

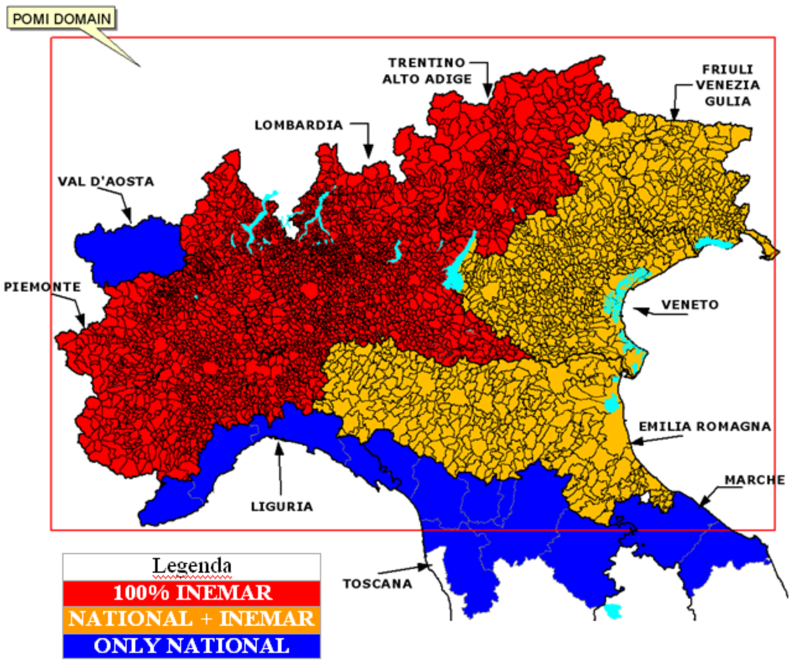

Figure 2. The Italian regions where the INEMAR emission inventory (emissions by municipality) has been completely (in red) or partially (in yellow) implemented. In blue the regions that where not involved in the project and did not supply a regional inventory The red rectangle represents the modelling domain.

Spatial disaggregation methodology

Regional and national emission inventories, defined and delivered with reference to the main administrative boundaries, need to be spatially resolved in a consistent format suitable as input to AQMs which is typically a regular grid. In this project a grid of 3 x 3 km cells was used.

Regional INEMAR databases can be considered bottom-up emission inventories as they are calculated mostly from municipal information, keeping as many point sources as possible separated from diffusive emissions and estimating linear mobile source emissions on the basis of traffic assignment models on the local road network.

The Italian emission inventory reported to the European Commission is a database aggregated at national level containing data of 236 SNAP activities and 43 pollutants. Only the major point sources are reported and mapped separately (almost 200 sources, mostly Large Combustion Plants). The highest level of top-down disaggregation of diffusive emissions is done at the provincial level through proxy variables[8].

Spatialization of emissions on to a regular grid is then realized by a set of spatial surrogates. The most commonly used surrogates for weighting emissions into grid cells in a more accurate way than a simple uniform distribution are geographic datasets with their attributes (e.g. land use, roads, traffic data, population, etc.).

In order to improve the accuracy of the emission gridding process, a first spatial disaggregation of the national emission inventory was applied, allocating provincial emissions (by activity) to municipal polygons by means of a large and very detailed set of proxy variables. Such preliminary spatial allocation on the municipal boundaries makes

the process more accurate than gridding aggregated (i.e. provincial, regional or national) emissions directly. The same activity information used to estimate total emissions at national level are officially reported at municipal level (from bottom-up census or other surveys by the National Institute of Statistics) and this gives the opportunity to downscale emissions on to smaller spatial units in a consistent way instead of directly considering spatial surrogates with simple assumption on how homogeneously these attributes are allocated on the different land uses-surrogates across the provincial territory.
The spatial disaggregation methodology used in this work updates the former work of another team[9] with some enhancements and additional values:

- Local bottom-up inventories have been integrated with the top-down disaggregated national inventory.
- A set of new and more specific proxy variable have been introduced thanks to the availability of new spatial layers and of a new important statistical archive of operative companies, productive activities and employees created by ISTAT (Italian Statistical Office) in 2005.
- Specific weighting profiles have been used for land use and road networks in the gridding procedure.

Gridding procedure

Once merged, the municipal annual emissions of the regional and national inventory were spatialized on the 3 x 3 km modelling grid through previous allocation of emissions on specific spatial entities used as surrogate variables. Extra urban road links and highway links, weighted with average daily traffic, were used for spatial distribution of the linear fraction of mobile sources emissions while land use classes weighted with sector-specific assignation profiles served as surrogate for diffusive emissions. Point sources emissions have been subtracted from the total municipal emissions of the related activity and elaborated separately.

Diffusive emissions

The underlying concept of using land use assignation profiles as weighting factors for distributing diffuse emissions at sub-municipal scale is that pollutant emissions are directly related to human activity and that the spatial distributions of the emissions reflect the spatial patterns and intensity of human activity. Land use data, which provide an indicator of the spatial distribution of specific human activities, can therefore be used to infer the distribution of pollutant emissions. Overlaying the CORINE Land Cover spatial dataset with the boundaries of municipalities allows a proportional assignment of specific sector emission of a certain municipality to the more suitable set of sub-municipal parcels of land-use (e.g. municipal emissions from the sectors “industrial combustion” and “production processes” are mostly allocated on industrial areas but also, with a lower weight, on discontinuous urban fabric, continuous urban fabric, construction and mineral extraction sites, airports).

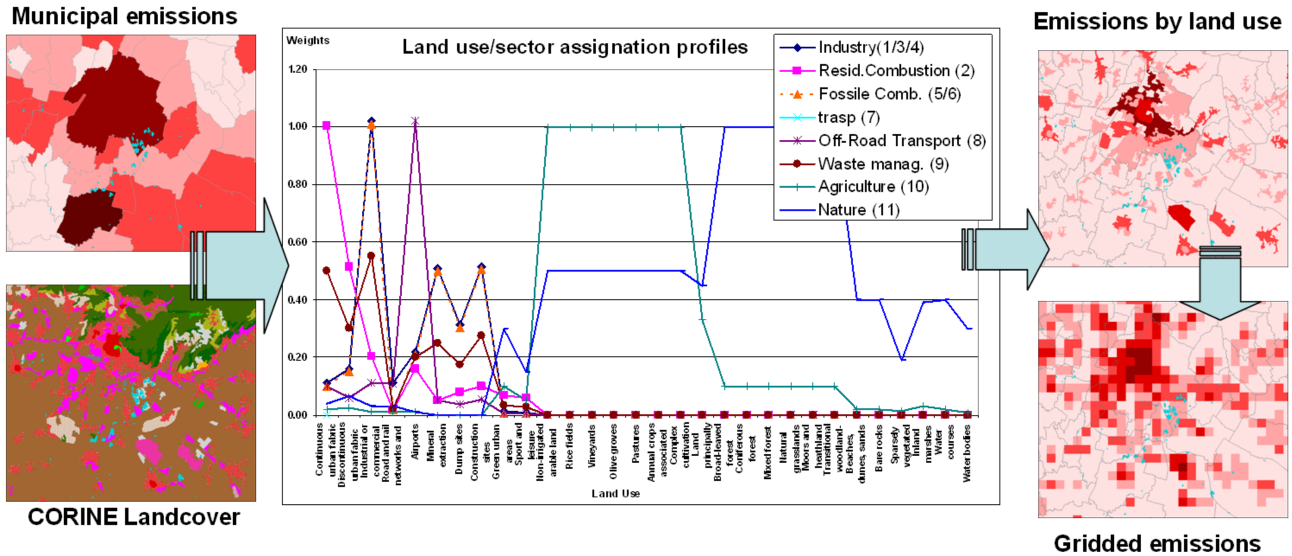

Figure 3 – The gridding scheme based on land use assignation profiles.

The assessment of the parameters describing the spatial distribution of emission-generating activities on the basis of land-cover maps in several European sites was done in the frame of the IMPRESAREO project[10,11]. Results from the IMPRESAREO case studies indicated that the methodology can be applied at the national and regional level to give good results, provided that additional and detailed information on point sources and line sources are introduced in the analysis and only diffuse emissions are distributed on the grid cells according to emission weighting profiles (Detail level 2c in IMPRESAERO).

The method of land use assignation profiles was successfully tested by the JRC in the City Delta project[12]. Yearly municipal emissions of Lombardy were disaggregated on a 5 x 5 km grid covering the whole region, using the knowledge on the land-use percentage of each municipality in the grid cell[13].

Spatialization of linear sources

Road transport emissions account for a large fraction of the total emissions for the majority of pollutants considered in this study, and hence a reliable mapping for this sector, separating the linear portion of traffic emissions from the diffusive, was important, also to make more effective and reliable the application of the IMPRESAREO methodology.

Three regions within the Po Valley supplied their linear emissions calculated in detail by the INEMAR database with the support of a specific traffic assignment model and specified for each single road link. The other three regions of the POMI domain supplied mobile sources emissions also calculated by the INEMAR database but defined as municipal totals without considering road links. The rest of the domain was covered by the municipal totals of mobile sources emissions derived from the national inventory (**figure 4**).

Line sources emissions specified for single road links were gridded directly overlaying the regional road networks with the modelling grid. Mobile sources emissions specified as municipal totals were assigned in part to the urban land use polygons (diffusive portion) and in part to the road network (linear portion).

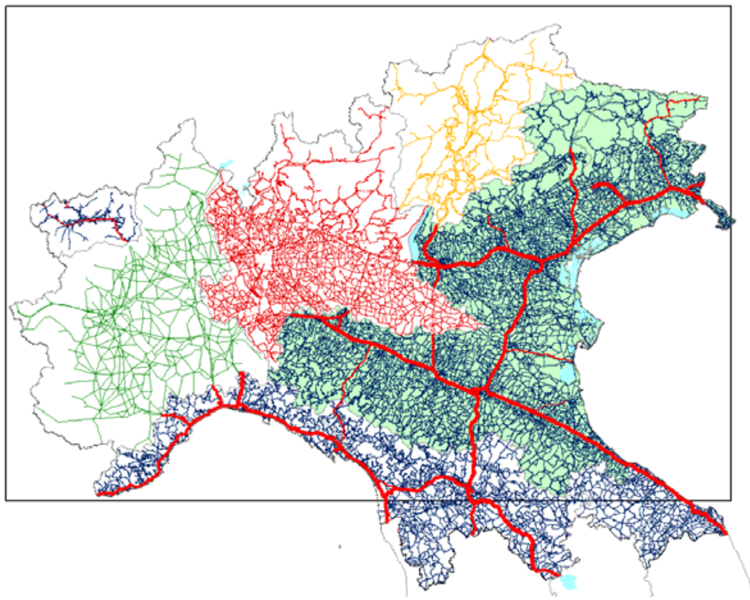

Figure 4. Merging scheme of the supplied mobile sources emission data. In three regions (network coloured in green, red and yellow for Lombardy, Piedmont and Trentino A.A) traffic linear emissions were available by road link. In the other regions the emissions were uniformly spatialized on the roads crossing each municipality. For the regions in green INEMAR emission data were available at municipal level. For the rest (blue network and highways in red) APAT emission data were used.

Each link of the highway network in the regions where INEMAR is not completed was characterized by its average daily traffic flow determined for the year 2005 by the Italian Association of the Highways Concessionaire Societies. This information was used as a proportional weight to differentiate the emission allocation on different highways tracts. The extra urban network was elaborated using GIS by extracting only the fraction of national and provincial roads and some of the major municipal roads positioned outside the urban areas. As no traffic flow estimation was available for this part of the road network, extra urban linear emissions were assigned uniformly to the road links located in each municipality.

Point sources

Like all the other emission data, also point sources emissions were merged giving higher priority to the detailed local information of regional emission inventories which account for a much larger number of point sources than the national inventory (almost 1000 point sources in the INEMAR datasets available for the Po Valley versus 200 point sources of the national emission inventory). Incompleteness and lack of consistency among the point source data received from the regions (INEMAR) and the national inventory imposed a series of pre-processing steps to be carried out in order to release a consistent and homogenized modelling input. At the end of the pre-processing, the INEMAR point

sources have been classified according with the magnitude of the emissions and with the availability of spatial coordinates, and stack parameters. Each source category entered then at a different level in the spatially resolved emission inventory.
For the regions where no INEMAR data were available, point sources from the national inventory were used and allocated to the grid cell due a complete lack of information about stack geometry and flow.

CONCLUSIONS

In this project a highly detailed and spatially resolved emission inventory was implemented for the Po Valley (Northern Italy), giving priority to the information collected locally in the regional emission inventories (INEMAR) which implementation is now completed in 3 Italian regions (Lombardy, Piedmont and Trentino Alto Adige) and still in progress in other 3 regions of the Po Valley (Veneto, Emilia Romagna and Friuli Venezia Giulia). The rest of the POMI domain was covered by the national and EMEP emission inventories.
The integration of local bottom-up inventories with the top-down disaggregated national inventory on such a wide area like the Po Valley represent the first experience in Italy while air quality modelling exercises previously realized at national scale or at scales analogous to the Po Valley, used the Italian national emission inventory at provincial level as input to the modelling chains.
The 2005 spatially resolved emission inventory is now being used for defining a series of emission scenarios as input for the air quality forecasts at different time horizons within the next 15 years: Tendency-CLE (Current LEgislation) and AQP (regional Air Quality Plan scenario).
The base case inventory and the emission scenarios are also the basis for another very important tool under development at the JRC: a Regional Integrated Assessment Tool, which is intended to support the implementation of cost-effective regional/local policies aiming at reducing the burden of adverse air quality on health.

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Key Words

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spatialization

air quality modelling

GIS