Pollutant data mapping at municipality level for exposure assessment on European countries

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Introduction

Within the European Union ***LIFE+ project*** MEDiterranean Health Interview Survey Study (***MED HISS*** LIFE12 ENV/IT/000834), in order to evaluate health effects of long-term exposure to air pollution for the entire population of countries involved in the project (Italy, France, Slovenia, Spain), it was necessary to provide ***annual air pollution maps at municipality scale*** on national basis. We here present maps produced for Italy and Spain for the main atmospheric pollutants (PM_{10} and NO_2), combining two sources of information: ***observations*** from monitoring stations and ***concentration fields*** from Chemical Transport Models (CTMs). CTMs data were output of the subsequent modeling systems running at national scale: for Italy, the National Integrated Modeling system for International Negotiation on atmospheric pollution (MINNI[1]), for Spain, the CALIdad del aire Operacional Para España (CALIOPE[2]). Both the CTMs data are available at a spatial resolutions representative of urban background pollution levels (4x4 km^2). The available years are different for each country since they are linked to available health data: MINNI outputs are provided for years 2003, 2005, 2007 and 2010 while CALIOPE outputs from 2009 to 2013.

Methodology and Results

The methodology is split in two steps: firstly, in order to reduce model uncertainty, a ***data fusion*** technique is used to combine MINNI concentration fields and pollutant observations. Thus, it is possible to conform Italian results to Spanish ones (CALIOPE outputs were provided with data fusion) and to provide a more realistic representation of pollutant spatial distribution. In the second step, Italian and Spanish assimilated pollutant concentration fields are up-scaled at the municipality level.

Data Fusion

MINNI is a modeling system for Italy, including an atmospheric chemical trasport model fed by emission data (national emission inventory of anthropogenic sources, biogenisc VOCs, sea-salt, natural dust) and meteorological prognostic fields. MINNI covers Italy with 4 x 4 km^2 fields at hourly resolution.

A ***Kriging with External Drift*** (KED)[3,4] procedure has been used to account for the observed data into MINNI concentration fields. Specifically, the kriging is applied on the observed data and the external drift is constituted by the MINNI model output. Observations were interpreted as realizations of a Gaussian spatial process $Y(s)$ at spatial location s, in the domain S. $Y(s)$ has the following structure: $Y(s) = \mu(s) + w(s) + \varepsilon(s)$, where in the trend component $\mu(s)$ the MINNI model output is introduced, $w(s)$ is a stationary Gaussian random process and $\varepsilon(s)$ is the error term. Regarding observed data introduced in the dispersion model outputs, we retrieved data from other Italian regional environmental agencies out of BRACE database (national system: http://www.brace.sinanet.apat.it/). Only background stations and only monitoring sites with more than 80% of data have been considered and averaged to obtain annual observed values. Moreover, orography was added to the trend component as auxiliary covariate, in order to introduce information about the complex Italian terrain. Then, to choose the spatial covariance function, the leave-one-out cross-validation method has been performed: best results were obtained with the *exponential* function for all the pollutants and every years. A Box-Cox transformation has been applied to the original data (separately per pollutant) in order to stabilize the variances and make the distributions approximately normal. To fit the model, first the parameters of the Box-Cox transformation and then the parameters of the model were estimated by the use of restricted maximum likelihood method. Finally, KED has been performed on three different domains (Northern Italy, Southern Italy and whole Italy) for all pollutants and years: the domain choice was done looking at best results of the leave-one-out cross-validations.

A leave-one-out cross-validation analysis has been carried out in order to evaluate KED performance: a comparison between observations and KED output at monitoring station locations showed a good agreement, also where the spatial coverage of monitoring stations is low (see the Taylor diagram in Fig. 1).

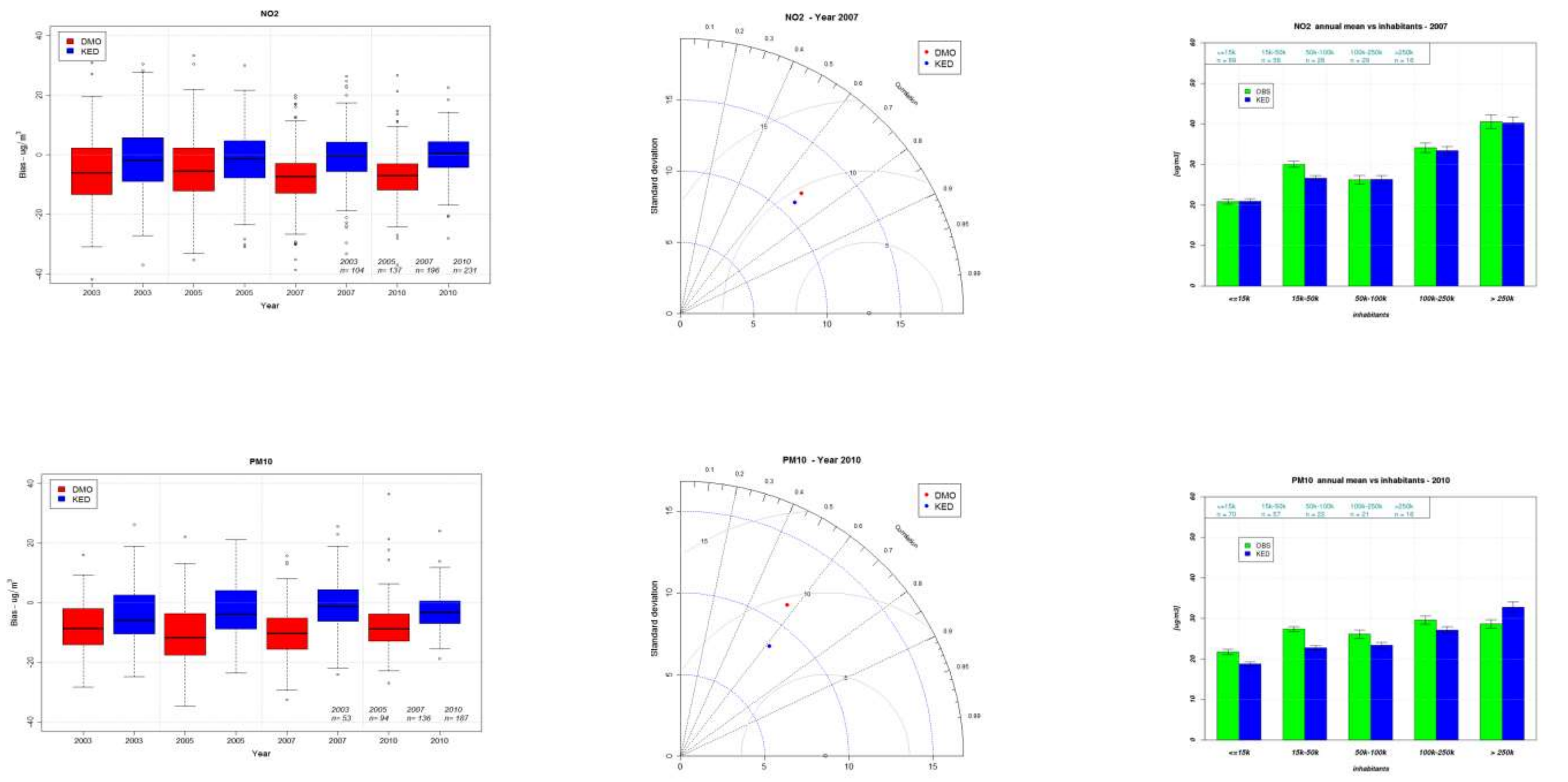

Fig. 1: On the left, two examples of bias distribution of KED cross-validation results (KED) and MINNI output (DMO). NO_2 bias distribution medians (top) tends to the zero-value in the different years. The most pronounced improvement is for year 2007 and 2010 (because we have more observations). PM_{10} bias distribution medians (bottom) instead go near to the zero-value but there always is an underestimation in median.

In the center, two examples of Taylor diagrams for NO_2, year 2007 (top) and PM_{10}, year 2010 (bottom). Diagrams show an improvement of KED results on all the three indexes.

On the right, barplots for year and inhabitant classes compare observed (OBS) and KED annual means at monitoring station locations. In NO_2 barplots (top) there is a very good correspondence of background concentration levels with observations in 2007, except a little underestimation for municipalities with a number of inhabitants between 15k and 50k. PM_{10} barplots present in 2010 a little underestimation everywhere, except in municipality with more than 250k inhabitants.

Up-scaling

Following this data fusion approach, the exposure assessment was carried out for Italy and Spain by ***up-scaling*** the gridded data at the municipality level[4]. Using a weighted block averaging procedure accounting for built-up surface percentages, annual exposure maps at municipality level for the two countries were obtained. Built-up area information have been collected from CORINE LAND COVER data (http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster-2) using land use classes belonging to *Artificial Surfaces categories*. Looking at resulting maps, concentrations levels and main spatial patterns are well preserved (Fig. 2).

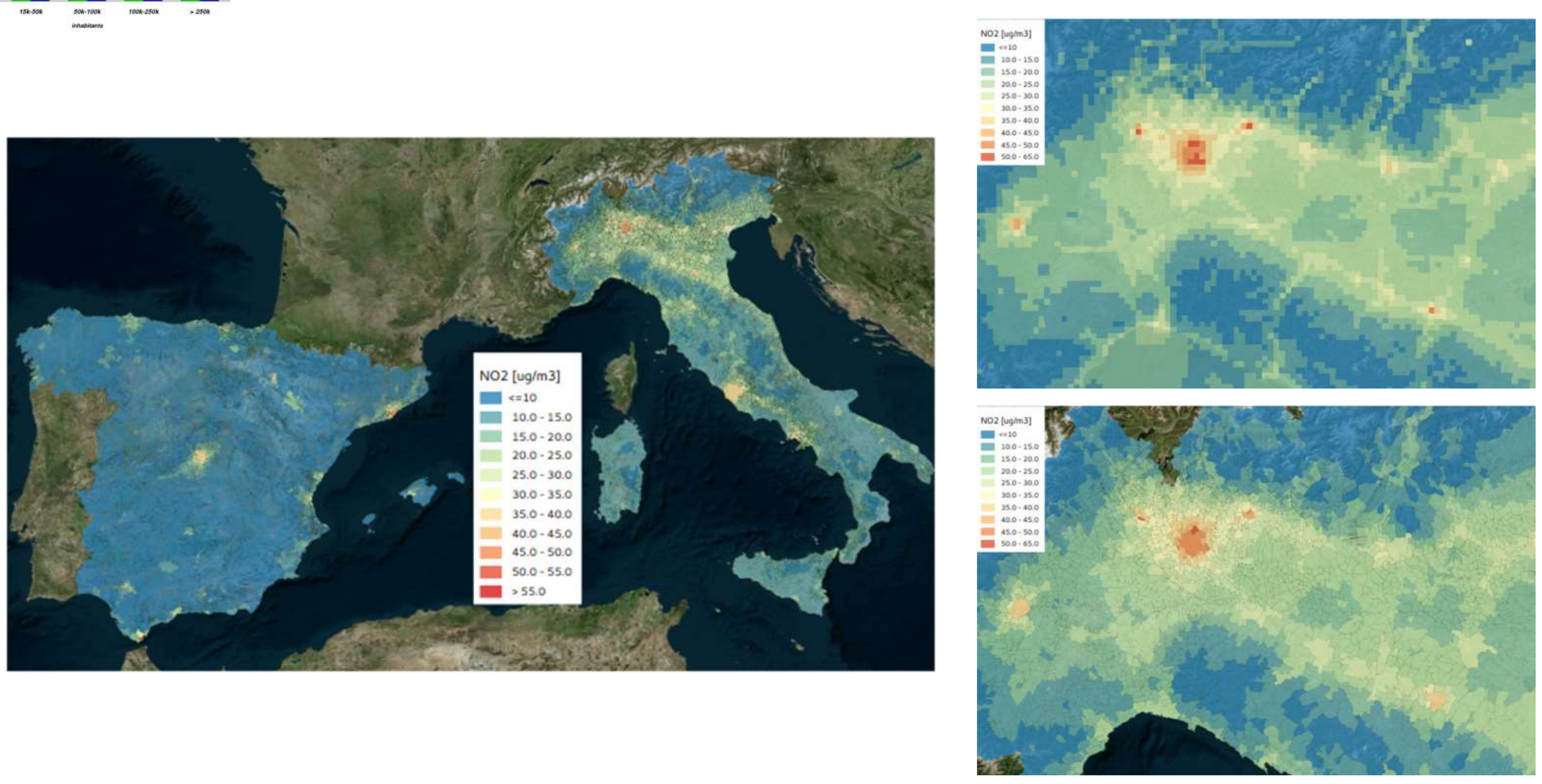

Fig. 2: NO_2 annual mean concentrations in 2010: on the left concentrations fields up-scaled at municipality level for Italy and Spain: on the right Northern Italy domain: KED concentration fields at grid level (top) and concentrations up-scaled at municipality level (bottom).

Conclusion

Within the MED HISS project, in order to obtain the population exposure assessment to air pollution on national basis, it was necessary to provide an annual pollutant value at municipality level. In this study we have implemented a methodology consisting of two steps: first, the use of KED to introduce observations in pollutant concentration fields, and second the use of a weighted block averaging procedure to up-scale assimilated concentration fields at municipality scale. The first step has been implemented only for Italy, since Spain pollutant concentration fields already include observed data. The adopted data fusion technique produced satisfactory results on PM_{10} and NO_2 concentration fields for all the studied years.

Secondly, the up-scaling technique was applied both on Italian and on Spanish assimilated gridded data. Also the up-scaling provided consistent exposure estimates at municipality level that account for the areas where people really live.

References

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MED HISS

Arpa PIEMONTE Agenzia Regionale per la Protezione Ambientale

ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development

CREAL centre for research in environmental epidemiology