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 (MEDIHSS 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 (PM10 and NO2), 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 CALItad delaire Operational Para España (CALIOPE)2. Both the CTMs data are available at a spatial resolutions representative of urban background pollution levels (4x4 km2). 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 confine 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 transport model fed by emission data (national emission inventory of anthropogenic sources, biogenic VOCs, sea-salt, natural dust) and meteorological prognostic fields. MINNI covers Italy with 4x4 km2 fields at 1 and 3 km2 resolution.

A Kriging with External Drift (KED)3 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) = μ(s) + w(s) + ε(s), where in the trend component μ(s) the MINNI model output is introduced, w(s) is a stationary Gaussian random process and ε(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)). NO2 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). PM10 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 NO2, year 2007 (top) and PM10, 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 NO2 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. PM10 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. 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: NO2 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 MEDIHSS 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 average procedure to up-scale assimilated concentration fields at municipality scale. The first step has been implemented only for Italy, while Spain pollutant concentration fields already included observed data. The adopted data fusion technique produced satisfactory results for PM10 and NO2 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