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A comparative analysis of two highly spatially resolved European atmospheric emission inventories

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HIGHLIGHTS

- Inter-comparative analysis of distinct spatial disaggregation methods of emission inventories.
- 2 EU emission inventories converted into 3 gridded datasets, under a common grid with 12 × 12 km^2.
- Gridded emission inventories, well discretized and detailed, suitable for air quality modelling.
- Different databases and disaggregation methods lead to different spatial emission patterns.

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ABSTRACT

A reliable emissions inventory is highly important for air quality modelling applications, especially at regional or local scales, which require high resolutions. Consequently, higher resolution emission inventories have been developed that are suitable for regional air quality modelling.

This research performs an inter-comparative analysis of different spatial disaggregation methodologies of atmospheric emission inventories. This study is based on two different European emission inventories with different spatial resolutions: 1) the EMEP (European Monitoring and Evaluation Programme) inventory and 2) an emission inventory developed by the TNO (Netherlands Organisation for Applied Scientific Research). These two emission inventories were converted into three distinct gridded emission datasets as follows: (i) the EMEP emission inventory was disaggregated by area (EMEParea) and (ii) following a more complex methodology (HERMES-DIS – High-Elective Resolution Modelling Emissions System – DISaggregation module) to understand and evaluate the influence of different disaggregation methods; and (iii) the TNO gridded emissions, which are based on different emission data sources and different disaggregation methods. A predefined common grid with a spatial resolution of 12 × 12 km^2 was used to compare the three datasets spatially.

The inter-comparative analysis was performed by source sector (SNAP – Selected Nomenclature for Air Pollution) with emission totals for selected pollutants. It included the computation of difference maps (to focus on the spatial variability of emission differences) and a linear regression analysis to calculate the coefficients of determination and to quantitatively measure differences.

From the spatial analysis, greater differences were found for residential/commercial combustion (SNAP02), solvent use (SNAP06) and road transport (SNAP07). These findings were related to the different spatial disaggregation that was conducted by the TNO and HERMES-DIS for the first two sectors and to the distinct data sources that were used by the TNO and HERMES-DIS for road transport.

Regarding the regression analysis, the greatest correlation occurred between the EMEParea and HERMES-DIS because the latter is derived from the first, which does not occur for the TNO emissions. The greatest correlations were encountered for agriculture NH_3 emissions, due to the common use of the CORINE Land Cover database for disaggregation. The point source emissions (energy industries, industrial processes, industrial combustion and extraction/distribution of fossil fuels) resulted in the lowest

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coefficients of determination. The spatial variability of SO_x differed among the emissions that were obtained from the different disaggregation methods.

In conclusion, HERMES-DIS and TNO are two distinct emission inventories, both very well discretized and detailed, suitable for air quality modelling. However, the different databases and distinct disaggregation methodologies that were used certainly result in different spatial emission patterns. This fact should be considered when applying regional atmospheric chemical transport models. Future work will focus on the evaluation of air quality models performance and sensitivity to these spatial discrepancies in emission inventories. Air quality modelling will benefit from the availability of appropriate resolution, consistent and reliable emission inventories.

1. Introduction

Under the EU (European Union) National Emission Ceilings Directive and the UNECE (United Nations Economic Commission for Europe) Convention on Long-range Transboundary Air Pollution (LRTAP) and its protocols annual submission of air emissions inventory data are required at the national level. Such data are made publicly available. Similarly, while many environmental regulators within European countries have made industrial facility emissions data available at the national level, it is only in the last few years that such data have been made publicly available in a coordinated initiative at the European level (EMEP, 2007).

The EMEP (European Monitoring and Evaluation Programme) Centre on Emission Inventories and Projections (CEIP) has been assigned the task of collecting emissions and projections of acidifying air pollutants, heavy metals, particulate matter and photochemical oxidants from LRTAP Convention parties. In addition, the EMEP has been assigned the task of obtaining input data for long-range transport models, which estimate air pollution levels at the European scale. Currently, the centre operates the UNECE/EMEP emission database (WebDab), which contains information regarding emissions and projections from all parties of the LRTAP Convention in two separate datasets, including the official emissions that are submitted by the parties, and the emissions used by modellers (EMEP – CEIP, 2010; EEA, 2010).

In addition to the inventory based on obligatory reporting of national emissions, other emission inventories covering Europe are available, including the CGEIC (http://www.ortech.ca/cgeic), RETRO (http://retro.enes.org), EDGAR (http://www.mnp.nl/edgar), TNO-GEMS (Visschedijk et al., 2007) and PAREST-MEGAPOLI (Denier van der Gon et al., 2010) inventories. These inventories are partly independent of the EMEP database, but maintain some of its features. The ECCAD – GEIA database (Emissions of atmospheric Compounds & Compilation of Ancillary Data – Global Emission Inventory Activity) (http://eccad.sedoo.fr; http://www.geiacenter.org) is a link to most of these emission inventories. The most recent EDGARv4.2 database (EDGAR, 2011) provides global annual emissions data per country and on a grid with three different spatial resolutions (up to 0.1 by 0.1° since 2005) for all relevant air pollutants and GHGs. The E-PRTR (European Pollutant Release and Transfer Register database) has built diffusive emissions grid maps based on officially submitted national emissions data at a resolution of 5×5 km^2 that cover all EU27 states and EFTA countries (Theloke et al., 2011). The High-Elective Resolution Modelling Emission System (HERMES), developed between 2005 and 2006 by the Barcelona Supercomputing Centre, is currently being used within the CALIOPE operational air quality forecasting system for Europe and Spain. HERMES is divided into two main modules that can work together or separately, depending on the working domain (Baldasano et al., 2008). The first module, named HERMES-BOUP, was specifically developed for Spain and uses a combination of bottom–up approaches for estimating emissions at high spatial (1×1 km^2) and temporal (1 h) resolution. The other module, HERMES-DIS is used for Europe, and performs a SNAP (Selected Nomenclature for Air Pollution) sector-dependent spatial (12×12 km^2, and up to 1 km^2) and temporal (1 h) disaggregation of the original annual EMEP gridded emissions at a 50×50 km^2 resolution.

In many cases, emission inventories clearly reflect the purpose that they have been designed for (i.e., serving for regulatory purposes such as the UNFCCC and UNECE CLRTAP EMEP inventories). Specifically, compliance with international protocols drives the need for a pragmatic emissions accounting system. In contrast, inventories such as the EDGAR emission database are bottom-up science driven emission compilations that are based on emissions factors and generally provide openly available statistical information regarding activity rates (Van Aardenne et al., 2005). While the legal implications and validation of national submissions are important in the former inventory, the main objective of the latter inventory is to provide comprehensive and consistent datasets for air quality modelling. This difference is somewhat reflected in the sectorial structure in which these inventories are compiled (Reis et al., 2009).

The spatial and temporal coverage of emissions for use in air quality models is important. On a global scale, a resolution of between 10 and 12 km is used to capture the general spatial distributions of pollutants. However, for urban scale modelling, inventories with a grid spacing of less than 1 to 4 km potentially overlook vital distribution patterns, which result in mismatch between model results and observations. This mismatch occurs when the model fails to adequately represent street canyons and transport routes, which influences the spatial distributions of urban air pollution.

The geographical distribution of emissions within countries plays a larger role in explaining the differences between the inventories than in explaining the differences in the countries total emissions. Very large differences were found between the contributions of various sectors to the total emissions from each city. These differences are related to the different methodologies that are used in inventory development (Butler et al., 2008). Emissions can be spatially distributed based on population (total, urban or rural), the locations of individual emitting facilities, or a combination of these factors. Butler et al. (2008) recommend the use of an ensemble of inventories, placed more attention on the geographical distribution of emissions, and on the integration of local inventories into global emission inventories.

A detailed evaluation of the GEMS-TNO emission inventory, which was used for several modelling applications along with the EMEP inventory, for 2003, showed that the annual differences between the two inventories were relatively small (typically of 10% or less), although a few larger differences were obtained for specific sectors and/or pollutants (Simmons et al., 2010).

Moreover, Reis et al. (2008a, 2009) investigated different NO_x emission inventories and highlighted some of the most relevant similarities and differences. One question that arose from this