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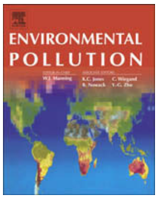

Effective pollutant emission heights for atmospheric transport modelling based on real-world information

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The comprehensive analysis of real-world stack data provides detailed default parameter values for improving vertical emission distribution in atmospheric modelling.

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ABSTRACT

Emission data needed as input for the operation of atmospheric models should not only be spatially and temporally resolved. Another important feature is the effective emission height which significantly influences modelled concentration values. Unfortunately this information, which is especially relevant for large point sources, is usually not available and simple assumptions are often used in atmospheric models. As a contribution to improve knowledge on emission heights this paper provides typical default values for the driving parameters stack height and flue gas temperature, velocity and flow rate for different industrial sources. The results were derived from an analysis of the probably most comprehensive database of real-world stack information existing in Europe based on German industrial data. A bottom-up calculation of effective emission heights applying equations used for Gaussian dispersion models shows significant differences depending on source and air pollutant and compared to approaches currently used for atmospheric transport modelling.

1. Introduction

Accurate emission data at the appropriate spatial, temporal and species resolution are a prerequisite for the operation of atmospheric chemistry and transport models (CTMs). Emission inventories distinguish between area, line and point sources. Area sources such as smaller stationary or fugitive sources are usually allocated to land use categories and administrative units, line sources such as road traffic to road sections. Emission data for large point sources should be provided for an individual plant or emission outlet in conjunction with coordinates representing their location. Emissions from area and line sources are usually released near the ground, whereas point sources usually have tall stacks with a plume rise due to the thermal buoyancy and mechanical momentum of the emission fluxes. The effective emission height of point sources – that include stack height and plume rise – is an important factor in atmospheric dispersion modelling and may have a significant influence on modelled concentration values. Thus, an accurate use of emission data requires the correct assignment to vertical model layers. Stack height and flue gas temperature, flow rate and velocity should therefore be known for point sources to be able to calculate the effective emission height.

Calculating emission data as well as generating a spatial distribution of emissions are usually not complicated mathematical problems. Data availability, a comprehensive data review and an assessment of data representativeness lead to the choice of emission factors and the development of calculation and allocation methodologies. The quality of a resulting emission database strongly depends on these data processing and analysis. Including available industrial emission data based on stack measurements may significantly improve the accuracy of an emission inventory. The use of flexible computer aided emission calculation models – such as the tools developed at IER, University of Stuttgart (see Friedrich et al., 2000; Wickert, 2001; Friedrich and Reis, 2004) – enables the generation of emission data and scenarios with a detailed resolution on regional scale including a vertical, temporal and species distribution. A validation of calculated emission data requires an interdisciplinary scientific approach considering CTM application and model uncertainty, parameter sensitivities and the comparison of modelled and measured concentrations and source contributions for selected grid cells/locations. The vertical distribution of emissions is an important issue in this process, along with others such as uncertainties and representativeness of monitoring data. Atmospheric dispersion modelling without an accurate

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vertical emission distribution may result in a systematic over- or underestimation of modelled concentrations at ground level. This matter is well known but it is often not addressed by the modellers in the sense of sensitivity analyses or comprehensive documentation and discussion of the assumptions used for deriving a vertical emission distribution. Recent analyses of two different European emission data sets by De Meij et al. (2006) showed that modelled SO_2 concentrations can differ by a factor of two due to different vertical emission distributions (see Chapter 2). In Wickert (2001), respectively, Wickert et al. (2001) sensitivity studies were performed applying the IER emission calculation tools and database for Germany and Europe coupled with the Eulerian chemistry transport model EURAD at meso-scale resolution. The results showed that the inclusion of point sources and their effective heights affect modelled concentrations of the secondary pollutant ozone at ground level, especially in urban areas. Overestimated NO_x emissions near ground result in underestimated ozone concentrations particularly during night-time. If point source emissions were represented without vertical distribution, hourly ozone concentrations per model grid cells (urban areas in middle Europe, 18×18 km resolution, hourly values of 2 days in summer) differed up to 45 $\mu g/m^3$ (0.95 quantile) compared to the reference case including real-world stack information (Wickert, 2001: Fig. 6-39).

However, there is often a lack of information about the effective emission height of point sources. To overcome this problem it would be helpful to have a set of default parameters which allow estimating typical effective heights, if type and size of the emission source are known. The objectives of this paper are to provide such a set of parameters and use it for exemplary calculations of emission heights. Substantial real-world data on emission sources have been collected in the frame of the German Tropospheric Research Programme (TFS) and the EUREKA project EUROTRAC-2 subproject GENEMIS (Generation and Evaluation of Emission Data) (Friedrich and Reis, 2004). A database of point source emissions and additional information for the calculation of emission heights were built up by Wickert (2001). For Germany, a large number of industrial data could be included into this database which had to be reported officially to the individual State Agencies for licensing purposes as required by the German Federal Immission Control Act (BImSchG, 2002). Meanwhile, the database has been further developed and updated for some of the Federal States and applied for the generation of highly resolved emission data for several national and EU projects such as MERLIN (http://www.merlin-project.de), ESPREME (http://espreme.ier.uni-stuttgart.de), CarboEurope GHG and IP (http://www.carboeurope.org), and NATAIR (http://natair.ier.uni-stuttgart.de).

This paper provides findings that emerged from an in-depth analysis of this point source database collected and applied at IER during the last decade. The analysis concentrates on the collected German industrial data providing the most comprehensive basis for the characterisation of point sources in Germany and probably also in Europe regarding their emissions as well as stack and flue gas parameters. Major results of this study are typical average values and standard deviation of these parameters for various source types and pollutants. In addition to that, exemplary results of bottom-up calculations of effective heights are shown for gaseous emissions. Finally it is analysed to what extent stack and flue gas parameters may vary with the year of reporting by comparing data from 1996 to 2004.

2. State of knowledge

Major point sources are operated by energy and transformation industries, metal, mineral, chemical, wood, paper and pulp, food and drink and other industries. These sources contribute significantly to anthropogenic emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and fine particulate matter in Europe. Emissions of major sources have to be reported periodically to the European Pollutant Emission Register (EPER), respectively, the subsequent Pollutant Release and Transfer Register (PRTR). EPER was established by a Commission Decision (2000/479/EC) of 17 July 2000. The first two reporting years were 2001 and 2004. For the third reporting year 2007, EPER was replaced by PRTR (see Regulation (EC) No 166/2006). PRTR builds on the same principles as EPER, but goes beyond, by e.g. including reporting on more pollutants and more activities. EPER and PRTR are the most important European data sources for atmospheric emissions from large point sources. The integration of this information is a basic requirement for European emission inventories and can significantly improve the accuracy of generated emission maps, provided that EPER/PRTR data are reviewed and accurate. Unfortunately neither EPER nor PRTR require the provision of stack and flue gas information, which would allow determining effective emission heights.

Different approaches are used in CTMs to take into account the vertical emission distribution. Currently applied three-dimensional models on regional scale such as EMEP, EURAD, CHIMERE or LOTOS-EUROS have various numbers and heights of vertical model layers (see e.g. ETC/ACC, 2006) and therefore use different emission allocations. The height of the near surface layer is often about 50 m. Total model height is typically about 3 km or higher. The vertical distribution of emissions is usually based on rough estimates for coarse source categories.

The following examples illustrate differences and uncertainties in the current use of vertical emission distributions in atmospheric modelling. Table 1 shows the vertical emission distribution applied in the EMEP model widely used for regional air quality studies in Europe (EMEP, 2003). Significant shares of the emissions from power plants, industrial combustions and waste incineration are allocated to model layers above 300 m and partly range up to 1100 m. De Meij et al. (2006) recently applied a modification of these data which is shown in Table 2 for the nested global transport chemistry model TM5 analysing the sensitivity to the two different emission inventories from EMEP (see http://www.emep-emissions.

Table 1
Vertical distribution of anthropogenic emissions: percentage of each source sector allocated to the vertical layers of the EMEP model (EMEP, 2003).

Source category	Height of emission layer (m)					
	0–92	92–184	184–324	324–522	522–781	781–1106
1. Combustion in energy and transformation industries	0%	0%	8%	46%	29%	17%
2. Non-industrial combustion plants	50%	50%				
3. Combustion in manufacturing industry	0%	4%	19%	41%	30%	6%
4. Production processes	90%	10%				
5. Extraction of fossil fuels	90%	10%				
6. Solvents and other product use	100%					
7. Road transport	100%					
8. Other mobile sources and machinery	100%					
9. Waste treatment and disposal	10%	15%	40%	35%		
10. Agriculture	100%					