1 Introduction and Summary

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1.1 Aims of this book

Understanding and quantifying the emissions of air pollutants from human activities and from natural sources is the first, essential step in understanding, controlling and mitigating air pollution. For this, it is necessary to describe the sources of emissions and their geographical distribution, describe the strength of the emissions from a particular source under particular conditions (commonly called emission factors), collect or calculate the volume of activity, that leads to emissions, calculate emission rates by connecting activities with emission factors, quantify the uncertainties of emission rates and identify emission reduction measures and their potential and costs. In this book, advances in all the above mentioned areas are described. These advances have been achieved with research carried out in the frame of the EUROTRAC-2[1] subproject on the Generation and Evaluation of Emission Data (GENEMIS). The pollutants covered include anthropogenic and biogenic precursors of ozone, aerosols and acidifying substances. As methods for developing emission inventories for CO, SO_2 and NO_x are more advanced and the resultant uncertainties in their emission estimates are lower than those for VOC, PM and NH_3, the focus lies on the latter pollutants.

The general aim of the results described here is to support the generation of validated emission data that can be used for the development of air pollution abatement strategies in Europe. This includes

- the improvement of methods, models and emission factors for the generation of emission data (*described in Chap. 2 of this book*),
- the assessment of the accuracy and the validation of emission data (*Chap. 3*) and
- the development and improvement of tools that generate emission data for atmospheric models *(Chap. 4)*.

The following sections of this chapter summarize the findings, that are explained in more detail in chapters 2 – 4 of this book. References are given, so that for each result the reader is referred to the corresponding section in the book, where more details are presented.

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[1] The EUREKA project on the transport and chemical transformation of trace constituents in the troposphere over Europe; second phase (http://www.gsf.de/eurotrac)

1.2 Summary

1.2.1 Anthropogenic emissions of volatile organic compounds

The main sources of anthropogenic non-methane volatile organic compounds (NMVOCs) are road transport and solvent use. Thus, in the following progress on generating NMVOC emission data for these source categories is described first. Then some other anthropogenic sources are analysed Next, progress in splitting information about total NMVOC into single species and classes of species is described. A very important contribution to NMVOC emissions stem from trees, this is addressed in the last section.

1.2.1.1 Road transport

Although the majority of vehicle kilometres are driven under highway conditions at normal operating temperatures, a significant fraction of journeys in urban areas are driven at sub-optimal engine (and catalyst) temperatures. Such cold start periods of passenger cars with the current emission control equipment are characterized by inefficient operation of the catalyst. It takes a few minutes for the catalyst to reach operating temperature (cf Sect. 2.2.2.3: Hassel et al.). In this period a substantial fraction of transport-related VOC emissions takes place and these cold start emissions are gaining in relative importance as other emission pathways are being reduced. Until now, cold start emissions have been estimated by using results of dynamometric tests based on the test driving cycle. However, recent research has shown that real world driving patterns e.g. in Germany are very different from those of the test cycle – the engine takes longer to reach its normal operating temperature – and that cold start emissions of VOC are up to 50% higher than previously assumed.

Another important contribution to the NMVOC emissions is that made by poorly maintained vehicles and those with defective catalysts, as illustrated by Sjodin et al. in Sect. 2.2.2.4. Real-world emission measurements on road vehicles have been carried out by means of optical remote sensing (FEAT) at two different sites in Gothenburg, Sweden, during 2001. The measurements indicate that, for petrol passenger cars, vehicle age is the most important factor affecting the tailpipe exhaust concentrations and the mass emission of CO, HC and NO per litre fuel burned. The largest differences can of course be observed between non-catalyst cars and catalyst cars, however, there are also significant differences between catalyst cars of more recent model years and earlier model years. Results also show that less than 10% of the passenger cars cause ca. 50% of the HC and CO emissions.

An analysis of measurements of in-use cars in Germany revealed that the exhaust emissions of VOC from cars with catalysts (current fleet) are about 9%

higher than calculated with actual emission models due to malfunctioning equipment.

1.2.1.2 Solvent use

While for road transport, methods to calculate non-methane VOC emissions are well established and harmonised throughout Europe, this has not been the case for emissions from solvent use. This leads to data sets of different quality for the different countries of Europe, and in some cases not all processes will be accounted for. Thus, a method has been developed by Theloke et al. (Sect. 2.2.3) and applied to Germany which is based on statistical data on the production of goods containing solvents and the import and export of such products.

The share of emissions from solvent use as one of the main anthropogenic NMVOC emission sources has increased during recent years relative to that of traffic, the second largest emission source for NMVOCs. In 2000, roughly 50% of all German NMVOC emissions originated from the use and application of solvents, in total ~ 945 kt. About 450 kt originated from paint application (48%), 158 kt from domestic solvent use (17%), 79 kt from the printing industry, 31 kt from the processing of synthetic materials and 33 kt from degreasing, dry cleaning and electronics production. The remaining share of emissions originates from a number of other sectors. The increase in emissions from solvent use observed from 1994 to 2000 currently prevails. Thus, it is not clear if Germany can comply with the emissions target of the recently adopted EC National Emissions Ceilings Directive for the year 2010. The implementation of additional measures to further reduce emissions of anthropogenic NMVOC emissions in Germany has to be taken into consideration.

The developed method for estimating solvent use emissions could be used throughout Europe, as it uses available statistical data. Important sources of solvent emissions include paint application, degreasing processes, domestic solvent use, printing processes, application of glues and adhesives and the preservation of wood.

1.2.1.3 Other sources

Emissions of VOC compounds have been measured in several stove types used for the combustion of brown-coal briquettes (Sect. 2.2.2.6: Michael and Engewald). Such stoves are typically used in houses in Eastern Germany. Species in the range C3-C18, mainly alkanes, alkenes, aromatics, aldehydes, phenols and thiophenols were found. Surprisingly, the share of oxygenated species was – with 45% of the total NMVOC- much larger than previously assumed.

Activities during refuelling and transport of petrol are important anthropogenic VOC emission sources. These activities include the handling of fuels within gas stations and other refuelling units respectively transport systems such as ships and road tankers, tanks and tank cleaning. To determine the emission rate from diffuse area sources and heterogeneous distributed sources measurements have been carried out, using inverse modelling to determine emission rates of fuel stations and of ships. Results for fuel stations show (Sect. 2.2.2.5: Schäfer et al.) that diffuse emissions have been seriously underestimated in emission inventories. For tank ships, it was shown that the ventilation of the tank atmosphere of river tank ships via the loading/unloading pipes into the land-site vapour recovery unit is a technical solution to reduce VOC emissions drastically.

1.2.2 VOC split

VOC is a collective name for a very large number of different chemical species that have different physico-chemical properties, and which can contribute to the formation of secondary pollutants with different efficiencies. It is therefore important to have information on the speciation of the VOCs, i.e. to split the total VOCs into species or classes of species with similar chemical and physical properties. However, emission inventories usually only provide data for total non-methane VOC only. A detailed speciation of VOCs has been developed for the different source categories by specific measurements of selected sources as well as by using data from measurements performed elsewhere (for an in-depth discussion of the VOC Split, see Chap. 2.2). Measurements included emissions from passenger cars as well as stationary sources.

To determine VOC splits of NMVOC emissions from passenger cars, measurements were made independently by several groups (e.g. Klemp and Mittermaier, Sect. 2.2.2.2) for diesel and petrol motors in different driving cycles.

Road traffic VOC splits were determined for different car types under various conditions (driving pattern, maintenance etc.). The experimental determination of VOC splits of cars shows a strong dependency of the split on the driving pattern of vehicles with three-way-catalysts. For non-catalyst and diesel cars the split differs significantly less. For diesel vehicles alkenes and carbonyls dominate, whereas in the exhaust gas of petrol cars aromatics or alkanes have the highest share of the VOC's.

Based on these measurements and other findings a detailed VOC-split data base has been developed and is now available (Sect. 2.2). Combustion processes and solvent evaporation emit very different VOC species. Solvents emit mainly alcohols and other oxygenated VOCs, whereas combustion processes tend to emit alkanes, aromatics and alkenes (Theloke et al. 2001, 2003; Friedrich and Obermeier 1999).

1.2.3 Biogenic emissions of volatile organic compounds

Recent work has shown, that – during hot sunny episodes – biogenic emissions in Europe are higher than anthropogenic emissions. On the other hand, uncertainties of estimates of biogenic emissions are much larger than those estimated for anthropogenic emissions. So, the improvement of the methodology for estimating biogenic emissions is a research topic with high priority (Sect. 2.2.1: Steinbrecher et al.).

In order to extrapolate BVOC emissions from the leaf or plant level to the ecosystem, regional or global scales, detailed information on meteorology, the area of the emitting land use type in each grid cell of the model area, leaf biomass or leaf area index (LAI), and emission factors are needed. Land use data are generally given in categories, such as agriculture, deciduous, coniferous or mixed forest. This classification is available at high resolution, e.g. in the CORINE database (www.dataservice.eea.eu.int), but this coarse land cover classification causes large systematic errors in the emission inventories, especially in landscapes where deciduous forest consists of both non-emitting plant species like beech and high emitting species like oak.

For constructing BVOC emission inventories at different spatial and temporal scales a geographical information system (GIS) and a relational data base management system (RDBMS) has been set up, managing land cover and plant species-specific data (VOC emission factors, biomass and LAI values) (Sect. 2.2.1 Steinbrecher et al. and Sect. 4.2 Smiatek et al.). GIS handles all geo-data, such as land use, administrative boundaries and other data in raster or vector form. The RDBMS stores all data on the species area and biomass as well as descriptive information. In total more than 44 different land use data sets with 14 different categories, 30 data sets with vegetation index (VI) and leaf area index (LAI) data covering Germany and large areas of Europe have been processed.

As an indication of the complexities involved in modelling BVOC emissions, it may be noted that more than 130 European plant species, 33 chemical compounds and 668 emission factors have been collated from various sources, 3600 records of information on forest area with 6 different categories and more than 400 regions have been integrated. Information on species specific emission factors for 1100 plant species is available.

A monthly-average BVOC inventory for Germany has been established for the year 1998, with hourly-average emissions estimated for a 3 days ozone episode in August 1998. Most of the biogenic emissions occur in the middle and southern part of Germany with values of more than 400 kg C km^{-2} month^{-1}. Compared to BVOC emission inventories which only consider general forest types (e.g. deciduous, coniferous, and mixed forest), the use of tree species distribution for the six major forest trees in Germany significantly reduced systematic errors associated with the assignment of emission factors to source categories. Isoprene emissions using plant species data are in general 30% lower compared to emission estimates considering only forest types. Furthermore, the plant specific emission inventory for Germany shows significantly different geographic distribution patterns shifting the focus from areas with large forest cover to areas with large oak stands.

The total annual emission rate of BVOC for Germany for 1998 was 547 kt C BVOC, or 20% of the total VOC emissions for the country. However, under high temperature and light conditions during August 1998 the BVOC contribution rose to 60% of the total VOC emission. Since the reactivity of BVOCs towards OH is greater than that of the anthropogenic VOCs, their role in ozone formation is likely to be greater than is apparent from just considering the mass emission rates.

1.3 Anthropogenic emissions of ammonia

Most emissions of ammonia (NH_3) originate from agricultural practices, principally the production of manure and the application of fertiliser. Emissions from animal husbandry depend on many factors (Sect. 2.4 Asmann et al.). The nitrogen excretion of animals is influenced by the nitrogen content of the feed intake and the relative share of amino acids in the feed. For animals housed indoors, the ammonia emissions depend on factors such as the type of building floor, the ventilation rate, the frequency of cleaning and the type of manure (liquid or solid) produced. Emissions during storage depend on the type of storage system used (pile, open or closed tanks) and to some extent on meteorological conditions (wind speed, temperature). Following the application of manure, ammonia emissions depend on factors such as the properties of the manure and the meteorological and soil conditions. Emissions resulting from different manure handling systems for the same kind of animal can be up to a factor of two different. Recently control techniques have been applied in some areas to reduce agricultural ammonia emissions.

Experimental work has shown that ammonia emissions after manure application in the field increases by 2% when the temperature increases by 1° C; it increases by 4% when the wind speed increases by 1 $m\ s^{-1}$ and it is 10% higher for wet soil than for dry soil (Hutchings et al. 2002).

In many countries, no statistical information is available on different manure handling systems. Even when information is available it is not usually geographical disaggregated within countries.

Mechanistic models have been developed for ammonia emissions following application of manure. These models give a better understanding of the complex interactions during the emission process and their results agree reasonably well with measurements. However, there is a need for further development of such models so that a coherent description can be given of all processes influencing ammonia emissions. The ammonia emission rate is influenced by atmospheric turbulence, but vertical mixing in the atmosphere depend also on the atmospheric turbulence. It has been demonstrated that when there is much turbulence, the emission rate is higher, but also that the emitted NH_3 is transported over longer distances before it is deposited back to the surface, either as NH_3 or as NH_4^+.

This co-dependence is not yet taken into account in most atmospheric transport models that are used to make policy decisions concerning ammonia emissions. This is important because it may change the ”blame-matrices” for acidifying and eutrophying compounds that are used to develop strategies for emission reduction. Model experiments have shown that a significant fraction of emitted NH_3 is lost from the atmosphere by dry deposition very close to the source. This is important to consider as otherwise the ammonia emission rates feeding into atmospheric transport, chemistry and deposition models may be overestimated.

1.4 Emissions of particulate matter to the atmosphere

Information on emission sources and factors has been systematically collected and detailed emission inventories have been set up for Germany (Sect. 2.3.3.2: Pregger et al..) and Austria (Sect. 2.3.3.1: Winiwarter et al.). In addition to that, measurements of emission factors have been carried out, investigating particulate emissions of small wood combustion furnaces in Hungary (Sect. 2.3.2: Török et al.) by microchemical analysis methods, focussing on including elemental concentrations and aerodynamic parameter. The majority of stack-gas particles were found in the respirable size range. The completeness of PM inventories is now substantially improved.

For Austria (Sect. 2.3.3.1: Winiwarter et al.) results indicate, that the emissions of all sources except road dust suspension (base year 1995) amount to 75,000 t of TSP, 45,000 t of which are PM_{10}, and 26,000 t are $PM_{2.5}$. Most important source sectors are fugitive emissions from bulk materials handling in industry as well as building and agricultural operations. Wood combustion is the most important source of fine particle emissions.

An important, yet very uncertain source might be vehicle-induced suspension and abrasion of particles from road surfaces (Sect. 2.3.1.1, Sturm.et al.) A first model has been set up to calculate vehicle induced emissions; the model is based on a model design developed by US-EPA, but adjusted to European conditions using measurements in Berlin. It shows that suspension and abrasion processes might lead to PM_{10} emissions in the same order of magnitude as those from exhaust gases from diesel engines (Pregger and Friedrich 2003). Further results show that suspension of road dust may be the cause of up to half of the total PM_{10} emissions for Austria. The model methodology is under dispute, however, and more measurements (Sect. 2.3.1.3 Sjodin et al.) are required under a range of European conditions to confirm this result.

1.5 Assessment of the quality of emissions data

Emission data are needed to estimate future trends in the concentration and deposition of air pollutants, to identify air pollution control strategies that lead to an avoidance of exceeding ambient thresholds and to report emissions for different reporting obligations in the frame of conventions and directives, e.g. IPCC, national emissions ceilings directive, and others. Emissions data however can only be used as useful aid for decision making in the field of air pollution control if their quality is known. There are several aspects of inventory quality, basically all of which deal with the question: how well does the inventory fit reality.

An overview of potential quality control options in urban emission inventories has been prepared (Sect. 3.2.1 Sturm et al.).

To assess the quality of emission data, two options have been used and are described here; one is the analysis of input uncertainties in emission inventories and their representation in the result (Sect. 3.3.1 Winiwarter et al.), and the other is the comparison of an inventory with independently derived information on emission fluxes, especially with measurement data (Sect. 3.3.2 and 3.3.3).

Quantifying uncertainties in emissions data requires a statistical approach. The spreads of statistical errors of model input parameters can be calculated by basic statistical methods such as error propagation or Monte-Carlo analysis. Statistical evaluations provide confidence intervals of calculated emission values. However, they give no information on the true emission values, as possible systematic errors (missing sources, wrong assumptions) are not fully detected, even if attempts have been made in this direction; so in addition to a statistical analysis verification is necessary (see Sect. 3.2.2. Kühlwein et al).

The verification of emissions data requires the comparison of the calculated emission rates with emission rates derived with other independent methods (see 3.2.2). The use of an inter-comparison of different emission inventories is limited as they will, at least in part, make use of the same methods and parameters. Nevertheless, comparisons of available inventories for the same regions, but prepared by different groups, show quite large deviations, this demonstrates the necessity of quality assurance and control (Sect. 3.3.3.2, Slemr et al.). A further possibility for verification is the comparison of emission trends with ambient concentration trends (short term as well as long term). True emission rates can be estimated within a certain error margin by measurements of ambient concentrations. Methods include the measurements of upwind and downwind fluxes, e.g. for tunnels (Sect. 3.3.2.1, Staehlin and Sturm), motorways or whole cities. Furthermore, tracers can be released (see Sect. 3.3.3.4, Moellmann-Coers et al.) at known emission rates and the ratio of measured tracer concentration to the concentration of another substance then used to determine the emission rate of this substance. Other methods include the comparison of concentration ratios with emission ratios of individual substances (cf. Sect. 3.3.3.7, Mannschreck et al.) and receptor modelling (Sect. 3.3.3.6, Klemp et al.). Measurements under real conditions are restricted to particular conditions (e.g. emissions from one motorway section with a particular road gradient, fleet composition and driving pattern). All this methods have been applied and are described here.

Road tunnel studies have been used to validate road traffic emission models (see Chap. 3.3.2.1). Measurements of primary air pollutants performed in different years in the same European road tunnels impressively demonstrated the large success in the reduction of the emission factors of total Non Methane Volatile Organic Compounds (t-NMVOC), carbon monoxide (CO) and nitrogen oxides (NO_x) of petrol powered vehicles during the 1990s, largely attributable to the introduction of catalytic converters.

In general it is necessary to use compilations of data from as many experiments as possible to get a full picture of the uncertainties in emissions estimates. Results of such a metaanalysis demonstrate clearly that there is a systematic error in the calculation of emissions from trucks: the commonly used NO_x emission factors for the current truck fleet are too low by a factor of 2 (Kühlwein and Friedrich 2003).

In another experiment, emissions from fuel stations have been measured with remote sensing devices (Schäfer et al. 2000). This showed that the vapour recovery systems in use often do not work properly, with VOC emissions 3 to 5 times larger than from well maintained stations. This shows that more efforts should be made to regularly maintain emission reduction technologies and to check them to ensure effective operation.

Within the evaluation project EVA, whose aim was to evaluate emissions from all sources of a whole city, two field campaigns were successfully performed in March and October 1998 (see Sect. 3.3.3) using aircraft, tethered balloons, air ships, radio sondes, ground stations, and remote sensing techniques. For the experiment, the city of Augsburg has been chosen, as the terrain there is relatively flat and there are not too many large emission sources outside the city borders. Augsburg has on the one hand significant emissions, on the other hand it is small enough to be analysed with the limited number of measurement devices and aircrafts available. Emphasis has been laid on QA/AC during the measurement campaigns. At the first and last days of each field experiment an intercalibration with transfer standards and comparisons of measurements under field conditions has been carried out.

Three different measurements (two mass balance approaches including aircraft measurements, see Sect. 3.3.3.3 Slemr et al. and Sect. 3.3.3.8 Baumbach et al., one tracer experiment, described in Sect. 3.3.3.4, Moellmann-Coers et al.) and two different models have been used to determine the emissions. Given the anticipated standard deviation of modelled (Kühlwein et al. 2002a) as well as measured emission rates of ca. 20%, no statistically significant deviation could be detected for NO_x and CO (Kühlwein et al. 2002b). However, for some single VOC species derived from solvent use, especially from white spirits, calculated emission rates are much higher than measured values, suggesting that emissions from solvent use may be currently overestimated. Unfortunately VOC species from solvents are rather difficult to measure and so relatively few reliable data are available. This suggests that more measurements of higher alkanes and oxygenated VOC emissions in urban areas are necessary.

This overestimation of solvent use emissions was also detected in another analysis (Sect. 3.3.3.10., Staehlin et al.) for Swiss emission inventories. Based on a statistical analysis of extended monitoring measurements the conclusion was drawn, that the proportion of VOC from motor traffic emissions including fuel vaporisation amounts to 48-67% whereas the Swiss emission inventory (basis year 1990) gives lower values (33-48%).

In summary, modelled emissions data still have considerable sources of error associated with them. Future efforts to improve activity data and emission factors should reduce these uncertainties. Statistical uncertainty analyses of modelled emission rates of CO, NO_x and NMVOCs result in coefficients of variation in the order of 10% to 50%. Uncertainties in individual VOC emission rates can be much higher. Comparisons between measured and modelled emission values at individual road sections in general show lower model emission factors especially for trucks. Good agreement between modelled and measured total NO_x and CO emission rates from the city of Augsburg has been found within the 1 σ confidence intervals.

1.6 Improvement and application of emission models and tools

1.6.1 Urban modelling

In the case of urban modelling, work focused on developing specifications of emission data for emission modelling and development of methodologies for emission inventories models and especially methodologies for the estimation of traffic and biogenic emissions. A group from Turkey (Müezzinoglu et al, Sect. 4.3.4) developed a specific decision support system for urban air quality management for the İzmir metropolitan area. An emission inventory for five air pollutants of sulphur dioxide (SO_2), particulate matter (PM), nitrogen oxides (NO_x), volatile organic compounds (VOC) and carbon monoxide (CO) by using appropriate emission factors was prepared. The results show that industry is the most polluting sector in the study area contributing about 91% of total SO_2 emissions, 40% of total PM emissions, 90% of total NO_x emissions, 40% of total VOC emissions and 70% of total CO emissions per year.

New EU guidelines with the intention to restrict concentrations of harmful pollutants came into force recently. Model based pollution maps are necessary to recognize receptor points where concentration limits might be exceeded. To prepare these maps, emission data in different spatial scales need to be available. Thus, a microscale traffic emission model is being established as described by Kühlwein et al. (see Chap 3). Emission data in high spatial resolution (< 50 m) is calculated and provided as input data for high-performance chemistry transport models.

1.6.2 Regional modelling

A number of emission models (EMIMO, MIMOSA, ECM, see San Jose et al., Lewyckyi et al. and Reis et al., Chap. 4) have been developed which can be used by air quality mesoscale models for all parts of the world. The EMIMO model uses both the top-down and the bottom-up approaches together with an important set of global and European emission inventories such as EMEP, CGEIC, GEIA and EDGAR.

Due to the increasing demand of emission data for CTMs, a geographic preprocessor (GIS) has been designed and implemented into the GENEMIS emission module (ECM) by Friedrich et al. (1999 and 2003) to improve the spatial resolution of the European database and enable the conversion of data in model grids of any geographic projection. The fine spatial structure of emissions is based on land-use data sets, on digital road and railway maps and other available information.

Ozone forecasting using the ECM model

To provide emission data in high temporal and spatial resolution, a large amount of data has to be generated. It is difficult and inefficient to generate these data, e.g. for a year in advance and then to deliver it to the location of the atmospheric model. Instead, a module (named ECM) has been developed, that can be coupled to the atmospheric model generating the input data in the moment they are needed (Friedrich et al. 1999). The most important part of this module is a data base containing data and specifications for possible data manipulations. The information in the data base allows the emission model to determine emissions of different pollutants in a high spatial and temporal resolution, e.g. hourly values for a 1 km x 1 km-grid for any investigation project. ECM is in fact more a flexible modelling toolbox than just a single emission model. ECM was and is further used for preparing emission data for various investigation areas including small-scale urban areas, regions, countries and the whole of Europe. ECM is currently applied by EURAD to provide emission data for ozone forecasting (http://www.eurad.uni-koeln.de/index_e.html) and provides emission data as input for a number of chemical transport models on different scales.

1.7 Outlook

Air pollution is still a major problem in Europe, as current or planned thresholds or critical levels and loads are frequently exceeded (e. g. for Ozone, PM_{10}, acid deposition and nutrient deposition). So, further reductions of emissions are necessary. It is obvious, that a prerequisite of identifying abatement measures is a profound knowledge of emissions and the structure of emission sources. Furthermore, the increasing emission reductions necessary to improve air quality require more and more expensive emission reduction measures. To achieve acceptance of additional measures, it is increasingly important to establish proof, that the planned measures lead to a fulfilment of the environmental goals and that the emission reduction is reached efficiently, i.e. with the least costs possible. To show this, emission data with high quality are needed, as well as input for atmospheric models as base for investigating possible abatement measures and related costs.

The results described here have contributed to the improvement of the quality of emission data including the improvement of methods for calculating

- emissions with high spatial and temporal resolution;

- PM emissions for all emission sectors;
- NMVOC emissions from solvent use;
- Biogenic emissions from forests
- Emissions from road transport (cold start, evaporation)
- measurements of VOC emission factors and VOC split
  - from fuel stations and tankers;
  - from passenger cars;
  - from lignite firings.

Furthermore, new knowledge on uncertainties of emission data has been acquired by carrying out or analysing results from whole city, tunnel and open road experiments and statistical analyses of uncertainties. Uncertainties still are large, this has to be taken into account when interpreting results of atmospheric models.

A number of models to set up emission inventories for street canyons, for urban areas and for regions have been developed and improved. A large number of regional and urban emission data sets have been generated and provided to groups applying atmospheric models.

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