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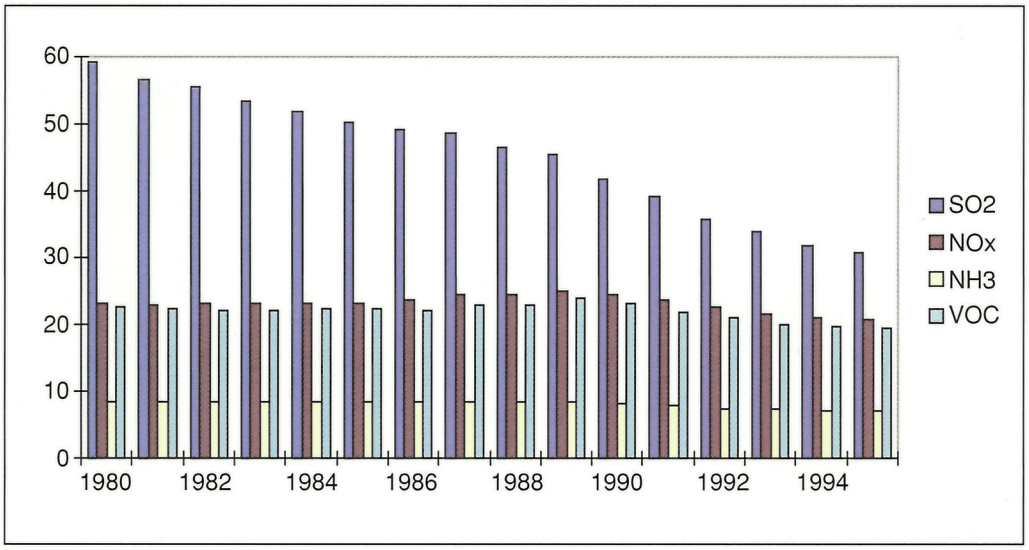
Transboundary Air Pollution in Europe



MSC-W Status Report 1997
Part 1;

Emissions, dispersion and trends of acidifying and eutrophying agents.

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Transboundary Air Pollution in Europe

PART 1:

Emissions, dispersion and trends of acidifying and eutrophying agents

Erik Berge
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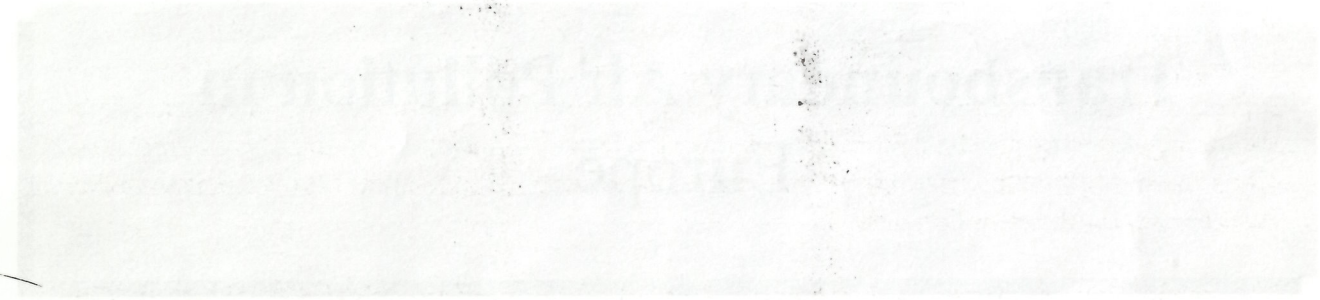

Acknowledgements

The editor would like to thank all authors for their large efforts and cooperativeness in preparing the different chapters of Part 1 and Part 2 of the 1997 Status Report of the MSC-W. All information on transboundary air pollution contained in this report is the product of continous development of atmospheric transport models and the emission database by scientists and technical experts at the MSC-W during many years.

The editor would also greatly acknowledge the following persons for their contributions to this report; Mr. David Simpson for his expert assistance in preparing emissions data, Mr. Egil Støren for his expert assistance in preparing meteorological data, emission data, figures and tables, Ms. Lisbeth Rackwitz for her layouting, typing of emission data and assistance in producing the report. Thanks are also due to Professor Trond Iversen and Professor Anton Eliassen for valuable discussions and suggestions, and Ms. Sophia Mylona for valuable information on the emission data.

The calculations presented in this report are based on the meteorological data obtained from the Numerical Weather Prediction model at the Norwegian Meteorological Institute. From 1996 a special version of the HIRLAM (HIgh Resolution Limited Area Model) has been set up for EMEP purposes. In this respect we would specially like to thank Drs. Jan Erik Haugen and Dag Bjørge and Mr. Anstein Foss for their efforts in providing meteorological data to the MSC-W.

The calculations presented here were facilitated by access to a CRAY J90 and a CRAY T3E at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. The assistance of the staff at NTNU has been of invaluable importance in preparing such a volume of calculations.

The cooperation with the UN-ECE secretariat has been of large value for the work on the emission data and the development of the emission database. Mr. Tony Webster at Lloyds Register is also greatly acknowledged for the provision of the new emission data from international shipping in the North Sea and in the Northeast Atlantic Ocean.

Thanks are also due to Drs. Jean-Paul Hettelingh and Maximillian Posch at the Coordination Centre for Effects for providing the latest information on the critical loads.

Preface

This report was prepared for the twenty first session of the Steering Body of EMEP (Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe). Last year the first report in the annual series from MSC-W covered for the first time all important aspects of the work at MSC-W. This year we continue the same style of reporting. Due to unexpected difficulties with the ozone model runs, the ozone modelling acitivity could not be finalized in time to be included in this report. Instead it is presented in a separate MSC-W report.

The report is organized in two volumes. In **PART 1**, we overview the major aims of the MSC-W, the basic modelling and meteorological tools, the status of the emissions data, the trends in transboundary transport and deposition of sulphur and nitrogen since 1980, and the latest transboundary flows of sulphur and nitrogen, in both the 150km and the 50km grid. Complete source receptor matrices are now available in the 50km grid derived from the multi-layer eulerian model. The new 50km data constitutes a basis for further assessments of acidifying air pollution in the 50km grid by subsidiary bodies under the Convention.

In **PART 2** we present the numerical fields and budgets of the acidifying and eutrophying air pollution.

Transboundary Air Pollution in Europe
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Part 1

Transboundary Air Pollution in Europe
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NUMERICAL ADDENDUM

Chapter 1

INTRODUCTION

1. Introduction.

The main objective of the EMEP programme (Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe) is to provide Governments and subsidiary bodies under the Convention on Long Range Transboundary Air Pollution with regular information on the emissions and the spatial distribution and temporal variation of concentrations and/or depositions of air pollutants, as well as on the quantity and significance of long-range transmission of pollutants and their fluxes across boundaries (see Annex I, ECE/EB.AIR/46). The main elements in supporting this objective are (1) collection of emission data, (2) measurements of pollutants in air and precipitation, and (3) modelling of atmospheric transport and deposition by using emission data, meteorological data and descriptions of the transformation and removal processes.

The timing of the three above mentioned main elements is important for a consistent assessment of the data available through the EMEP programme. The Parties are required to complete emission reporting to the UN-ECE secretariat for any one year by 31 December of the following year. In this report we can therefore present the emissions updated to and including 1995. Similarly, measurements for 1995 have been subject to quality control at the Chemical Co-ordinating Centre (CCC) of EMEP and are now available for application. This means that depositions of acidifying compounds and concentrations of photochemical oxidants calculated by the LRTAP models (LRTAP = Long Range Transport of Air Pollution) at the MSC-W by using the latest information on emissions, can be analysed together with the measurements of the same time period.

One important goal of this work is to support the development of international emission reduction agreements. Two emission reduction protocols on sulphur, and one on nitrogen oxides and one on volatile organic compounds (VOC) have been adopted to date. The latest and second sulphur protocol, the 1994 Oslo Protocol on Further Reduction of Sulphur Emissions, was more based on scientific and technical information such as country-attributed depositions (delivered by EMEP) and effects-based critical loads of sulphur to achieve a more cost-efficient control strategy. At present, work under the Convention is progressing toward a renewal of the protocols on nitrogen oxides and VOCs. A large portion of the activity at the MSC-W is directed towards technical support for the preparation of these new protocls.

Presently, the EU is also preparing a strategy to combat acidification (see Amann et al., 1997). Their approach is largely similar to that of UN-ECE, e.g. to close the gap between existing deposition levels and critical loads in a cost-effective way. The transfer matrices derived from the LRTAP (LRTAP=Long Range Transport of Air Pollution) models at MSC-W constitute a part of this data material.

1.1 Aims of the MSC-W and basic tools.

The main modelling tasks of MSC-W is defined in the 1997 Work Plan for the implementation of the Convention (ECE/EB.AIR/49, Annex I) as "... to produce information on annual transboundary fluxes, concentrations and depositions of sulphur and nitrogen compounds over Europe, to evaluate short- and long-term country-to-country matrices for photochemical oxidants ... ".The present modelling tools at MSC-W to fulfil these tasks are

the one-layer lagrangian trajectory acid deposition and ozone models with 150 km resolution model, the multi-level eulerian acid deposition and ozone model with 50 km resolution and the one-layer lagrangian acid deposition model with 50 km resolution.

The core LRTAP models at MSC-W have up to now been the lagrangian acid deposition and ozone models. Originally, the model was developed for sulphur (Eliassen and Saltbones, 1975, 1983), but it was later extended to acidifying and eutrofying nitrogen (Hov et al., 1988) and photochemical oxidants (Eliassen et al., 1982, Hov et al., 1985, Simpson, 1992). The acid deposition version was further improved by Iversen (1990). The dry deposition modelling of acidifying compounds was revised in Tuovinen and Kruger (1994) and Seland et al. (1995). Oxidant chemistry has been revised by Simpson et al. (1993) and Simpson (1995) as has the treatment of biogenic emissions (Simpson et al., 1995).

Evaluations of the lagrangian acid deposition models can be found in for example Iversen (1993) and Barrett and Berge (1996). Assessments of the photochemical oxidant model is given in for example Simpson (1993), Solberg et al. (1995) and Malik et al. (1996). With the latest available computing technology it is now possible to calculate long-term (many years) country-to-country allocations for European ozone.

One criticism of the lagrangian approach has been that it is two-dimensional and therefore the model can not properly account for processes in the free troposphere above the planetary boundary layer (PBL). Inevitable, a direct linkage of the photo-oxidants and the acidic compounds is difficult since it often occurs in the free troposphere for example in clouds. Furthermore, resolving small source regions in montainous terrain and the description of transport beyond 1000 km would often need model layers above the PBL in order to source allocate the emitted pollutants transported above the PBL.

On this basis, the MSC-W has developed a multi-layer eulerian model with 50 km resolution (see Berge, 1993, Jacobsen et al., 1995, Jacobsen et al., 1997, Jonson et al., 1997). The model is evaluated in Jakobsen et al. (1997). A discussion of preliminary source-receptor matrices was given in Berge et al. (1996), which concluded that a larger fraction of the sulphur deposition for U.K and Switzerland could be allocated to the emissions compared to the one-layer lagrangian models. The multi-level model will in the future also aim to support multi-pollutant protocols by tying together acidification, eutrophication and oxidant problems. The development of the multi-layer model has had to balance between the need for details and at the same time long term calculations. Considerable resources have been invested into constructing high speed computer codes applicable to massive parallel computing. With the latest available computing technology it is now possible to calculate complete country-to-country allocations for sulphur and nitrogen components in Europe for a full year.

A 50 km version of the lagrangian trajectory model was also developed by Sandnes (1995). The source-receptor matrices of this model were discussed in Berge et al. (1996). It was concluded that a smaller fraction of the deposition could be allocated to the sources by employing the 50km approach compared with the 150 km version of the model. Due to this difficulty of the mass budget ,and the necessity of focusing the use of our resources, no further development and application of the 50 km lagrangian model has taken place the last year.

In addition to modelling, the other main task of the MSC-W is the work on the emission data. The objective of this activity is defined in the 1997 Work Plan (ECE/EB.AIR/49, Annex I) "...

to assist the Parties to fulfil their reporting tasks, control the quality of reported emission data and evaluate emission inventory requirements under the Convention to ensure adequate flow of reliable information on emissions and emissions projections, giving particular attention to the emission inventories of heavy metals and POPs ". The main tool to fulfil this task is the emission database at MSC-W (EB.AIR/GE.1/R.94, EB.AIR/GE.1/1997/3). The database operates national total emission, the eleven source sectors (level 1), 50km*50km and 150km*150km gridded data, emissions above and below 100 m, large point sources etc. A continuos co-operation on the European emission data takes place together with the UN-ECE secretariat, the other EMEP centres, the Task Force on Emission Inventories and the European Environmental Agency and its Topic Centre on Air Emission.

1.2 Present activities at the MSC-W.

The activities during the last year have been focused on further development and application of the model tools and the emission database. Particular, focus is also on delivery of model data and emission data to the subsidiary bodies under the Convention.

The model domain of the 150km lagrangian model has been extended toward souteast. This is possible due to the set up of a new meteorological model for 1996 which covers a larger domain than earlier. The model therefore now for the first time includes Cyprus and entire Turkey. Complete source-receptor matrices for 1996 are derived for these two Parties. Source-receptor matrices, total deposition and concentrations for the acidifying compounds have also been calculated for 1995 based on the latest officially reported emissions. The matrices and the depositions have been updated for all previous years (prior to 1995) since a few rather substantial changes in the emissions have been recorded for a few Parties (for example Italy, Romania, Germany, Lithuania, Latvia and Estland). For simplicity the new matrices and depositions have been obtained by scaling the calculations presented last year to the Steering Body of EMEP (see Barrett and Sandnes (1996)).

A new emission data set for shipping based on information from Lloyds Register has been implemented and analysed by the model. The total emissions of sulphur and nitrogen in the North East Atlantic and the North Sea are increased by a factor of 2.4 for SO_2 and 3.2 for NO_x compared to previous estimates.

New photolysis rates and deposition velocity for ozone have been introduced to the EMEP ozone model. The model is now optimised for parallel processing on high speed computers in order to more efficiently employ the model for long term periods. Model runs including long-term source-receptor matrices for the summer seasons of 85, 89, 90, 92, 93, 94 have been carried out. The model data is presently extensively applied to the on-going work on renewal of the NO_x and VOC protocols.

The dry and wet deposition modules and the chemical mechanism of the multi-layer eulerian acid rain model have been improved and now includes an explicit treatment of the wet scavenging of acidifying compounds. The model code has also been further optimised for parallel processing on high speed computers. The complete source-receptor matrices for one year for oxidized sulphur, and oxidized and reduced nitrogen is derived with the latest version of the model. A larger fraction of the depositions in each country can be allocated to the emitting countries with the multi-level model compared to the 150 km lagrangian model. The

oxidant/ozone version of the multi-layer model has been further developed and tested. An improved version of the advection scheme is implemented. Preliminary emission scenario studies have also been carried out.

The emission data for 1995 has, during the winter and spring, been received and entered into the emission database. The updated emission data is made available for the modelling activities. The first verification and consistency check have also been carried out in collaboration with EEA and its Topic Centre on Air Emission.

1.3 Structure of this report.

In **Part 1** of this report, chapter 2 describes the meteorological data end the land use data. In chapter 3 we continue with a description of the emission data and the maintenance of the emission database. Furtheron, in chapter 4, trends in depositions, critical loads exceedances, and source receptor relationships are presented. Chapter 5 provides the latest budgets of the transboundary fluxes of sulphur and nitrogen compounds based on twelve years of data using the 150km lagrangian model. In chapter 6 we describe and discuss one year source receptor matrices calculated with the 50km multi-layer eulerian model. Finally, Part 1 ends with an appendix describing the EMEP grid definition.

In **Part 2** we provide the numerical fields and source-receptor matrices of acidifying eutrophying species.

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Chapter 2
METEOROLOGICAL DATA

2. Meteorological Data.

Hugo A. Jakobsen, Erik Berge and Egil Støren.

The basic parameters of the system for atmospheric transport modelling operated at the MSC-W, are described in this section. The EMEP grid definition is given in Appendix 1.

2.1 The meteorological data.

The meteorological data has up to 1 January 1996 been derived from a special version of the Numerical Weather Prediction (NWP) model at the Norwegian Meteorological Institute (DNMI). The algorithms used solving the model equations are described in Bratseth (1983) and Grønås et al. (1987). The parameterization of the physical processes is given in Nordeng (1992). A description of the initialisation method and the analysis method can be found in Bratseth (1987) and Grønås and Midtbø (1987) respectively.

Between 1985 to May 1991 a 150 km version with 10 layers in the vertical direction was employed. Since May 1991 a 50km version (LAM50E = Limited Area Model 50 km, Europe) with 20 layers in the vertical has been the basic tool for achieving meteorological data for the MSC-W modelling. The model is formulated in Cartesian co-ordinates on a polar stereographic projection with a terrain following vertical co-ordinate (σ). The geographical area covered by the LAM50E model is presented in Fig. 2.1. In the vertical direction the NWP-model domain extend approximately up to the tropopause.

Recently, DNMI moved from the LAM50E to the Nordic/Dutch/French/Irish/Spanish co-operation on short range, numerical weather prediction model, the so-called HIRLAM model system (HIRLAM = HIgh Resolution Limited Area Model). The model equations are formulated in Cartesian co-ordinates on a rotated spherical grid with a hybrid terrain following vertical co-ordinate (i.e. η, hybrid between σ and pressure co-ordinates). The main reason for moving to this model is that the co-operation between several European countries will make the model development more efficient and comprehensive. The parameterization schemes implemented in HIRLAM describing the physical processes are updated and based on more recent publications. A documentation of the HIRLAM modelling system is found in Gustavsson (1993). From 1 January 1996 a special version of the HIRLAM model forms the basis for the meteorological data of MSC-W. This new model covers a larger area than earlier (see Fig. 2.1) and has 31 layers in the vertical direction. HIRLAM gives better coverage especially toward east and south-east with a horizontal resolution of 1/6 x 1/6 degrees. This eliminates the limitation on the EMEP calculation domain, that formerly did not include all the parties of the Convention. In particular, Cyprus was not covered. Based on the new meteorological data the EMEP calculation domain has been extended as illustrated in Fig. 2.1. To obtain an even better meteorological data archive we have initiated a project for re-running the HIRLAM model using a horizontal grid corresponding to the extended EMEP area and with the same polar stereographic projection as applied in the LAM50E model.

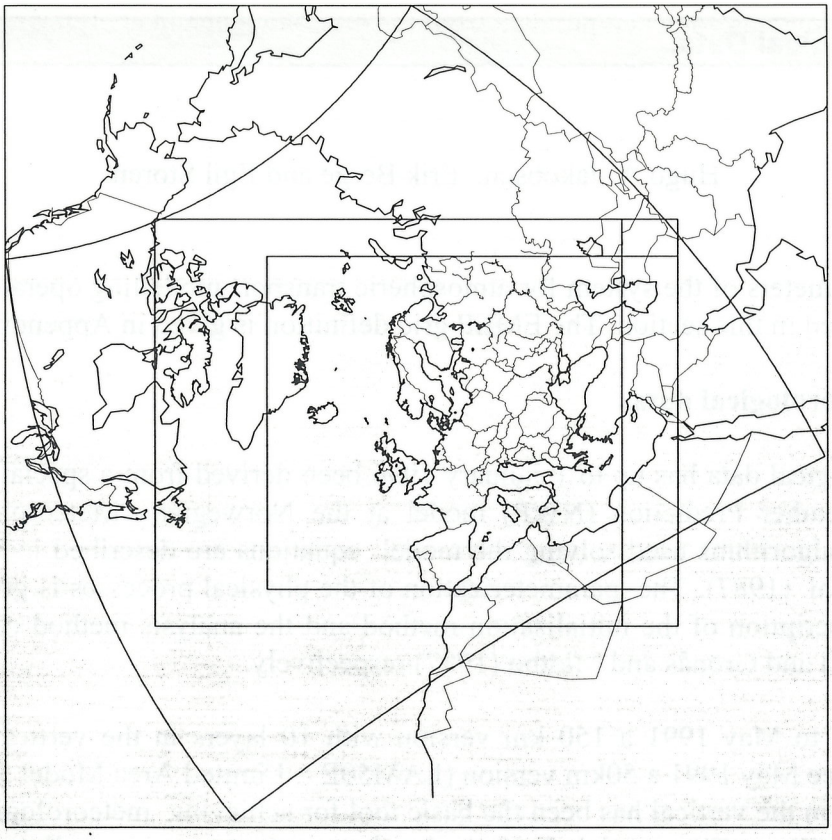

Figure 2.1 *A sketch of the various calculation domains: 1. The HIRLAM calculation domain (the largest area within the figure frame). 2. The LAM50E calculation domain (second largest domain on the figure, without the southeasterly extension). 3. The traditional EMEP domain (smallest area on the figure, without the southeasterly extension, previously used for the 150 km models up to 1995). 4. The extended EMEP 150 km modelling domain used for the 1996 calculations (as for area 3, but with an extension in the southeasterly direction). 5. The extended EMEP/LAM50E domain (as for area 2, but with an extension in the southeasterly direction).*

A complete meteorological data set is archived every 6 hours. The most important variables from the NWP model contained in the meteorological data archive are summarised in Table 2.1. The quantities are stored in all layers. The three-dimensional fields represented are winds (all three components), temperature, humidity, cloudiness, cloud liquid water, and precipitation intensities. From the surface layer the two- dimensional fields of turbulent fluxes, surface temperature, pressure, humidity and precipitation are required. Meteorological data for the 150 km lagrangian models is calculated from the 50 km grid. In addition to information from the NWP-model, the lagrangian models utilise analysed observed fields of the height of the Planetary Boundary Layer (PBL) based on radiosonde data. The 150 km version further employs analysed observed precipitation fields over most land areas with modelled precipitation used over sea. The preparation of the meteorological input from the radiosondes and observed precipitation has been updated and documented by Jakobsen (1996).

Table 2.1. The meteorological input data from the NWP-model and analysed observations.

Physical parameter	**Level of output**	**Purpose**
Height of model surfaces (in η)	all model surfaces	pressure and height of the model surfaces
Horizontal wind (x and y direction)	all model surfaces, and at 10 m.	horizontal transport, eddy diffusivity
Vertical wind	all model surfaces	vertical transport
Temperature	all model surfaces, and at the ground	height of model surfaces, chemistry, eddy diffusivity
Specific humidity	all model surfaces	relative humidity
Cloud liquid water	all model surfaces	Wet scavenging, chemistry
Cloudiness	4 model layers	wet scavenging, chemistry, radiation fluxes
Rate of precipitation	all model surfaces, and at the ground	wet deposition, surface wetness
Air pressure	ground level	density, height of model surfaces
Turbulent heat flux density	ground level	aerodynamic resistance
Turbulent stress	ground level	aerodynamic resistance

Analysed observations:		
Mixed layer height	200m-2500m	initial dilution of emissions
Rate of precipitation	ground level	wet deposition

2.2 The land-use data.

The nature of the ground surface is an important variable for determining rates of deposition and rates of some biogenic emissions. At a resolution of 1/6 x 1/6 degrees land use data has been supplied by RIVM (National Institute of Public Health and Environmental Protection, Netherlands), and subsequently aggregated to a 50 km resolution at the MSC-W. For dry deposition purposes the classification finally used is divided into 10 different categories: Grass (1), Arable (2), Permanent crops (3), Coniferous forest (4), Deciduous forest (5), Water (6), Urban (7), Other (8), Desert (9) and Ice (10).

The two land use classes, "desert" and "ice", have been constructed from the NWP-model data (LAM50E). Further, the RIVM class "water" which consists of inland water alone has been revised to include sea areas according to surface area in each grid square. Information concerning snow cover is also employed, with monthly averaged snow cover fields constructed from the NWP-model (LAM50E). The details on the land-use data are to be found in Sandnes (1995) and Seland et al. (1995).

Another application of land use is for estimating biogenic emissions of terpenes. A database giving percentage cover of Oak forest, other broadleaf forest, spruce forest, other coniferous forest and crops has been derived from a combination of the gridded forest database of

Lubkert and Schöpp (1989) and the national forest species data presented in Veldt (1989). Details are given in Simpson et al. (1995).

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Chapter 3
EMISSIONS

3. Emissions.

Krzysztof Olendrzynski

Introduction

Under the Convention on Long Range Transboundary Air Pollution (LRTAP), the supply of good quality emission data is both essential in assessing the state of air pollution in Europe, and in establishing the compliance of the Parties to LRTAP with individual protocol commitments. The additional requirements for higher resolution modelling within EMEP, have further encouraged rapid accumulation of a large amount of emission data in recent years. The need to co-ordinate efficiently the activity of national emission reporting and data storage has made further development of the United Nations Economic Commission for Europe (UN/ECE) emission database a high priority task. An important element in the effort of MSC-W to fulfill its task, is the maintenance of strong links with the Chemical Co-ordinating Centre (CCC), the Meteorological Synthesizing Centre - East (MSC-E) and the European Environment Agency's (EEA) Topic Centre on Air Emissions (ETC-AEM). Such a set-up is expected to assist the Parties to fulfill their reporting tasks, enhance quality control of emission data and ensure a well-functioning database.

The emission inventorying activities are greatly assisted by the Task Force of Emission Inventories (TFEI) under the Convention. The Task Force provides a sound technical basis for exchanging information on emissions, evaluating emission factors and methodologies, and harmonizing emission methodologies through co-operation with other international organizations working on emission inventories. Its major product was of the first edition of the Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook in early 1996. The Task Force will continue to update the guidebook.

The aim of this chapter is to present the current state of the emission data and the database and outline the needs for further improvement. Some background information on the established reporting procedure is given first. Then the emission data used for modelling are presented in detail. Both country totals and spatial distributions are given. The chapter concludes with the source sector split and emission trends for the main pollutants in Europe over the period 1980-2010. This chapter is an update to and an extension of the emission part in the 1996 EMEP/MSC-W main report (EMEP, 1996).

3.1 Reporting procedure

Approach and timetable

Parties to the Convention should submit their official emission data and agreed related information to the UN/ECE Secretariat. Official submissions received by the secretariat should be forwarded immediately to MSC-W for storage and management. All three EMEP Centres and the secretariat have access to the database. MSC-E continues to assist countries of the Commonwealth of the Independent States (CIS) in preparing their emission inventories and in using the atmospheric emission inventory guidebook (ECE/EB.AIR/46). Co-operation

between MSC-W and the European Topic Centre on Air Emissions should be further strengthened, in particular, to develop data evaluation/verification procedures.

The good functioning of EMEP requires proper adherence to the approved timetable for the reporting of emission data, measurements of air and precipitation quality and model calculations by the Parties, the EMEP centres and the secretariat. The timetable for the emission and modelling activities under the Convention is the following. In early autumn, Parties are requested to submit their emission data before 31 December for the year preceding the year concerned, including possible updates to previous figures (ECE/EB.AIR/24, para. 28 (e) and EB.AIR.GE.1/16, para. 18). The quality of the national totals should be controlled within three months from receipt. During this time Parties are expected to complete missing data with respect to source sector split. This is fairly consistent with the timetable for reporting monitoring data, since by June Parties should also complete their reporting to CCC. Thus, by April of the following year emission data are expected to be ready for the modelling activities of EMEP which should be completed by the end of May. Emissions and the MSC-E and MSC-W modelling activities are reported to the Steering Body of EMEP in September. The main results are submitted to the LRTAP Executive Body at its annual session in November/December. The Parties should report their 1996 emission data by 31 December 1997 with a final delivery by March 1998.

The latest official submissions used in this report refer to 1995 together with the updates for previous years. These data were received by the secretariat in late 1996 and early 1997. All emission tables and figures presented in this report are based on data received by 31 May 1997.

Reporting guidelines

So far, national emission data have been reported in accordance with the guidelines for estimation and reporting of emission data (EB.AIR/GE.1/R.65), approved by the Executive Body at its ninth session in 1991 (ECE/EB.AIR/29, para. 34). Parties should also consult the comprehensive methodological guidance provided in the Atmospheric Emission Inventory Guidebook as recommended by the Executive Body (ECE/EB.AIR/49, annex I, section 2.3).

The present guidelines concentrate on emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x = NO and NO_2), ammonia (NH_3), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO) and methane (CH_4). Sulphur is released into the atmosphere not exclusively as SO_2, but also in form of SO_3, H_2SO_4, DMS, H_2S and sulphates. Therefore, it is recommended to report the total emitted amount of sulphur as of SO_2. Emissions of carbon dioxide (CO_2) should be reported as under the United Nations Framework Convention on Climate Change (ECE/EB.AIR/49). From 1995 onwards, Parties should also report their emissions on heavy metals (priority metals: cadmium (Cd), mercury (Hg), lead (Pb)) and selected persistent organic pollutants, including relevant data (production and use) for previous years if possible.

The guidelines concentrate on the requirements for minimum reporting, which encompasses the reporting of national emissions as totals, and at least for the major source categories. Eleven major categories constitute level 1 of the Selected Nomenclature for Air Pollution (SNAP) of the CORINAIR methodology (see Table 3.1). The minimum reporting also covers the spatial distribution of emissions in the 50km x 50km EMEP grid system every five years

starting with the year 1990, annual updates for large point sources (EB.AIR/GE.1/22, para.10 and ECE/EB.AIR/42, annex I, 2.3), and low (below 100 m) and high (above 100 m) emissions of SO_2 and NO_x. Extended reporting is recommended. It includes the gridded data broken down to major source categories, characteristics of individual sources (needed for plume rise calculations), as well as gridded data on vegetation type, biomass density and land-use data to assist calculation of natural VOC emissions.

Parties revising their methodologies for emission estimates are recommended to revise their emission data accordingly for previous years. They are also to report periodically on data used to estimate emissions, such as emission factors and activity statistics.

The inclusion of heavy metals and persistent organic pollutants into the database, the issue of the atmospheric emission inventory guidebook, the increasing modelling requirements and other relevant recent developments, have necessitated revision of the existing guidelines. A proposal for a new reporting procedure has been worked out by MSC-W, EEA and the secretariat in consultation with CCC and MSC-E. It introduces as minimum reporting level 2 of SNAP. Furthermore, in this proposal a detailed electronic data format has been worked out to facilitate the processing of the vast amount of data concerning the gridded values and source category split. Thus, beginning with their reports on 1996 emissions, Parties would be requested to provide their data both on paper and in form of computer files. The new procedure for reporting the emission data will be submitted for approval by the Executive Body in 1997.

Table 3.1. The CORINAIR/UN-ECE source category split of emissions

SOURCE CATEGORY	SO_2	NO_x	NMVOC	CH_4	NH_3	CO
1. Public power, cogeneration and district heating	■	■				
2. Commercial, institutional and residential combustion plants						■
3. Industrial combustion plants and processes with combustion	■	■				
4. Non-combustion processes			■			▒
5. Extraction and distribution of fossil fuels				■		
6. Solvent use			■			
7. Road transport		■	■			■
8. Other transport		▒				
9. Waste treatment and disposal				■		
10. Agriculture				■	■	
11. Nature			▒			
TOTAL						

Dark shaded boxes indicate major source categories. Light shaded boxes indicate that the given source category may be a major one for some countries.

3.2 Emission database

The emission database at the MSC-W consists of official national data (anthropogenic and natural) and estimates of land-based emissions over regions within the EMEP modelling area, releases from international shipping, biogenic emissions over sea and land as well as information on the temporal variation of SO_2, NO_x, NMVOC and CO emissions.

The status of the emission data available at the MSC-W was presented in EMEP/MSC-W Reports 2/95 and 1/96 (Berge et al., 1995; EMEP, 1996). Furthermore, a description of the

applied data wherever national values have not been supplied, was given in EMEP/MSC-W Report 1/94 (Tuovinen et al., 1994). In this report a summary of the current state of the emission database is given first, followed by a description of the data available for model calculations. The focus is on SO_2, NO_x, NH_3, NMVOC and CO, the releases of which are of major importance for acid deposition and photochemical modelling discussed in the following chapters.

The LRTAP Convention has 42 Parties including 39 European countries, Canada, the United States and the European Community. Emission data received from the latter three Parties are not used in the model calculations and are excluded from Tables 3.5-3.9 displaying data used for modelling purposes. On the other hand, Albania, Estonia, Georgia, Kazakhstan and the Former Yugoslav Republic of Macedonia are not Parties to the Convention, but are included in these tables as being within the EMEP modelling domain. Recently the domain has been extended (initially for the lagrangian model) to include Cyprus - a Party to the Convention. All references to Belarus, Croatia, Ireland, Slovakia and Slovenia refer to the respective Republics of those names, and Yugoslavia refer to the Federal Republic of Yugoslavia.

Official submissions

The state of reporting of ungridded national annual totals submitted for the period 1980-1995 is summarized in Table 3.2. National totals of SO_2 and NO_x have been supplied by more than 2/3 of the Parties for at least 10 individual years. Although improved in the 1990's, for all other components the reporting remains much poorer and needs to be improved. The only countries with (almost) complete reporting so far are Denmark, Lithuania, Germany and Romania. In 1996 three Parties: Latvia, Lithuania and the Republic of Moldova, submitted their emission data for the first time.

Disaggregation of the emission data in terms of source category split continues at the MSC-W. An overview of the information received on ungridded annual totals for the period 1980-1995 is presented in Table 3.3. Twelve Parties have also reported such information for the year 2000. Canada, Cyprus and Yugoslavia submitted data for 2005 and 2010 as well. Twenty Parties reported 1995 data for two (SO_2, NO_x) or more compounds. Poland and United Kingdom are the only Parties having submitted NMVOC data for all sixteen years. It should be stressed that in several cases the reporting does not include all source categories contributing to the totals (e.g. the Russian Federation's - SO_2 emissions and Yugoslavia's - SO_2 and NO_x data, refer to stationary sources only) and needs to be completed in future submissions.

The last column of Table 3.3 shows the latest year for which the source sector split has been reported by individual Parties. This latest available source split information is used below to show the contribution of individual source sectors to Europe's totals for SO_2, NO_x and NH_3. The only Parties that have not yet provided any source split data for the three components are Belarus, Bosnia and Herzegovina, Republic of Moldova, Turkey and European Community. On the other hand, Cyprus, Greece, Hungary, Iceland and Yugoslavia did not provide any data for ammonia.

Table 3.2 Reporting of ungridded national emission totals

	Number of annual totals 1980-1995 (max=16)							Latest year reported
	SO_2	NO_x	NH_3	NMVOC	CO	CH_4	CO_2	SO_2 / NO_x / NH_3 / NMVOC / CO / CH_4/ CO_2
Austria	11	11	5	11	11	5	11	1994 / 94 / 94 / 94 / 94 / 94 / 94
Belarus [2]	16	16	6	16	11	2	3	1995 / 95 / 95 / 95 / 95 / 95 / 95
Belgium	14	10	6	6	5	5	5	1993 / 93 / 94 / 94 / 94 / 94 / 94
Bosnia and Herzegovina	1	-	-	-	-	-	-	1990 / - / - / - / - / - / -
Bulgaria	10	9	6	6	9	9	4	1995 / 95 / 95 / 95 / 95 / 95 / 94
Canada	15	15	-	11	7	14	14	1994 / 94 / - / 94 / 93 / 94 / 93
Croatia [2]	7	6	6	6	6	6	6	1995 / 95 / 95 / 95 / 95 / 95 / 95
Cyprus	11	11	-	-	-	-	6	1995 / 95 / - / - / - / - / 94
Czech Republic	16	6	6	7	14	6	12	1995 / 95 / 95 / 95 / 95 / 95 / 95
Denmark	15	6	16	16	16	16	16	1995 / 95 / 95 / 95 / 95 / 95 / 95
Finland	16	6	2	5	6	5	16	1995 / 95 / 95 / 95 / 95 / 95 / 95
France	16	6	6	6	16	4	16	1995 / 95 / 95 / 95 / 95 / 93 / 95
Germany	15	15	15	15	15	15	15	1994 / 94 / 94 / 94 / 94 / 94 / 94
Greece	3	1	-	1	-	-	6	1990 / 85 / - / 85 / - / - / 89
Hungary	16	6	10	12	5	3	15	1995 / 95 / 94 / 95 / 94 / 90 / 94
Iceland	16	14	-	14	14	14	14	1995 / 95 / - / 95 / 95 / 95 / 95
Ireland [2]	16	6	6	6	6	6	4	1995 / 95 / 95 / 95 / 95 / 95 / 93
Italy	12	11	8	8	8	8	8	1993 / 93 / 92 / 92 / 92 / 92 / 92
Latvia	6	6	6	6	6	6	6	1995 / 95 / 95 / 95 / 95 / 95 / 95
Liechtenstein	15	15	3	15	15	3	15	1994 / 94 / 90 / 94 / 94 / 90 / 94
Lithuania	16	16	16	16	16	16	16	1995 / 95 / 95 / 95 / 95 / 95 / 95
Luxembourg	7	7	4	5	5	4	5	1995 / 95 / 95 / 95 / 95 / 95 / 95
Netherlands	16	16	16	7	7	16	8	1995 / 95 / 95 / 95 / 95 / 95 / 95
Norway	16	16	9	16	16	10	16	1995 / 95 / 95 / 95 / 95 / 95 / 95
Poland	12	12	12	16	5	5	8	1995 / 95 / 95 / 95 / 95 / 95 / 95
Portugal	6	6	5	6	5	5	5	1994 / 94 / 94 / 94 / 94 / 94 / 94
Republic of Moldova	16	16	5	6	16	-	-	1995 / 95 / 95 / 95 / 95 / - / -
Romania	15	15	15	15	15	15	15	1994 / 94 / 94 / 94 / 94 / 94 / 94
Russian Federation [1]	15	15	15	15	15	15	6	1994 / 94 / 94 / 94 / 94 / 94 / 94
Slovakia [3]	11	7	3	4	4	3	6	1994 / 94 / 94 / 94 / 94 / 94 / 94
Slovenia [2]	16	16	1	2	16	2	16	1995 / 95 / 90 / 90 / 95 / 90 / 95
Spain	11	11	4	8	4	4	10	1993 / 93 / 93 / 93 / 93 / 93 / 94
Sweden	16	16	6	5	6	6	16	1995 / 95 / 95 / 95 / 95 / 95 / 95
Switzerland	9	10	8	9	8	8	1	1995 / 95 / 95 / 95 / 95 / 95 / 90
Turkey	4	14	-	-	-	-	14	1986 / 93 / - / -/ - / - / 93
Ukraine	16	16	6	11	10	-	-	1995 / 95 / 95 / 95 / 94 / - / -
United Kingdom	16	16	3	16	16	16	16	1995 / 95 / 95 / 95 / 95 / 95 / 95
United States	15	12	2	15	15	1	1	1994 / 94 / 90 / 94 / 90 / 94 / 90
Yugoslavia [4]	16	16	-	-	-	-	-	1995 / 95 / - / - / - / - / -
European Community	-	-	-	-	-	-	9	- / - / - / - / - / - / 89

(1) The part inside the EMEP domain of calculation. (2) The Republic of. (3) The Slovak Republic.
(4) The Federal Republic of Yugoslavia.

Table 3.3. Reporting of ungridded national emission source category split (11 categories)

	Number of years 1980-1995 (max=16)						Latest year reported
	SO_2	NO_x	NH_3	NMVOC	CO	CH_4	SO_2 / NO_x / NH_3 / NMVOC / CO / CH_4
Austria	11	11	5	11	11	5	1994 / 94 / 94 / 94 / 94 / 94
Belarus [2]	-	-	-	-	-	-	- / - / - / - / - / -
Belgium	6	6	5	6[a]	5	5	1994 / 94 / 94 / 94 / 94 / 94
Bosnia and Herzegovina	-	-	-	-	-	-	- / - / - / - / - / -
Bulgaria	7	6	6	6	6	6	1995 / 95 / 95 / 95 / 95 / 95
Canada	6*	6*	-	6*	6*	-	1994 / 94 / - / 94 / 93 / -
Croatia [2]	6	6	6	6	6	6	1995 / 95 / 95 / 95 / 95 / 95
Cyprus	7	7	-	-	-	-	1995 / 95 / - / - / - / -
Czech Republic	6	6	6	6	6	6	1995 / 95 / 95 / 95 / 95 / 95
Denmark	6*	6*	5*	6*	6*	6*	1995 / 95 / 95 / 95 / 95 / 95
Finland	2	2	1	2	2	2	1995 / 95 / 90 / 95 / 95 / 95
France	5	5	5	5	5	5	1994 / 94 / 94 / 94 / 94 / 94
Germany	7	7	7	7	7	7	1994 / 94 / 94 / 94 / 94 / 94
Greece	1	1	-	1	-	-	1985 / 85 / - / 85 / - / -
Hungary	6	6	-	4	4	-	1995 / 95 / - / 95 / 93 / -
Iceland	7*	7*	-	7*	7*	7*	1995 / 95 / - / 95 / 95 / 95
Ireland [2d]	6	6	4	6	4	4	1995 / 95 / 95 / 95 / 95 / 95
Italy	8	8	8	8	8	8	1992 / 92 / 92 / 92 / 92 / 92
Latvia	6	6	6	6	6	6	1995 / 95 / 95 / 95 / 95 / 95
Liechtenstein	6*	6*	-	6*	6*	6*	1994 / 94 / - / 94 / 94 / 94
Lithuania	1	1	1	1	1	1	1995 / 95 / 95 / 95 / 95 / 95
Luxembourg	5*	5*	4*	5*	5*	4*	1995 / 95 / 95 / 95 / 95 / 95
Netherlands [d]	7*	7*	7*	7*	6*	7*	1995 / 95 / 95 / 95 / 95 / 95
Norway	8*	8*	8*	8*	8*	8*	1995 / 95 / 95 / 95 / 95 / 95
Poland	7	7	5	16	3	5	1995 / 95 / 95 / 95 / 95 / 95
Portugal	5	5	5	5	5	5	1994 / 94 / 94 / 94 / 94 / 94
Republic of Moldova	-	-	-	-	-	-	- / - / - / - / - / -
Romania	6	6	6	6	6	6	1994 / 94 / 94 / 94 / 94 / 94
Russian Federation [1b]	3	4	5	5	5	5	1994 / 94 / 94 / 94 / 94 / 94
Slovakia [3]	3	3	3	3	3	3	1994 / 94 / 94 / 94 / 94 / 94
Slovenia [2]	6	6	1	1	6	1	1995 / 95 / 90 / 90 / 95 / 90
Spain	5*	5*	4	5	4	4	1993 / 93 / 93 / 93 / 93 / 93
Sweden	6*	6*	5*	5*	5*	5*	1995 / 95 / 95 / 95 / 95 / 95
Switzerland	6	6	6	6	6	6	1995 / 95 / 95 / 95 / 95 / 95
Turkey	-	-	-	-	-	-	- / - / - / - / - / -
Ukraine [b]	5*	5*	5*	5*	5*	-	1994 / 94 / 94 / 94 / 94 / -
United Kingdom	16*	16*	3*	16*	16*	16	1995 / 95 / 95 / 95 / 95 / 95
United States [c]	6	6	2	6	6	-	1995 / 95 / 90 / 95 / 95 / -
Yugoslavia [4b]	6*	6*	-	-	-	-	1995 / 95 / - / - / - / -
European Community	-	-	-	-	-	-	- / - / - / - / - / -

(1) The part inside the EMEP domain of calculation. (2) The Republic of. (3) The Slovak Republic.
(4) The Federal Republic of Yugoslavia.
* Source category split has also been reported for 2000. Canada and Yugoslavia for 2005 and 2010 as well.
a The NMVOC figure for 1985 includes CH_4 emissions.
b Fewer than 11 source categories reported.
c Reported figures for 1995 are drawn from the EPA report: EPA-4544/R-96-007 (1996).
d Provisional data for 1995.

Table 3.4 National gridded distributions reported for one or more years

	Gridded information		
	Grid size: 50km x 50km or *150km x 150km		Low (below 100m) & high (above 100m) sources
	Compound	Latest year reported	
Austria	SO_2 NO_x NH_3 NMVOC CO	1990	Yes, LPS
Belarus [2]	SO_2 NO_x NH_3 NMVOC CO	*1994	-
Belgium [5]	SO_2 NO_x NH_3 NMVOC CO	1993	Yes
Bosnia and Herzegovina	SO_2	1990	-
Bulgaria	SO_2 NO_x NH_3 NMVOC CO	1995	Yes, LPS
Canada	-	-	-
Croatia [2]	SO_2 NO_x NH_3 NMVOC CO	1995	LPS
Cyprus	SO_2	-	LPS
Czech Republic	SO_2 NO_x NH_3 NMVOC CO	1995	-
Denmark	SO_2 NO_x	*1980	Yes
Finland	SO_2 NO_x NH_3 NMVOC CO	1995	Yes, LPS
France	SO_2 NO_x NH_3 NMVOC	1990	Yes
Germany	SO_2 NO_x	*1983	Yes
Germany, former GDR	SO_2 NO_x	*1988	-
Greece	-	-	-
Hungary	SO_2 NO_x CO	1994	Yes
Iceland	-	-	-
Ireland [2]	SO_2 NO_x NH_3 NMVOC CO	1990	LPS
Italy	SO_2 NO_x NH_3 NMVOC CO	1990	-
Latvia	SO_2 NO_x NH_3 NMVOC	1995	-
Liechtenstein	-	-	-
Lithuania	-	-	-
Luxembourg	-	-	-
Netherlands	SO_2 NO_x NH_3 NMVOC CO	1990	Yes, LPS
Norway [6]	SO_2 NO_x NH_3 NMVOC CO	1995	Yes
Poland	SO_2 NO_x NH_3 NMVOC CO	1995	Yes
Portugal	SO_2 NO_x NH_3 NMVOC CO	1990	Yes
Republic of Moldova	-	-	-
Romania	-	-	-
Russian Federation [1]	SO_2 NO_x NMVOC	1994	Yes
Slovakia [3]	SO_2 NO_x	1990	Yes
Slovenia [2]	SO_2 NO_x NH_3 NMVOC CO	1990	-
Spain [7]	SO_2 NO_x NH_3 NMVOC CO	1993	Yes
Sweden	SO_2 NO_x	1995	Yes
Switzerland [6]	SO_2 NO_x NH_3 NMVOC CO	1995	Yes
Turkey [1]	-	-	-
Ukraine	SO_2 NO_x NH_3 NMVOC	*1995	Yes
United Kingdom	SO_2 NO_x NH_3 NMVOC CO	1995	Yes, LPS
United States	-	-	-
Yugoslavia [4]	SO_2 NO_x	1995	-
European Community	-	-	-

(1) The part inside the EMEP domain of calculation. (2) The Republic of. (3) The Slovak Republic.
(4) The Federal Republic of Yugoslavia. (5) The missing data for Wallony have been recently reported
(6) The gridded data are disaggregated into SNAP level 1 source sectors. (7) The gridded data are disaggregated into SNAP level 2 source sectors. 'LPS' = Large Point Sources.

The state of reporting with regard to spatial distribution, low and high sources and large point sources (LPS) is summarized in Table 3.4. The reporting has improved substantially for NH_3, NMVOC, CO and CH_4 in the last years, during which higher resolution submissions were requested. Fifteen Parties have submitted complete information on five major pollutants (except CH_4 and CO_2) in the 50km x 50km grid for at least one year. Low and high emission sources have been reported by nineteen countries and large point source information by eight. Latvia reported its gridded emissions for the first time. Twelve Parties reported their gridded distribution for 1995 for one or more components. The Netherlands, Norway, Spain and Switzerland supplied gridded data with source category split for all compounds (for 1990, 1994-1995, 1990-1993, 1990 and 1994 respectively). Only Belarus and Ukraine reported their 1994/95 emissions in the 150 km x 150 km grid.

Emission data for modelling purposes

The emission inventories at the MSC-W for the various compounds do not give full spatial (EMEP modelling domain) and temporal coverage (1985-1995). Estimates for modelling are, first of all, based on data submitted officially to the secretariat and MSC-W. When no official information is available, estimates are taken from available open sources, or in some cases are made in collaboration with experts from the MSC-W and the CCC. Annual totals for missing years are based on linear interpolation or extrapolation of the most recent official value. When projected figures are not available, the 1995 values (or any other most recent year) are extrapolated through until 2010.

The national totals for SO_2, NO_x, NH_3, NMVOC and CO, as used in the present calculations (1985-1995), are displayed in Tables 3.5-3.9. Data for 1980 are also given. During the major review on strategies and policies for air pollution abatement in 1994 (EB.AIR/R.87), Parties were requested to submit national emission projections for the years 2000, 2005 and 2010, based on current reduction plans reflecting the politically determined intention to reach specific targets. The present state of the data in shown in the last three columns of Tables 3.5-3.9. There are few changes compared to last year (EMEP, 1996). Most information is available for SO_2 and NO_x. Belarus, Hungary, Lithuania, Republic of Moldova, Slovenia Ukraine, UK and Yugoslavia are the Parties with complete reporting for the two compounds. Officially submitted values are highlighted. Data drawn from other sources or inter (extra)polated are displayed with no background.

In this year's calculations emission figures used for Estonia are those reported officially except for NH_3, for which the reported value (1 ktonne) seems to be underestimated. Instead we applied 29 ktonnes - the estimate suggested recently by IIASA (Amann et al., 1997). Similar substitution was made for NH_3 emissions from Belarus (219 ktonnes rather than 4 ktonnes in 1990), Republic of Moldova (47 ktonnes rather than 0.19 ktonnes in 1990/91), and Ukraine (729 ktonnes rather than 13.6 ktonnes in 1995), using once again IIASA estimates. From the same literature source, several other estimates were employed: for SO_2 (Albania, The FYR Macedonia), NO_x (Albania, Bosnia and Herzegovina, Greece (1990), The FYR Macedonia), and NH_3 (Albania, Belarus, Bosnia and Herzegovina, The FYR Macedonia, Yugoslavia). For a few countries official emission estimates for NMVOC and CO are missing for all years. Also, these data are not included in the CORINAIR tables (e.g. Albania, Bosnia and Herzegovina, the FYR Macedonia, Turkey, Yugoslavia). In those cases a very crude assumption was made that NMVOC emissions are equal to NO_x emissions and CO emissions are equal 3.5 times the NO_x emissions (in ktonnes). This simple rule that we applied is in line

with the respective ratios for other countries for which the NO_x, NMVOC and CO data are available.

Natural versus anthropogenic emissions

Distinction between natural and anthropogenic emissions has improved considerably during the last years through the submission of information on source category split. However, in some cases it is not clear whether natural sources are included in the national totals. In the case of NMVOC emissions, unclear distinction between natural and anthropogenic contribution has implication for modelling and requires special attention under reporting. Several countries included NMVOC emissions from managed forests into SNAP-1 category 10 (agriculture).

Biogenic NMVOC emissions in the ozone model are not taken from submitted annual emission estimates. Instead, the emissions are calculated explicitly on an hourly basis for every grid square, using land-use data combined with the model's temperature and radiation data. The emission factors and algorithms have been thoroughly revised since the Simpson (1992, 1993) descriptions. Details, and isoprene emission estimates for a number of years, are given in Simpson et al. (1995).

With regard to natural emissions over the ocean, the MSC-W database includes currently only estimates of marine biogenic emissions of sulphur (DMS) made by Tarrasón et al. (1995). In Tables 3.5-3.9, the natural emissions have been subtracted from the totals wherever relevant information was available. For NMVOCs in addition, the emissions reported from agriculture have been excluded. Usually, these emissions are low except when managed forests are accounted for. Thus by subtracting agriculture we avoid possible double counting of forest emissions. Sulphur emissions from the oceans and volcanoes are listed separately.

A detailed information on natural sources for all chemical components was provided recently by Italy. The figures refer to period: 1985-1992. According to the data, the natural SO_2 emissions (volcanoes) varied between 1800-2800 ktonnes during the period. Previous estimate for 1990 was a factor of four lower (570 ktonnes). These new values significantly affect the computed sulphur deposition levels in the Mediterranean Basin.

Emissions from international shipping in the Atlantic Ocean, the North Sea and partly the Baltic Sea for SO_2 and NO_x have been estimated recently by Lloyd's Register of Shipping, and the data were made available to MSC-W. The emissions are for 1990 and have been disaggregated into 50km x 50km spatial distribution. The data for the Baltic Sea include merely the shipping in and out of the Basin. The shipping within the Basin is not accounted for. Compared to previous estimates (562 ktonnes), SO_2 emissions increased to 1366 ktonnes. The respective figures for NO_x are 621 ktonnes (previous estimate) and 1985 ktonnes (current estimate). It should be pointed out that the new estimates might involve double counting of domestic coastal shipping. National shipping and other marine sources such as coastal traffic and off-shore installations should be included in national totals.

Temporal and spatial distribution of emissions

Temporal variation of emissions is another important element included in the database and used in current model runs. A set of calculated 1990 daily national emission data for SO_2,

NO_x, NMVOC and CO has been provided to MSC-W by the GENEMIS project (Generation of European Emission Data for Episodes). These data refer to both national emission totals and to releases from combustion sources (sectors 1, 2, 3, 6 and 7 of the CORINAIR/UN-ECE methodology. In the recently proposed new reporting procedure, Parties are recommended to provide in future submissions detailed data on temporal variation of emissions. Both seasonal and daily variations should be reported wherever relevant data can be obtained.

The spatial distribution of emissions used in calculations is shown in Figures 3.1-3.10. The figures correspond to the 1995 totals, but the same relative distribution is used also for other years. Numbers in grid squares are presented at 150km resolution (Figures 3.1-3.6), including separation into 'high' and 'low' sulphur emissions. Emissions lower than 1000 tonnes/grid square are shown as zeroes. For acid deposition calculations, the modelling domain was extended to include Cyprus (Figures 3.1-3.4). Disaggregation into 50km resolution is shown in colour for SO_2, NO_x, NH_3 and NMVOC. Grid elements appearing in groups of nine indicate that 50km x 50km distribution was not available for the corresponding country and the old disaggregation has been used instead.

In the absence of officially submitted spatial distribution of emissions, information is drawn from the CORINAIR 1990 and 1985 inventories. In particular, gridded CORINAIR-90 data is used for Greece and Luxembourg for all components and CORINAIR-85 data for SO_2, NO_x and NMVOC is employed for Belgium, Denmark, the former Federal Republic of Germany and Spain. These data are based on national administrative units and have been converted to the 50km x 50 km grid by the EEA for use in the EMEP modelling activities.

Despite rather strict procedure and timetable for reporting, not all the Parties provide complete emission data in full and on time. New and revised data are being sent to the secretariat and MSC-W throughout the year. Therefore, the emission database at MSC-W is being constantly revised and updated. The Tables 3.5 - 3.9 and Figures 3.1 - 3.9 reflect the state of the database as of 31 May 1997. These data have been used in model calculations for 1995 (ROOT-150 Lagrangian model) described in the following chapter and the second part of this report, and for scaling the 1985-1994 depositions using the previously computed source-receptor matrices (EMEP, 1996). The only exceptions are the spatial distribution of emissions: from international shipping (SO_2 and NO_x) and from 'Remaining land areas' (northern Africa, Georgia, Kazakhstan and volcanoes; SO_2). The Figures 3.7 and 3.8 show the latest information available while the model input in those two case was computed by scaling the spatial distribution from last year's computation (EMEP, 1996) with the respective latest totals given in Table 3.5 and 3.6.

The acid deposition computations with the eulerian model (MADE-50) were made for the year 1992. There are some minor differences between the latest available 1992 figures and those actually used as the model input. Due to time constraints, the computations with the MADE-50 model started in early April i.e. before the presented in this report emission database was finalized. For SO_2 the largest difference is for Romania (559 ktonnes was used versus 951 ktonnes). In the case of NH_3 the applied total for Estonia was 1 ktonne (official figure), later replaced in the database by a higher estimate (29 ktonnes; see above). A few other minor changes were introduced for the three components: SO_2, NO_x and NH_3, mainly due to the more recent submissions and corrections in the database. See the respective chapters for more details.

Table 3.5 Emissions of sulphur (1000 tonnes of SO_2 per year)

	1980	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	2005	2010
Africa, north[1]	512	512	512	512	512	512	512	512	512	512	512	512	512	512	512
Albania	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
Austria	397	195	174	152	122	93	90	84	76	71	74	74	78	78	78
Belarus[2]	740	690	690	761	720	668	637	652	458	382	324	275	552	490	480
Belgium	828	400	377	367	354	325	317	324	304	294	253	253	248	232	215
Bosnia and Herzegovina	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480
Bulgaria	2050	2314	2367	2420	2228	2180	2020	1677	1128	1426	1480	1497	1374	1230	1127
Croatia[2]	150	165	168	171	174	177	180	108	107	114	89	63	133	125	117
Cyprus	37	37	37	41	43	47	55	41	45	43	46	46	62	62	62
Czech Republic	2257	2277	2177	2164	2066	1998	1876	1776	1538	1419	1270	1091	1128	902	632
Denmark	450	339	282	250	242	191	184	243	190	156	155	150	90	90	90
Estonia	239	239	239	239	239	239	239	233	179	145	141	110	110	110	110
Finland	584	382	331	328	302	244	260	194	141	124	112	96	116	116	116
France	3338	1470	1342	1290	1226	1334	1298	1376	1238	1121	1013	989	868	770	737
Georgia	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162
Germany	3164	2367	2228	1904	1215	942	885	908	878	870	874	874	150	87	87
Germany, former GDR	4350	5365	5413	5443	5263	5254	4441	3264	2558	2283	2121	2121	840	653	653
Greece	400	500	502	504	506	508	510	522	533	545	556	556	595	580	570
Hungary	1633	1404	1362	1285	1218	1102	1010	913	827	756	741	699	898	816	653
Iceland	18	18	18	16	18	17	24	23	24	24	24	24	24	23	23
Ireland[2]	222	140	162	174	152	162	178	179	161	157	177	166	155	155	155
Italy[6]	3800	1733	1742	1890	1911	1885	1678	1571	1424	1490	1437	1437	1209	1042	1042
Kazakhstan[1]	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140
Latvia	57	57	57	57	57	57	57	58	38	44	52	38	38	38	38
Liechtenstein	0.39	0.27	0.25	0.22	0.20	0.17	0.15	0.15	0.14	0.14	0.13	0.13	0.11	0.11	0.11
Lithuania	311	304	316	316	300	298	222	234	139	125	117	107	164	155	145
Luxembourg	24	17	16	16	15	15	14	14	15	15	13	8	4	4	4
Netherlands	490	261	264	263	250	204	205	195	170	157	154	147	92	74	56
Norway	140	97	91	74	67	59	53	45	37	35	34	35	34	34	34
Poland	4100	4300	4200	4200	4180	3910	3210	2995	2820	2725	2605	2337	2583	2173	1397
Portugal	266	198	215	232	249	266	283	297	351	300	272	272	304	294	294
Republic of Moldova	308	282	297	317	273	238	231	184	204	128	108	59	140	130	130
Romania	1055	1255	1293	1305	1469	1517	1311	1041	951	928	912	912	912	912	912
Russian Federation[1]	7161	6191	5707	5622	5145	4677	4460	4392	3839	3456	2983	2983	4440	4297	4297
Slovakia[3]	780	613	604	614	589	573	543	446	380	325	238	238	337	295	240
Slovenia[2]	234	241	247	222	210	212	195	181	190	183	177	119	92	45	37
Spain[6]	3319	2190	1961	1903	1587	1950	2266	2223	2195	2071	2061	2061	2143	2143	2143
Sweden	508	266	272	228	224	160	136	112	103	101	97	94	87	87	87
Switzerland	116	76	69	63	56	50	43	41	38	34	31	34	30	30	30
The FYR Macedonia	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106
Turkey[1]	860	322	354	354	354	354	354	354	354	354	354	354	354	354	354
Ukraine	3849	3463	3393	3264	3211	3073	2782	2538	2376	2194	1715	1639	2310	2310	2310
United Kingdom	4913	3766	3941	3927	3850	3722	3756	3585	3484	3185	2719	2365	1500	1160	980
Yugoslavia[4]	406	478	470	484	502	506	508	446	396	401	424	462	680	889	1135
The Baltic Sea	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
The Mediterranean Sea[1]	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
The North Sea	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Remaining N.E. Atlantic[1]	891	891	891	891	891	891	891	891	891	891	891	891	891	891	891
Natural Oceanic[1]	724	724	724	724	724	724	724	724	724	724	724	724	724	724	724
Volcanic[5]	2144	2144	2181	2114	2493	2807	1645	2235	2235	2235	2235	2235	2235	2235	2235
Total	59345	50202	49205	48620	46726	45660	41804	39350	35770	34061	31834	30724	30755	28866	27451

(1) The part inside the EMEP domain of calculation. Emissions from northern Africa, Georgia and Kazakhstan and volcanoes are considered as 'Remaining land areas' for NMVOC and CO, and when computing source-receptor matrices. (2) The Republic of. (3) The Slovak Republic.
(4) The Federal Republic of Yugoslavia. (5) Natural emissions reported by Italy. (6) CORINAIR-94 values are used for 1994-95.
Officially submitted data are printed inside a grey-shaded box. Countries in white boxes have not provided any data to ECE; data are drawn from open sources.

Table 3.6 Emissions of nitrogen oxides (1000 tonnes of NO_2 per year)

	1980	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	2005	2010
Africa, north[1]	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Albania	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Austria	246	245	240	234	226	221	222	216	201	182	177	177	155	155	155
Belarus[2]	234	238	258	263	262	263	285	281	224	207	203	195	217	184	180
Belgium	442	325	317	331	345	357	352	354	354	340	345	345	345	345	345
Bosnia and Herzegovina	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Bulgaria	416	416	416	416	415	411	376	266	239	242	230	266	380	350	290
Croatia[2]	83	83	83	83	83	83	83	57	50	53	59	55	87	83	83
Cyprus	16	16	16	16	18	19	20	17	20	21	21	21	21	23	23
Czech Republic	937	831	826	816	858	920	742	725	698	574	435	412	398	398	398
Denmark	282	301	320	312	302	282	279	321	276	274	272	250	203	192	192
Estonia	93	93	93	93	93	93	93	78	59	48	50	50	50	50	50
Finland	295	275	277	288	293	301	300	290	283	282	282	259	224	224	224
France	1823	1615	1618	1630	1615	1772	1585	1632	1597	1544	1682	1666	1666	1666	1666
Georgia	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188
Germany	2617	2540	2546	2427	2306	2146	1962	1954	1862	1810	1766	1766	1766	1649	1649
Germany, former GDR	717	736	740	750	743	746	678	555	495	464	444	444	444	481	481
Greece[5]	306	306	323	340	358	375	392	383	375	366	357	357	357	357	357
Hungary	273	262	264	265	258	246	238	203	183	184	188	171	230	210	196
Iceland[2]	18	16	17	18	19	19	20	21	22	23	22	23	21	20	19
Ireland	73	91	100	115	122	127	115	119	125	122	117	116	105	105	105
Italy[5]	1480	1589	1680	1782	1865	2019	2047	2090	2117	1997	2157	2157	2098	2060	2060
Kazakhstan[1]	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76
Latvia	90	90	90	90	90	90	90	52	43	37	45	29	29	29	29
Liechtenstein	0.71	0.67	0.66	0.65	0.65	0.64	0.63	0.61	0.58	0.56	0.54	0.54	0.41	0.37	0.37
Lithuania	152	166	169	171	172	173	158	166	98	78	77	67	109	110	110
Luxembourg	23	22	22	22	23	23	23	24	24	25	23	20	19	19	19
Netherlands	583	576	587	599	602	584	575	575	566	552	542	518	249	185	120
Norway	192	229	242	248	235	230	227	225	216	225	222	222	161	161	161
Poland	1229	1500	1590	1530	1550	1480	1279	1205	1130	1120	1105	1120	1345	1345	1345
Portugal	96	96	121	146	171	196	221	234	250	248	254	254	254	254	254
Republic of Moldova	58	42	49	47	47	48	39	31	49	28	35	25	30	35	34
Romania	523	542	559	580	590	579	546	464	357	318	319	319	319	319	319
Russian Federation[1]	1734	1903	1871	2653	2358	2553	2675	2571	2298	2269	1995	1995	1995	1995	1995
Slovakia[3]	197	197	197	197	212	227	227	212	192	184	173	173	173	173	173
Slovenia[2]	51	53	58	57	59	58	57	54	55	61	66	67	45	38	31
Spain[5]	950	839	854	892	892	992	1178	1227	1251	1223	1223	1223	892	892	892
Sweden	448	426	432	437	432	418	411	410	383	378	372	362	312	303	254
Switzerland	170	179	176	174	171	168	165	160	153	145	139	136	117	110	113
The FYR Macedonia	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
Turkey[1]	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175
Ukraine	1145	1059	1112	1094	1090	1065	1097	989	830	700	568	530	1094	1094	1094
United Kingdom	2416	2454	2535	2659	2744	2919	2897	2805	2720	2548	2422	2295	1530	1289	1186
Yugoslavia[4]	47	58	58	60	63	62	66	57	49	54	52	59	88	115	147
The Baltic Sea	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
The Mediterranean Sea[1]	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
The North Sea	710	710	710	710	710	710	710	710	710	710	710	710	710	710	710
Remaining N.E. Atlantic[1]	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275	1275
Natural Oceanic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Volcanic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	23215	23169	23616	24595	24442	25025	24480	23783	22604	21686	21199	20903	20288	19788	19509

(1) The part inside the EMEP domain of calculation. Emissions from northern Africa, Georgia and Kazakhstan and volcanoes are considered as 'Remaining land areas' for NMVOC and CO, and when computing source-receptor matrices. (2) The Republic of. (3) The Slovak Republic.
(4) The Federal Republic of Yugoslavia. (5) CORINAIR-94 values are used for 1994-95.
Officially submitted data are printed inside a grey-shaded box. Countries in white boxes have not provided any data to ECE; data are drawn from open sources.

Table 3.7 Emissions of ammonia (1000 tonnes of NH_3 per year)

	1980	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	2005	2010
Africa, north[1]	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56
Albania	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Austria	91	91	91	91	91	91	91	91	92	93	93	93	93	93	93
Belarus[2]	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219
Belgium	89	89	90	91	93	94	95	93	92	95	96	96	96	96	96
Bosnia Herzegovina	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Bulgaria	323	323	323	323	323	323	323	280	230	219	146	136	143	140	140
Croatia[2]	44	44	44	44	44	44	37	31	27	25	24	25	25	25	25
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	105	105	105	105	105	105	105	88	77	97	92	86	86	86	86
Denmark	141	126	122	117	115	113	109	110	114	119	113	114	103	103	103
Estonia	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Finland	35	35	35	35	35	35	35	34	33	33	32	31	32	23	23
France	700	700	700	700	700	700	700	690	676	666	668	668	668	668	668
Georgia	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Germany	572	588	580	572	560	556	516	456	441	431	423	423	423	423	423
Germany, former GDR	263	269	266	265	270	262	243	214	208	203	199	199	199	199	199
Greece	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
Hungary	170	170	170	150	160	170	176	150	140	140	155	155	180	160	145
Iceland	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Ireland[2]	126	126	126	126	126	126	126	126	126	126	123	124	124	124	124
Italy[5]	436	436	444	446	448	432	416	404	394	392	389	389	389	389	389
Kazakhstan[1]	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Latvia	44	44	44	44	44	44	44	42	33	20	17	17	17	17	38
Liechtenstein	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Lithuania	85	89	89	90	89	86	84	85	81	80	80	44	84	84	84
Luxembourg	7	7	7	7	7	7	7	7	7	7	8	8	6	6	6
Netherlands	234	256	258	258	237	232	236	237	188	197	171	155	82	82	50
Norway	21	21	21	21	21	23	23	24	25	25	25	25	25	25	25
Poland	550	550	550	550	550	550	508	450	342	382	384	380	380	380	380
Portugal	93	93	93	93	93	93	93	93	93	93	92	92	92	92	92
Republic of Moldova	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Romania	340	343	350	329	339	341	300	267	255	223	221	221	221	221	221
Russian Federation[1]	1189	1239	1286	1277	1269	1258	1191	1161	1084	903	772	772	772	772	722
Slovakia[3]	62	62	62	62	62	62	62	62	61	54	47	47	47	47	47
Slovenia[2]	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
Spain[5]	353	353	353	353	353	353	353	354	352	345	345	345	345	345	345
Sweden	61	61	61	61	61	61	61	60	59	58	58	61	55	54	53
Switzerland	71	64	64	63	63	62	62	61	61	60	60	60	59	59	58
The FYR Macedonia	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Turkey[1]	415	415	415	415	415	415	415	415	415	415	415	415	415	415	415
Ukraine	729	729	729	729	729	729	729	729	729	729	729	729	729	729	729
United Kingdom	320	320	320	320	320	320	320	320	320	320	320	320	320	320	320
Yugoslavia[4]	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
The Baltic Sea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
The Mediterranean Sea[1]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
The North Sea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Remaining N.E. Atlanti[c1]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Oceanic[1]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Volcanic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	8412	8491	8541	8480	8465	8430	8203	7877	7498	7293	7040	6973	6953	6920	6882

(1) The part inside the EMEP domain of calculation. Emissions from northern Africa, Georgia and Kazakhstan and volcanoes are considered as 'Remaining land areas' for NMVOC and CO, and when computing source-receptor matrices. (2) The Republic of. (3) The Slovak Republic.
(4) The Federal Republic of Yugoslavia. (5) CORINAIR-94 values are used for 1994-95.
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Table 3.8 Emissions of non-methane volatile organic compounds (1000 tonnes of NMVOC per year)

	1980	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	2005	2010
Albania	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Austria	362	400	414	427	420	422	418	413	397	382	358	358	305	305	305
Belarus[2]	549	516	506	509	535	511	533	546	412	372	366	367	380	323	321
Belgium	407	407	392	377	362	347	332	329	331	329	320	320	320	320	320
Bosnia and Herzegovina	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101
Bulgaria	187	187	187	187	187	187	187	145	150	170	141	141	151	71	60
Croatia[2]	105	105	105	105	105	105	105	84	63	68	73	72	72	72	72
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	275	275	307	339	371	403	435	398	359	338	310	286	286	286	286
Denmark	192	198	201	201	200	194	175	172	166	158	156	150	134	134	134
Estonia	23	23	23	23	23	23	23	22	17	13	13	13	13	13	13
Finland	210	210	210	210	213	211	209	205	200	195	190	185	151	108	108
France	2393	2393	2393	2393	2393	2393	2393	2329	2318	2187	2308	2223	2223	2223	2223
Germany	2522	2447	2456	2427	2372	2295	2213	2097	1986	1875	1800	1800	1800	1309	1309
Germany, former GDR	702	743	762	793	816	851	942	651	519	414	353	353	353	441	441
Greece[6]	155	155	183	210	238	265	293	310	328	345	362	362	362	362	362
Hungary	215	232	263	228	205	205	205	144	136	143	140	146	176	156	141
Iceland	6	6	6	6	6	6	6	7	7	6	6	6	6	6	6
Ireland[2]	102	102	102	102	102	102	102	105	104	120	93	96	171	138	138
Italy[6]	1850	1850	1880	1950	1981	2084	2080	2152	2199	2219	2239	2239	2239	2239	2239
Latvia	63	63	63	63	63	63	63	35	30	25	24	21	21	21	21
Liechtenstein	1.48	1.52	1.53	1.53	1.54	1.55	1.56	1.49	1.43	1.36	1.30	1.30	0.92	0.86	0.86
Lithuania	108	116	116	116	117	117	111	114	68	54	54	74	86	84	84
Luxembourg	20	20	20	20	19	19	19	18	17	16	17	17	13	13	13
Netherlands	463	463	454	446	437	429	420	390	375	377	375	337	196	158	120
Norway	174	234	255	262	253	280	299	298	323	351	365	378	196	196	196
Poland	1002	977	995	980	992	982	797	799	771	722	785	735	916	1091	1266
Portugal	199	199	200	200	201	201	202	203	215	218	227	227	227	227	227
Republic of Moldova	11	11	11	11	11	11	11	7	3	2	1	1	5	7	7
Romania	627	585	628	682	644	610	568	474	451	462	465	465	465	465	465
Russian Federation[1]	2843	2496	2338	2807	2790	3715	3566	3259	3204	2979	2861	2861	2861	2861	2861
Slovakia[3]	149	149	149	149	149	149	149	137	124	107	108	108	108	108	108
Slovenia[2]	39	39	39	39	39	37	35	35	35	34	34	34	33	30	25
Spain[6]	1265	1265	882	922	955	1003	1051	1104	1127	1117	1120	1120	1120	1120	1120
Sweden	553	553	553	553	553	540	526	513	500	480	459	446	342	287	287
Switzerland	315	315	309	303	296	290	284	268	248	231	218	202	164	162	165
The FYR Macedonia	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Turkey[1]	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175
Ukraine	1626	1626	1660	1687	1604	1512	1079	950	700	535	429	403	671	671	671
United Kingdom	2334	2439	2488	2550	2642	2879	2623	2582	2493	2413	2354	2257	1519	1340	1276
Yugoslavia[4]	47	58	58	60	63	62	66	57	49	54	52	59	88	115	147
Remaining land areas[5]	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
The Baltic Sea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
The Mediterranean Sea[1]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
The North Sea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Remaining N.E. Atlantic[1]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Oceanic[1]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	22624	22388	22139	22868	22890	24027	23055	21884	20960	20047	19712	19398	18709	18000	18075

(1) The part inside the EMEP domain of calculation. (2) The Republic of. (3) The Slovak Republic. (4) The Federal Republic of Yugoslavia. (5) See footnote one to Table 3.5. (6) CORINAIR-94 values are used for 1994-95; for Greece also CORINAIR-90 value for 1990.
Officially submitted data are printed inside a grey-shaded box. Countries in white boxes have not provided any data to ECE; data are drawn from open sources.

Table 3.9 Emissions of carbon monoxide (1000 tonnes of CO per year)

	1980	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	2005	2010
Albania	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84
Austria	1636	1648	1667	1685	1578	1605	1573	1503	1414	1326	1408	1408	1408	1408	1408
Belarus[2]	1654	1654	1605	1601	1590	1615	1722	1717	1381	1201	1241	1253	1409	1406	1404
Belgium	1308	1308	1308	1308	1308	1308	1308	1302	1325	1275	1245	1245	1245	1245	1245
Bosnia and Herzegovina	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280
Bulgaria	997	997	997	997	995	985	891	608	768	820	855	844	820	800	750
Croatia[2]	651	651	651	651	651	651	651	564	430	421	466	478	478	478	478
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	894	899	740	738	737	884	1055	1102	1045	967	1026	874	874	874	874
Denmark	681	754	785	791	783	780	794	808	779	730	720	713	647	562	562
Estonia	185	185	185	185	185	185	185	181	137	104	101	101	101	101	101
Finland	660	608	598	587	577	566	556	512	467	432	443	434	434	434	434
France	9216	8399	8156	8036	7821	7575	10736	10585	10265	9607	9602	9200	9200	9200	9200
Germany	11006	8975	8921	8612	8284	7876	7426	6876	6310	5956	5511	5511	5511	3799	3799
Germany, former GDR	3040	3159	3214	3324	3212	3109	3317	2170	1616	1422	1237	1237	1237	1551	1551
Greece[6]	1143	1143	1143	1143	1143	1143	1143	1180	1216	1253	1289	1289	1289	1289	1289
Hungary	804	804	804	804	804	804	804	914	836	796	774	774	800	800	800
Iceland	18	21	22	24	26	26	26	26	26	25	25	23	19	18	18
Ireland[2]	429	429	429	429	429	429	429	428	403	416	333	344	322	322	322
Italy	8960	8960	8921	8977	8881	9037	9905	9105	9089	9089	9089	9089	9089	9089	9089
Latvia	363	363	363	363	363	363	363	239	220	204	203	178	178	178	178
Liechtenstein	4.19	3.23	3.04	2.85	2.66	2.47	2.27	2.16	2.04	1.92	1.80	1.80	1.10	1.05	1.05
Lithuania	541	547	554	564	578	568	521	599	501	292	303	244	411	410	400
Luxembourg	240	240	226	212	199	185	171	187	203	219	145	101	102	102	102
Netherlands	1356	1356	1297	1237	1178	1118	1059	959	941	941	924	873	873	873	873
Norway	907	984	1029	1036	1020	975	961	901	870	853	864	829	829	829	829
Poland	7406	7406	7406	7406	7406	7406	7406	7245	7083	8655	5115	4547	4547	4547	4547
Portugal	1086	1086	1086	1086	1086	1086	1086	1111	1156	1175	1211	1211	1211	1211	1211
Republic of Moldova	136	123	155	133	160	163	193	162	204	128	98	169	160	150	150
Romania	3245	3307	3378	3196	3317	3314	3186	2695	2506	2434	2325	2325	2325	2325	2325
Russian Federation[1]	13512	14122	13142	13119	12988	13054	13174	12869	11574	11193	10495	10495	10495	10495	10495
Slovakia[3]	462	462	462	462	462	462	462	403	343	408	411	411	411	411	411
Slovenia[2]	68	68	78	79	75	75	77	75	77	87	93	91	57	44	31
Spain[6]	4752	4752	4752	4752	4752	4752	4752	4822	4787	4801	4801	4801	4801	4801	4801
Sweden	1347	1347	1347	1347	1347	1347	1347	1312	1275	1236	1058	1046	760	631	631
Switzerland	1280	990	933	877	820	764	707	665	621	578	549	510	408	369	370
Turkey[1]	613	613	613	613	613	613	613	613	613	613	613	613	613	613	613
The FYR Macedonia	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137
Ukraine	9832	9832	9722	9269	9085	8794	8141	7406	5496	4218	3375	3375	8141	8141	8141
United Kingdom	6923	7015	7114	7251	7421	7632	7377	7370	6991	6402	5973	5478	3324	1884	1374
Yugoslavia[4]	165	203	203	210	221	217	231	200	172	189	182	207	308	403	515
Remaining land areas[5]	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700
The Baltic Sea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
The Mediterranean Sea[1]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
The North Sea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Remaining N.E. Atlantic[1]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Oceanic[1]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	98717	96611	95207	94305	93296	92667	94549	90615	84341	81667	75304	73522	76038	72994	72522

(1) The part inside the EMEP domain of calculation. (2) The Republic of. (3) The Slovak Republic. (4) The Federal Republic of Yugoslavia. (5) See footnote one to Table 3.5. (6) CORINAIR-94 values are used for 1994-95; for Greece also CORINAIR-90 value for 1990.
Officially submitted data are printed inside a grey-shaded box. Countries in white boxes have not provided any data to ECE; data are drawn from open sources.

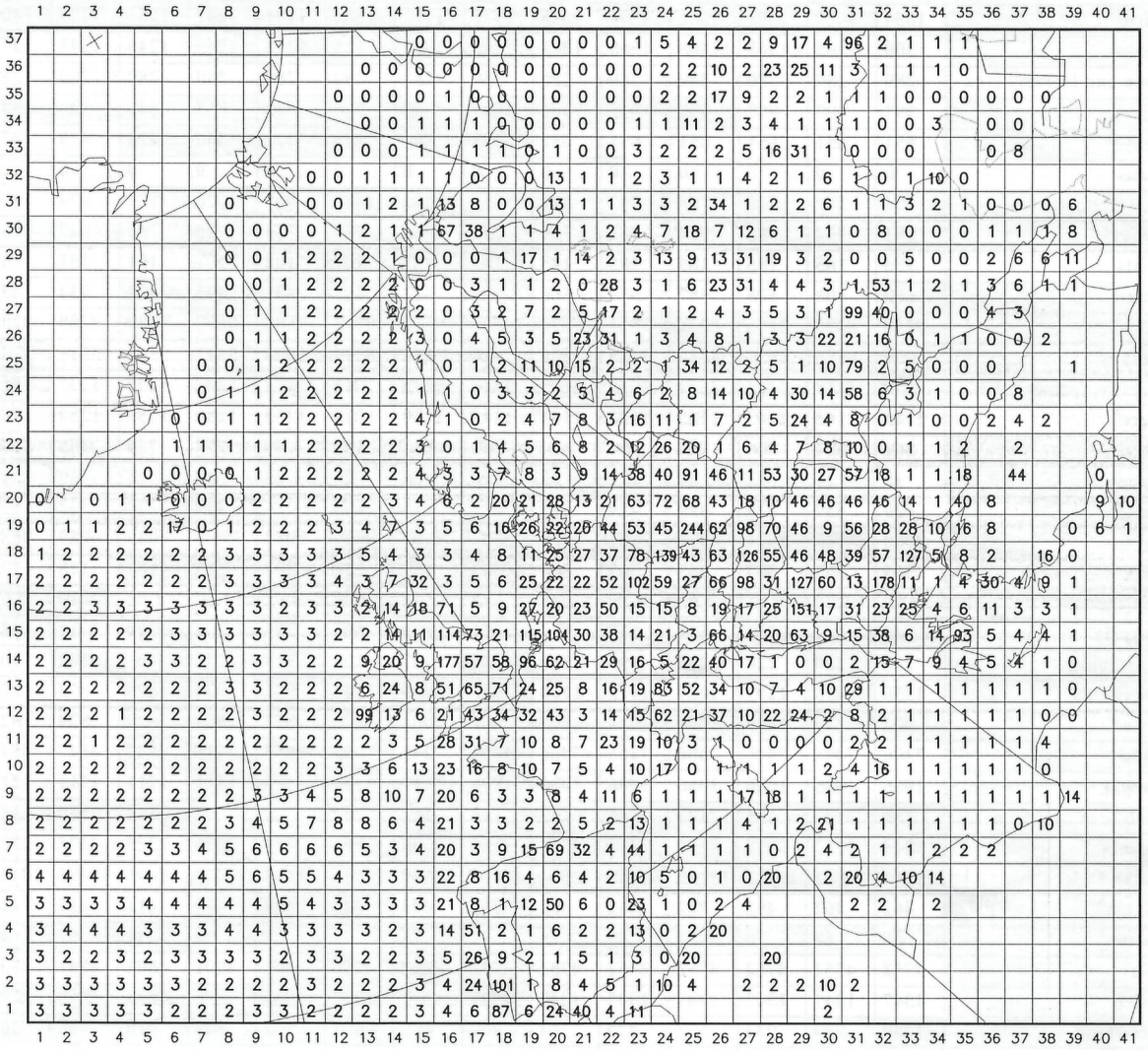

Figure 3.1. Emissions of sulphur dioxide below 100m in 1995 (1000 tonnes SO_2)

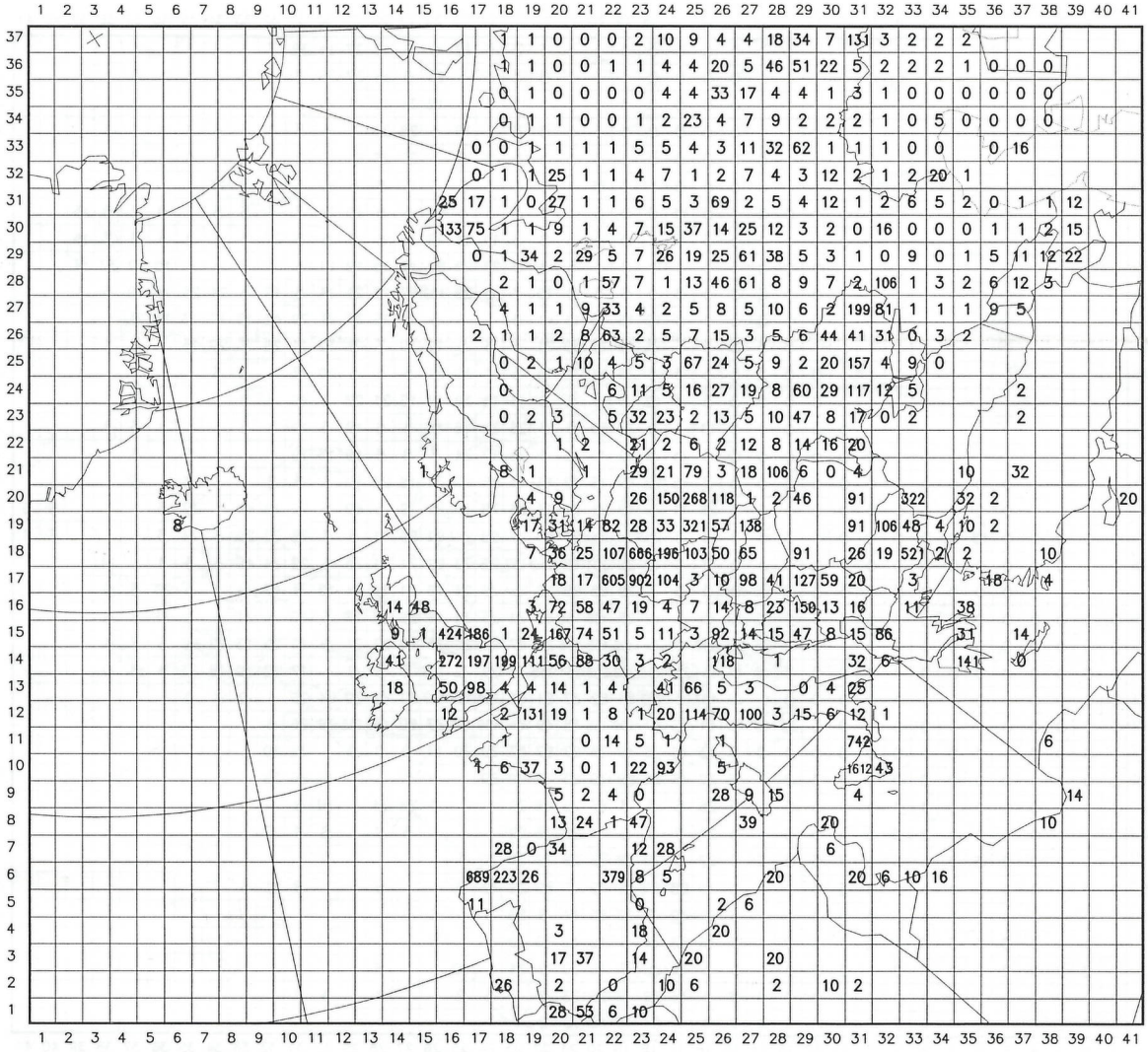

Figure 3.2. Emissions of sulphur dioxide above 100m in 1995 (1000 tonnes SO_2)

Figure 3.3. Emissions of nitrogen oxides in 1995 (1000 tonnes NO_2)

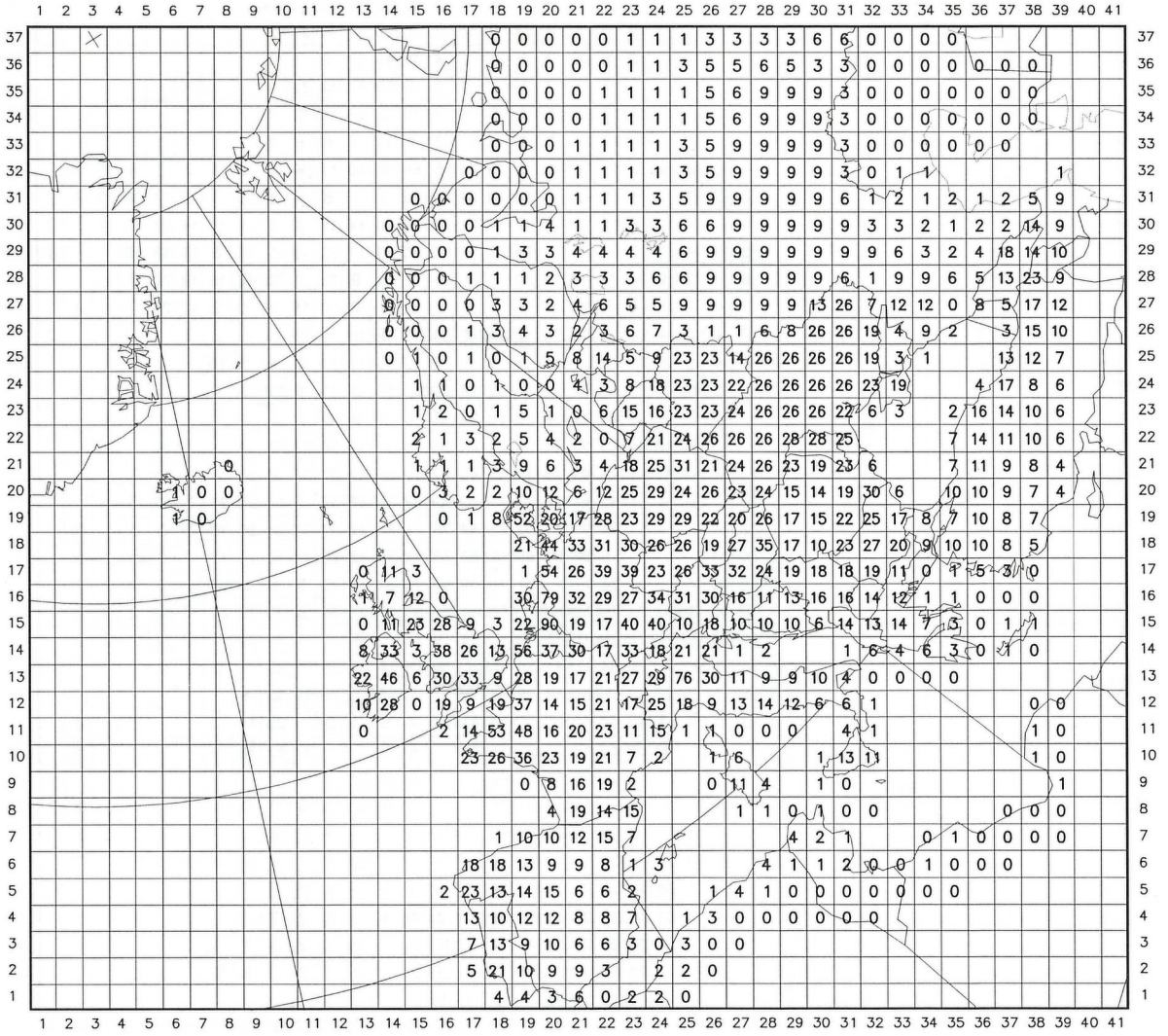

Figure 3.4. Emissions of ammonia in 1995 (1000 tonnes NH_3)

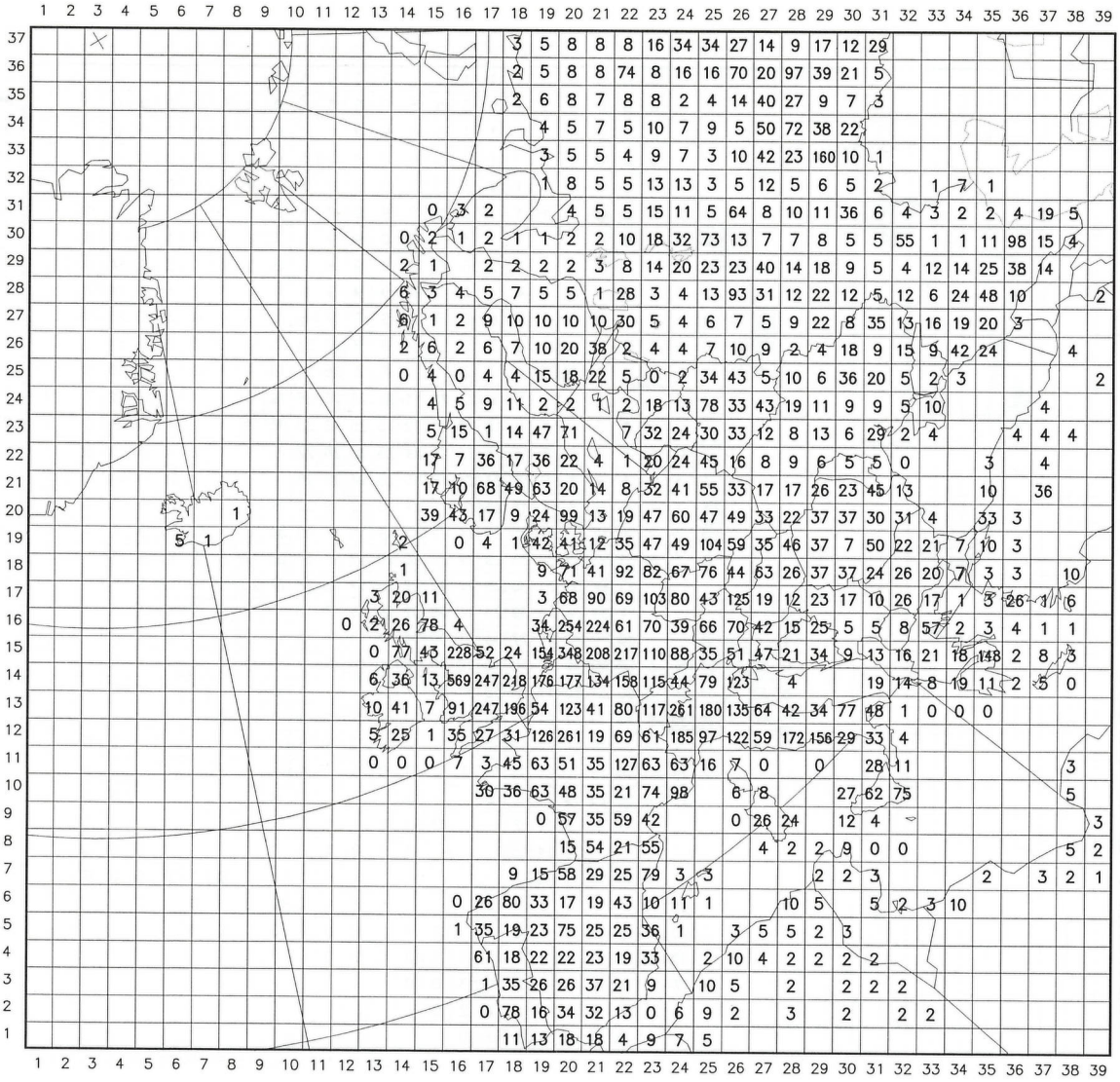

Figure 3.5. Emissions of non-methane volatile organic compounds in 1995 (1000 tonnes of NMVOC)

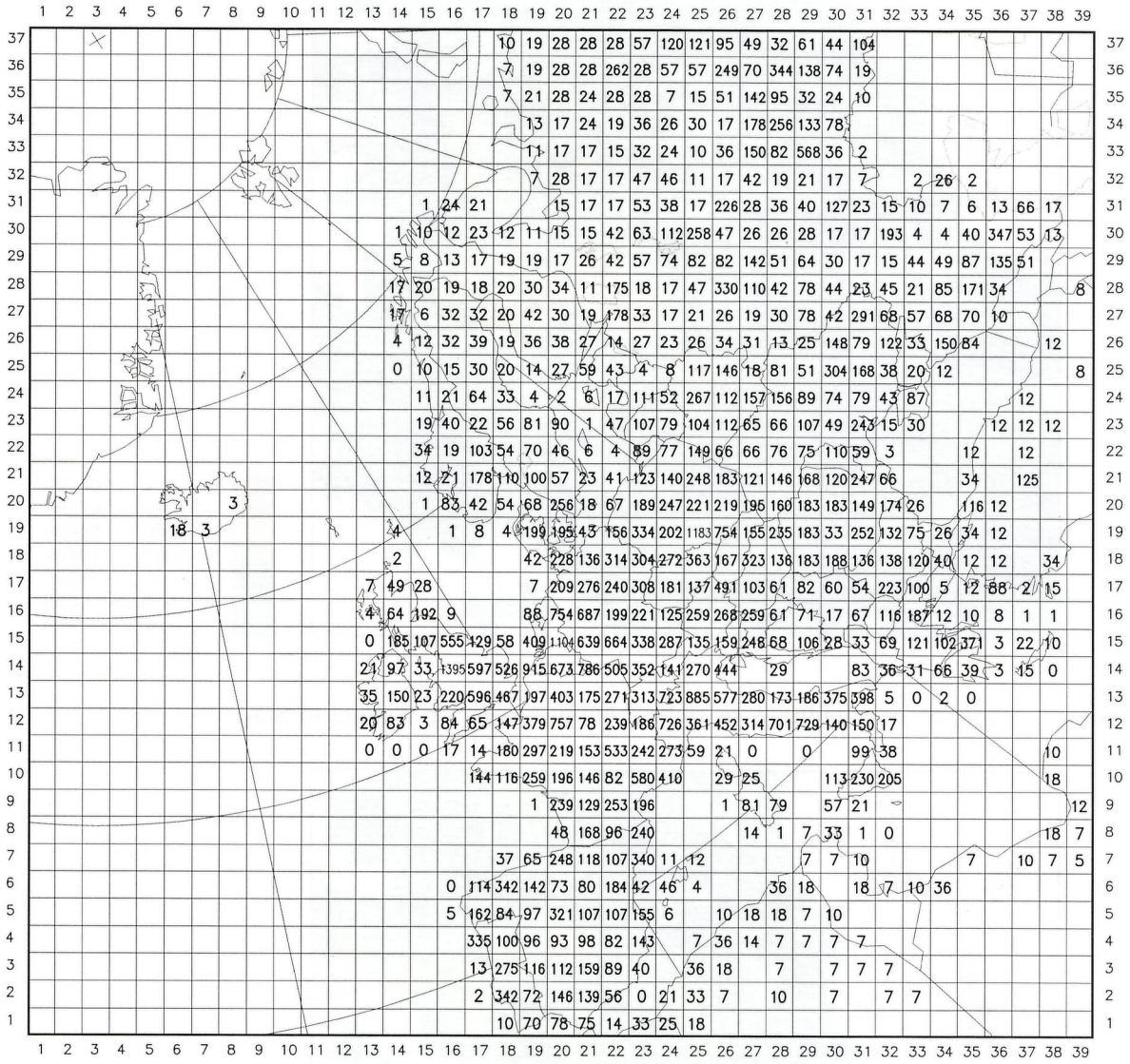

Figure 3.6. Emissions of carbon monoxide in 1995 (1000 tonnes of CO)

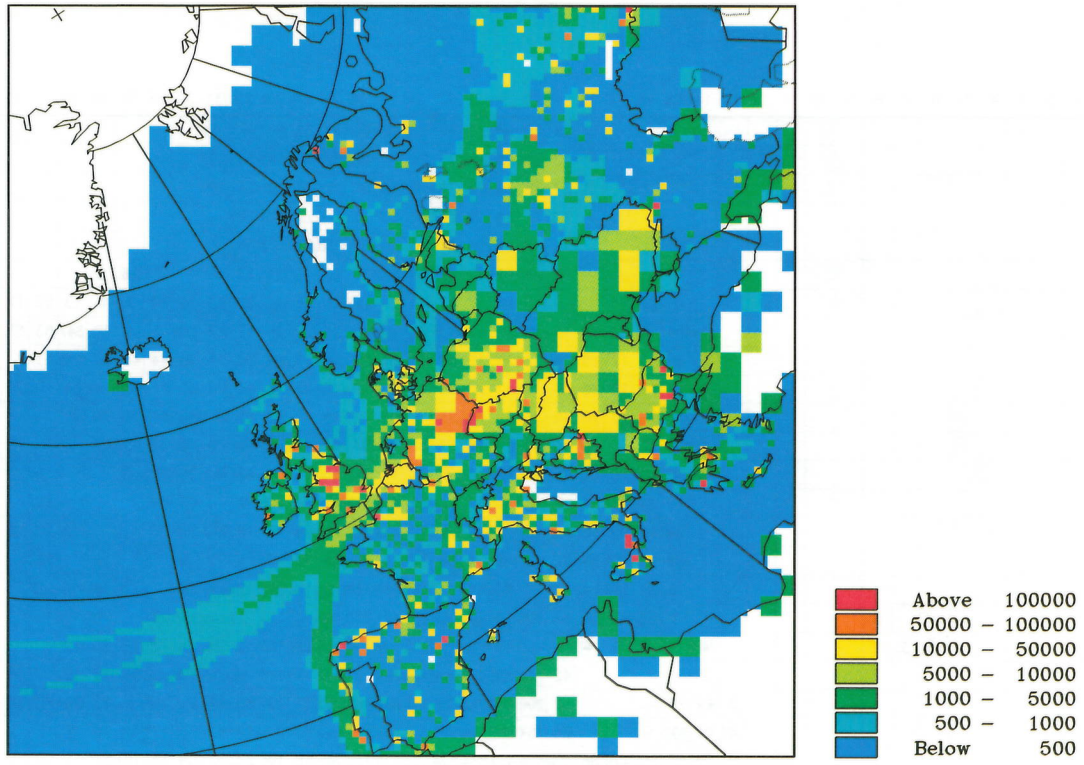

Figure 3.7. Emissions of sulphur in 1995 at 50km resolution (tonnes of SO_2)

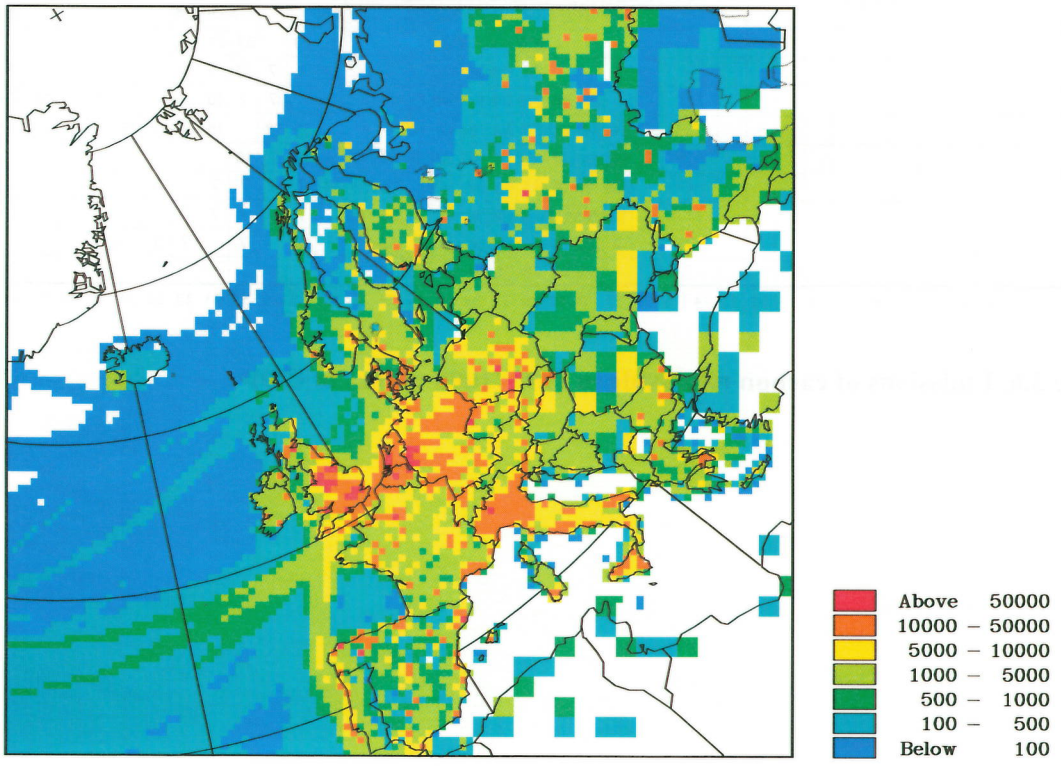

Figure 3.8. Emissions of nitrogen oxides in 1995 at 50km resolution (tonnes of NO_2)

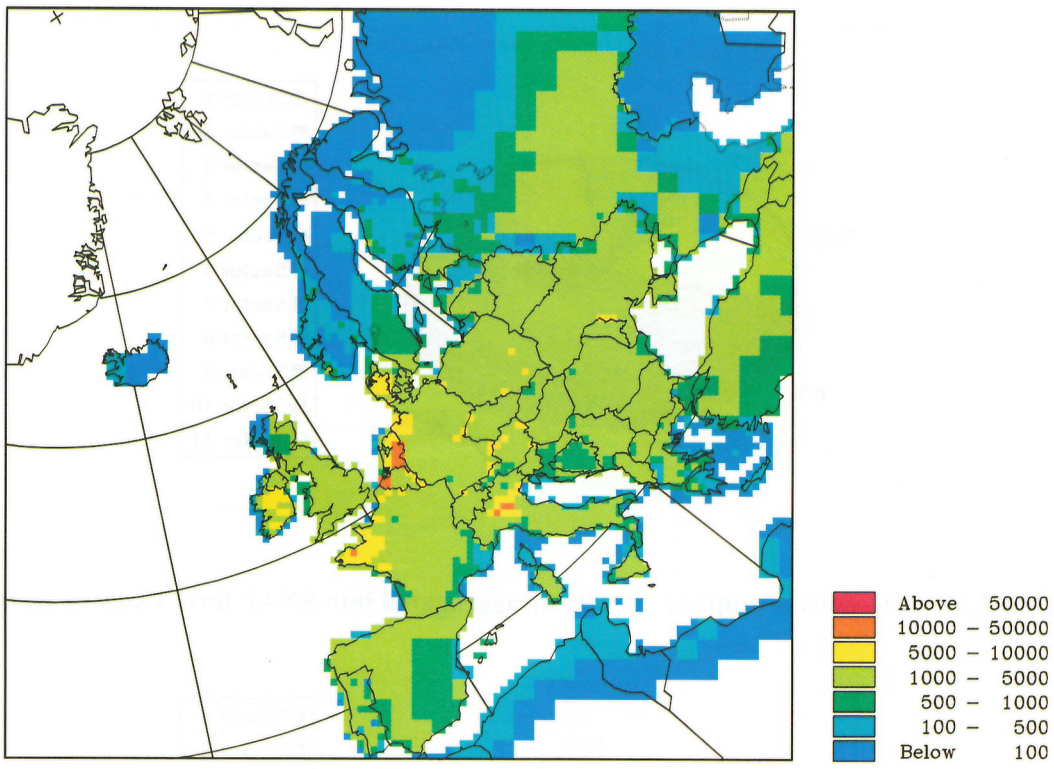

Figure 3.9. Emissions of ammonia in 1995 at 50km resolution (tonnes of NH_3)

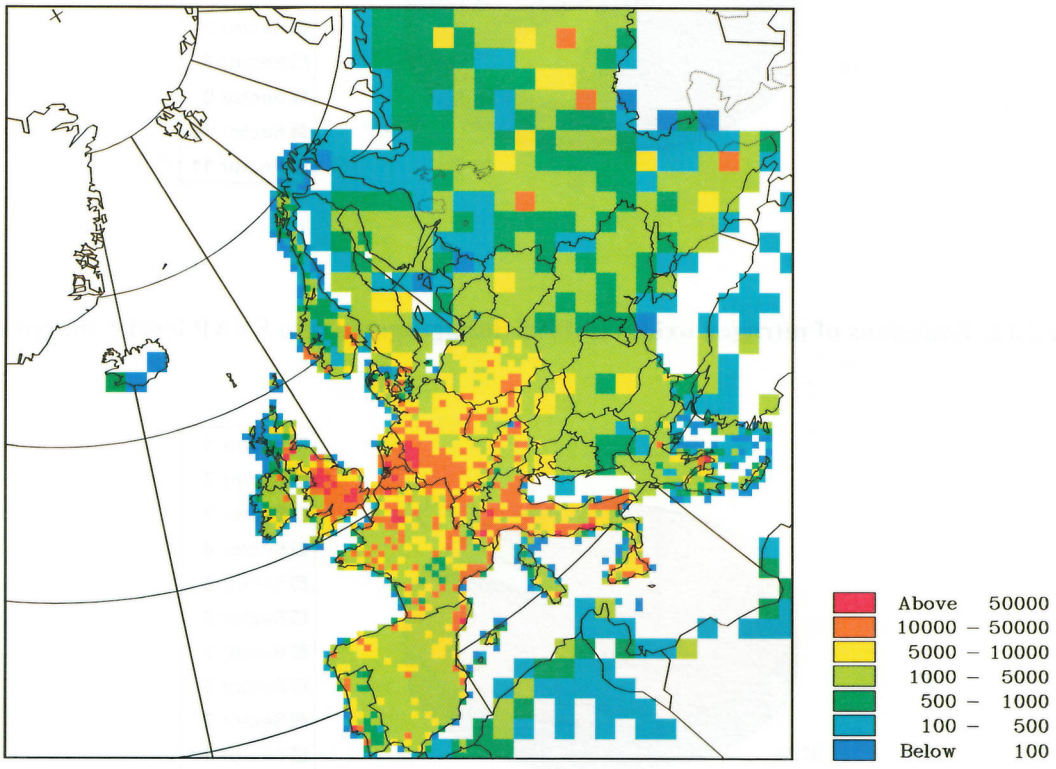

Figure 3.10. Emissions of non-methane volatile organic compounds in 1995 at 50km resolution (tonnes of NMVOC)

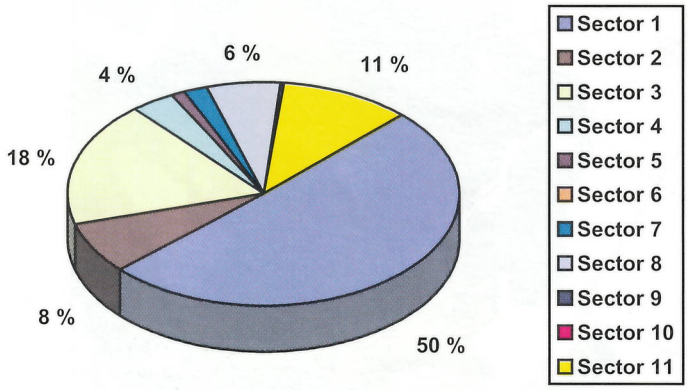

Figure 3.11. Emissions of sulphur in 1995 disaggregated into SNAP level 1 source sectors

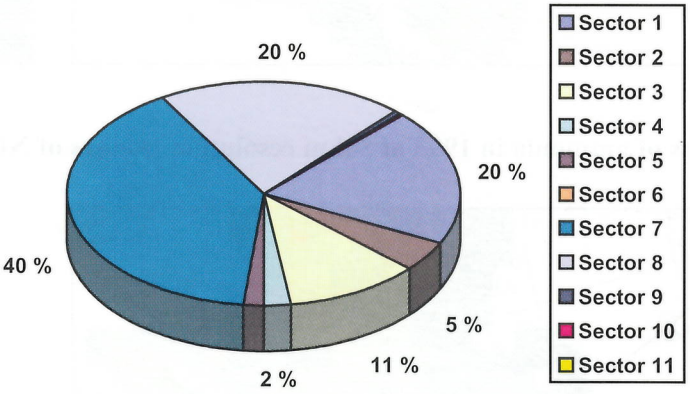

Figure 3.12. Emissions of nitrogen oxides in 1995 disaggregated into SNAP level 1 source sectors

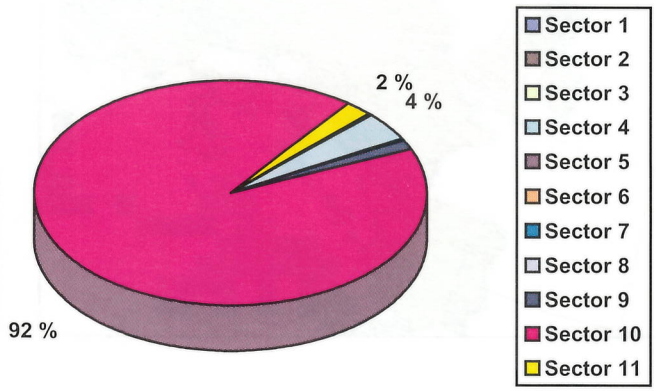

Figure 3.13. Emissions of ammonia in 1995 disaggregated into SNAP level 1 source sectors

3.3 Source sector split and emission trends

The disaggregation of Europe's totals into eleven source sectors for SO_2, NO_x and NH_3 is displayed in Figures 3.11-3.13. The eleven sectors SNAP level 1 were listed in Table 3.1. Most of the national data behind the figures refer to 1995. For a few countries earlier estimates have been used (the latest year reported). Neither SO_2 nor NO_x source split data have been reported by Belarus, Bosnia and Herzegovina, Republic of Moldova and Turkey. Moreover, Cyprus, Greece, Hungary, Iceland and Yugoslavia did not provide data for ammonia. The details can be found in Table 3.3.

Fifty per cent of sulphur emissions in Europe come from sector 1 (public power, cogeneration and district heating). Sectors: three (industrial combustion plants and processes) and eleven (nature: i.e. oceanic and volcanic emissions) contribute 18 and 11 per cent respectively. Minor contributions: 8, 6 and 4 per cent are released from sectors: 2 (commercial, institutional and residential combustion plants), 8 (other transport) and 4 (non-combustion processes) respectively (Figure 3.11). Road transport (sector 7; 40%) is the main source sector in case of NO_x emissions (Figure 3.12). Other important contributions (20% each) are from sectors: 8 and 1. Eleven and five per percent are released from sectors: 3 and 2. Figure 3.13 shows the respective data for ammonia. Almost all NH_3 emissions come from agriculture (sector 10; 92%). Other contributions are from sectors: 4, 9 and 11 (4%, 2% and 2% respectively).

On the basis of the emission figures used in the EMEP modelling activities (last rows in Tables 3.5 - 3.9), it is possible to assess total (anthropogenic and natural) emissions over Europe during the 1980-2010 period. The development of SO_2, NO_x, NH_3 and NMVOC emissions is given in Figures 3.14-3.17 respectively. The emission data include officially reported figures and when these are unavailable, estimates from other sources are used. It should be stressed that the presented totals for Europe are crude, as emissions over several regions are only first estimates. Moreover, for components such as NO_x and NMVOC there have been changes in emission methodology in recent years which have not always been applied to all preceding years.

European sulphur dioxide emissions (Figure 3.14) experience a clear downward trend. The total emission of SO_2 in 1995 shows a 48% reduction compared to the 1980 level and the reduction is expected to reach 54% by 2010 given the present projection figures. The trend in the emission of NO_x (Figure 3.15) is characterised by relatively high releases in the late 1980's and a gentle decrease in the 1990's. The 9% decrease in 1995 from the 1980 level, increases to 15% when 1990 is used as a base year.

European emissions of ammonia (Figure 3.16) exhibit an approximate 15% reduction between 1990 and 1995. The almost constant emission before 1990 is primarily a result of assumptions made to fill in the large amount of missing data for most countries, namely employing the first official annual figure available for all preceding years. NMVOC emissions (Figure 3.17) refer to anthropogenic releases only, although for a few Parties it is not clear whether natural releases are also included in their national totals. There is a slight downward trend in the 1990's, leading to an approximate 16% reduction in 1995 compared to the 1990 level. As noted above, however, NMVOC trends are particularly difficult to establish as only a few countries have supplied consistent methodologies to all years.

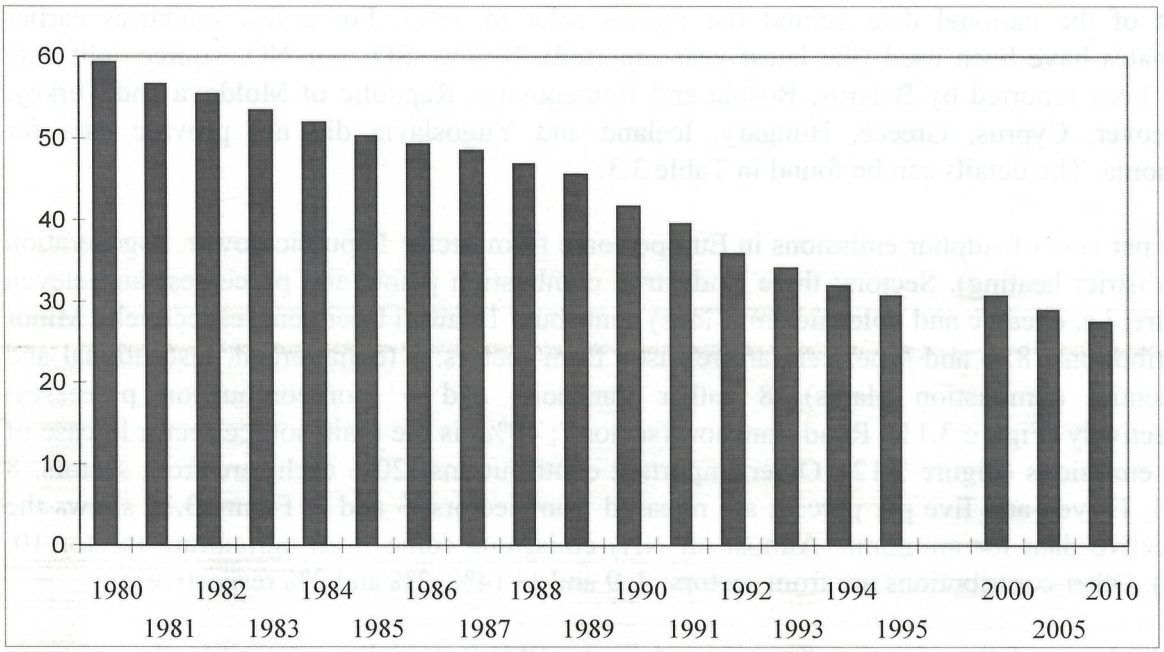

Figure 3.14. Emissions of sulphur in Europe 1980-2010 (millions of tonnes of SO_2).

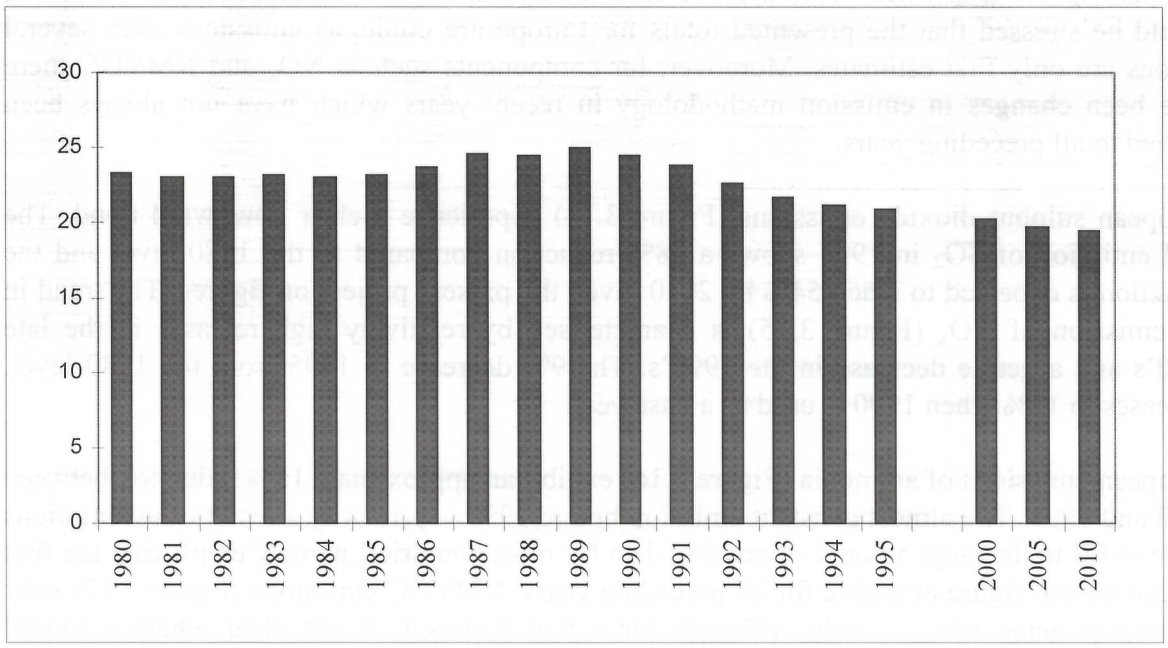

Figure 3.15. Emissions of nitrogen oxides in Europe (millions of tonnes of NO_2)

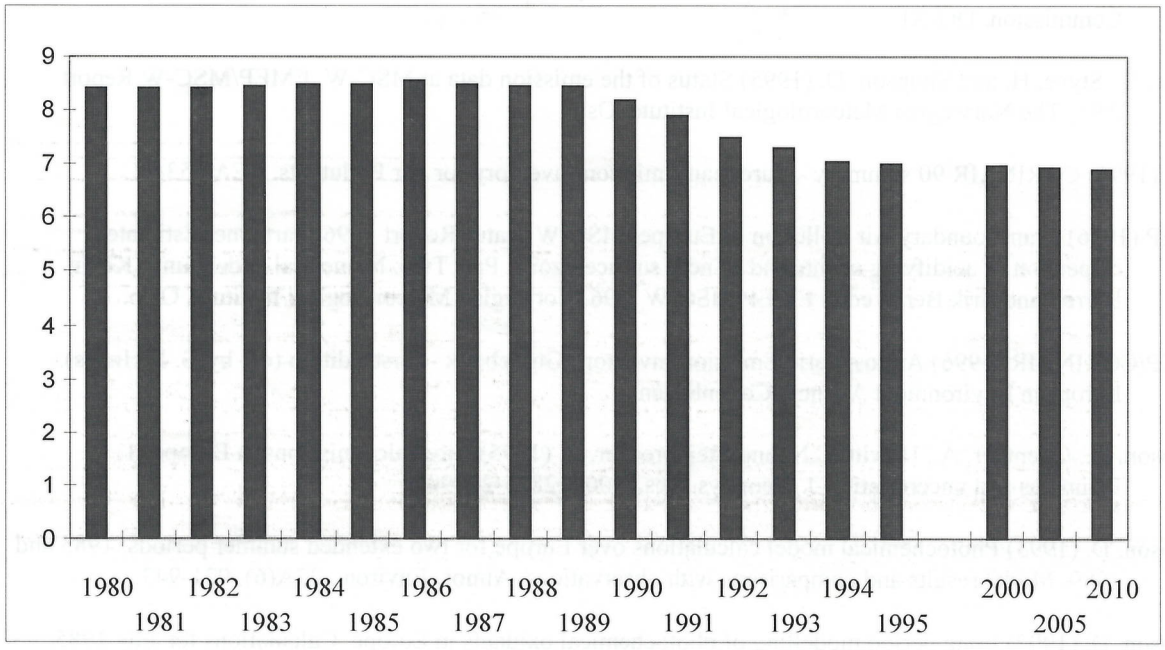

Figure 3.16. Emissions of ammonia in Europe (millions of tonnes of NH_3)

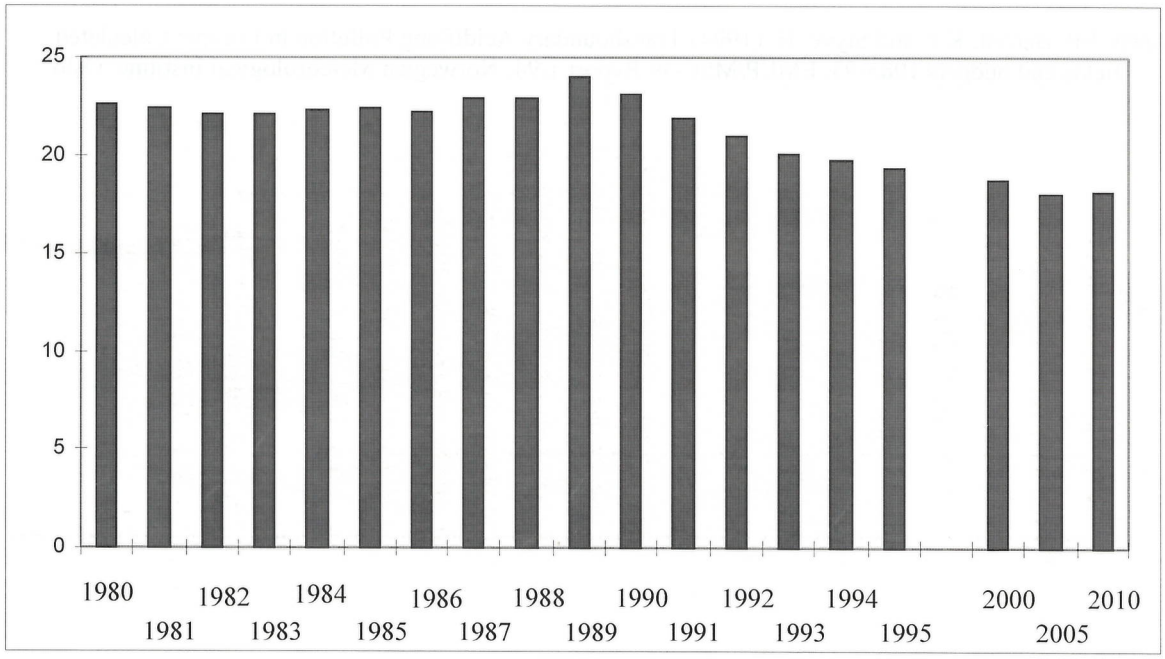

Figure 3.17. Emissions of non-methane volatile organic compounds in Europe (millions of tonnes of NMVOC)

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Chapter 4

TRENDS IN DEPOSITIONS, EXCEEDANCES AND THE SOURCE-RECEPTOR RELATIONSHIPS OF SULPHUR AND NITROGEN

4. Trends in depositions, exceedances and the source-receptor relationships of sulphur and nitrogen.

Erik Berge and Jerzy Bartnicki.

In the following chapter we give an overview of the time-variation of a few key parameters derived from the long-term lagrangian modelling in the 150km*150km grid. We will highlight the deposition trends in the EMEP modelling domain since 1980. We further elucidate the temporal evolution of the source-receptor relationships for two example countries. Based on the latest information on the critical-loads for sulphur and nitrogen as received from the Co-ordination Centre for Effects (CCE) we also present trends in exceedances above critical-loads integrated over the EMEP area. It must be noted that for the period 1980 to 1984 the depositions are obtained by scaling the average deposition derived from the years 1985-1995 by use of the emissions for each of the years 1980 to 1984. The reason for this is that the day-to-day meteorological data is not available before 1985. No comparison with measurements is made in this chapter. The reader is referred to Barrett and Berge (1996) for discussion of the model evaluation and how well it resembles the trends in the EMEP area.

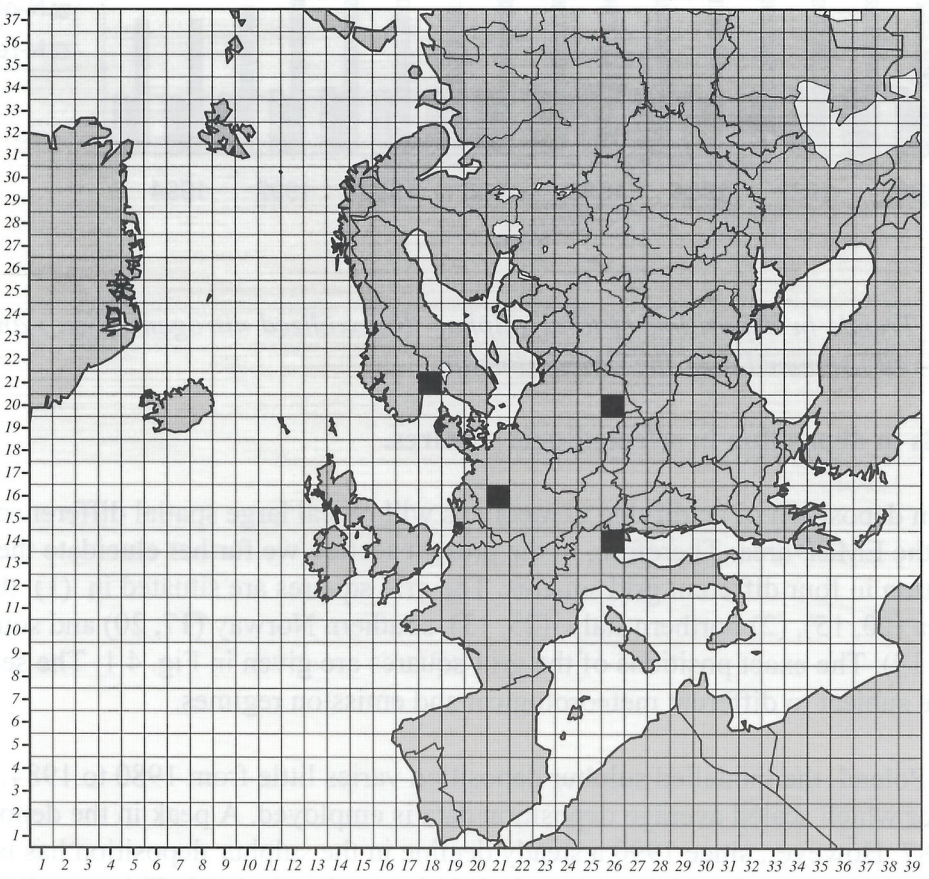

Fig. 4.1 *The EMEP modelling domain (1980-1995). The locations of the grid-squares (17,20), (20,15), (25,13) and (25,19) are marked on the map as black boxes.*

4.1 Trends in deposition.

4.1.1 Total deposition

The total depositions (integrated over the EMEP domain) of sulphur, oxidised nitrogen (originating from the NO_X emissions) and reduced nitrogen (originating from the NH_3 emissions) are derived from the model results presented in Chapter 5. The area of integration is given in Fig. 4.1. The trends in annual total deposition of sulphur, oxidised nitrogen and reduced nitrogen are shown in Fig. 4.2. The deposition trends follow rather closely the trends in the total emissions (Fig. 3.14, 3.15 and 3.16). For sulphur, a 47% decrease took place during the period. For oxidized and reduced nitrogen the decline was 10% and 14% respectively.

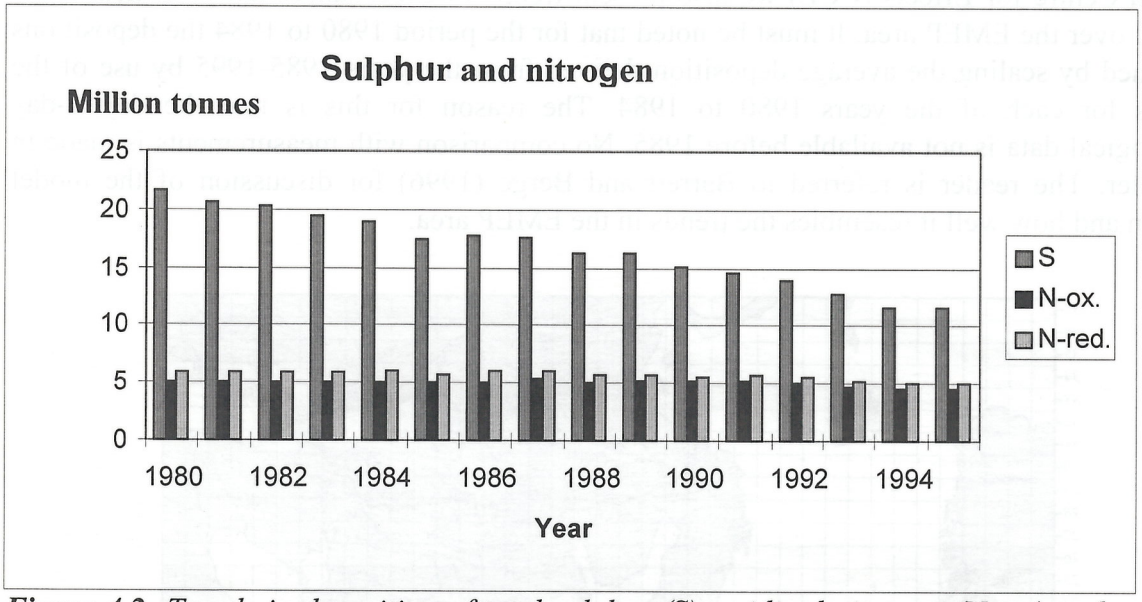

Figure 4.2 *Trends in deposition of total sulphur (S), oxidized nitrogen (N-ox.) and reduced nitrogen (N-red.) summed over the EMEP domain.*

4.1.2 Trends in deposition in selected grid squares.

The trends in deposition of acidifying compounds will reveal large spatial differences throughout the EMEP area. Therefore, in the present section we further elucidate the trends in total deposition in four different grid squares. The grid squares are situated in (1) the Benelux area (20, 15), (2) northern Italy (25, 13), southern Norway (17, 20) and southern Poland (25, 19). The exact positions of the grid-squares are given in Fig. 4.1. The selected locations are subject to different meteorological and emission regimes.

In southern Poland, the modelled sulphur deposition varies little from 1980 to 1984. This is the period for which scaled average deposition data is employed. A peak in the deposition is found in 1987. However, since 1990 a steady decline in the sulphur deposition has taken place, and the 1995 annual total deposition is 50% lower than in 1980. This is well in accordance with the reduction of the sulphur emissions in Poland and in the neighbouring countries (see Table 3.5). In the Benelux area the deposition in 1995 was only one third of the 1980 level. A large part of the reduction took place before 1990, in contrast to the much later on-set of the decline in southern Poland. However, this agrees with the reduction in the

sulphur emissions in western Europe which started already in the mid-seventies. Similarly, the deposition has been reduced by nearly a factor of three since 1980 in northern Italy. In southern Norway the reduction is somewhat smaller, but still close to a factor of two.

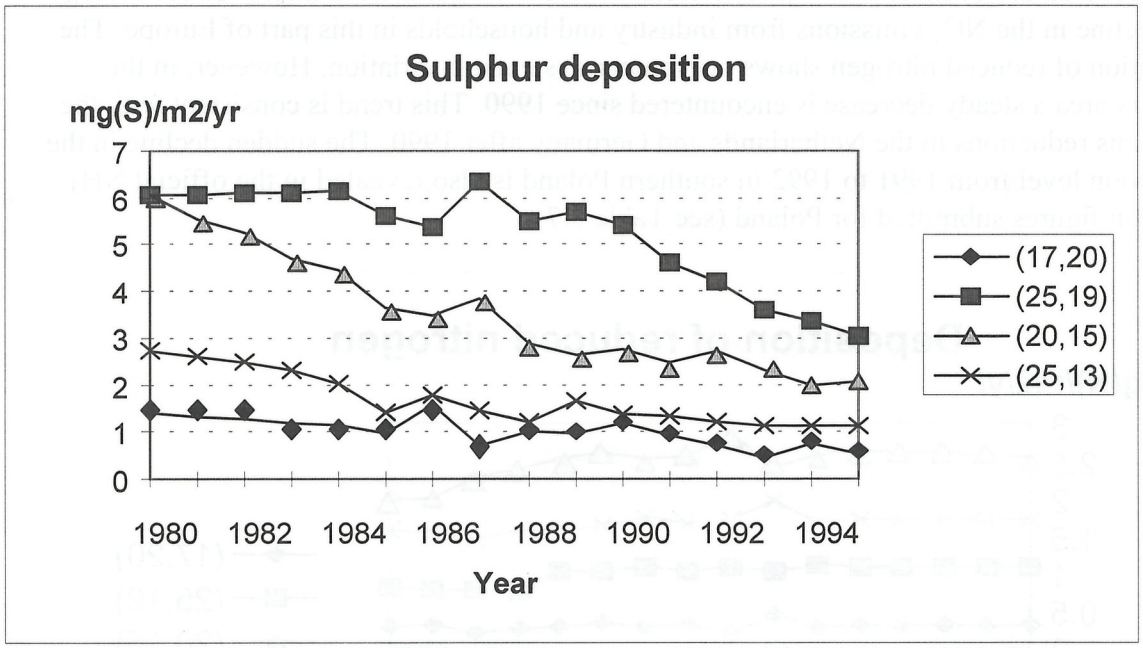

Fig. 4.3 *Trends in annual deposition of sulphur in four different 150km x 150km grid squares in Europe. The locations of the grid-squares are given in Fig. 4.1.*

Much smaller deposition trends are encountered for oxidized nitrogen (Fig. 4.4). A systematic decline can only be detected in southern Poland after 1990. For the three other grid squares no systematic increase or decrease can be seen. The interannual variability of the deposition of oxidized nitrogen has a maximum in the period 1985 to 1987. This is also true for the sulphur deposition (Fig. 4.3) and the deposition of reduced nitrogen (Fig. 4.5). In several central east

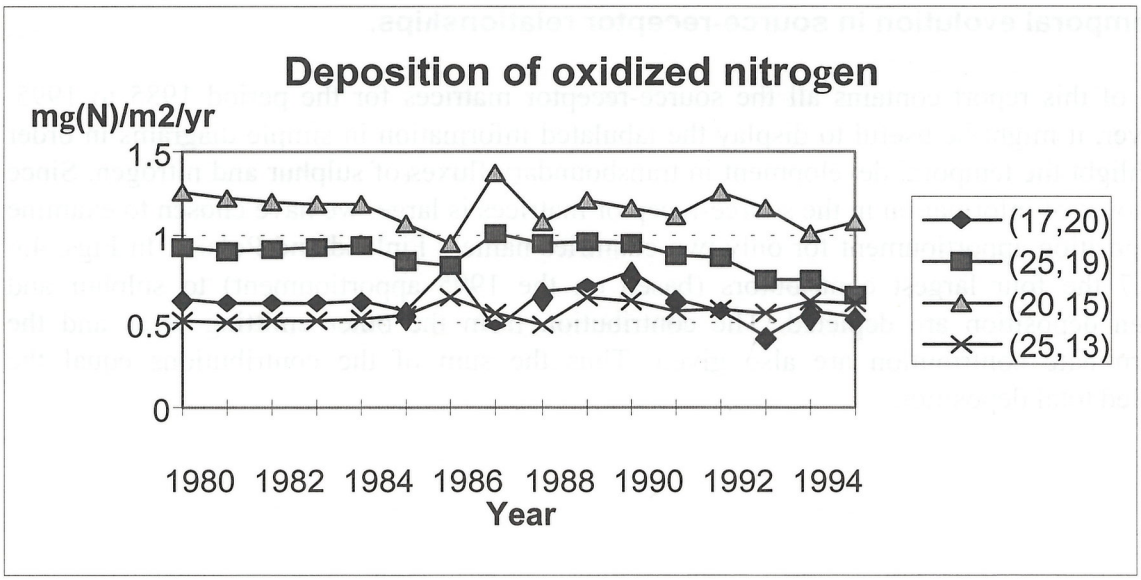

Fig. 4.4 *Trends in annual deposition of oxidized nitrogen in four different 150km x 150km grid squares in Europe. The locations of the grid-squares are given in Fig. 4.1.*

European countries there have been a clear decline in the NO_2 emissions since 1990 (see Table 3.6). However, in western Europe there are less systematic changes in the emissions. The increased use of motorised vehicles clearly offsets the gains from improved technology and decline in the NO_2 emissions from industry and households in this part of Europe. The deposition of reduced nitrogen shows only minor systematic variation. However, in the Benelux area a steady decrease is encountered since 1990. This trend is consistent with the emissions reductions in the Netherlands and Germany after 1990. The sudden decline in the deposition level from 1991 to 1992 in southern Poland is also revealed in the official NH_3 emission figures submitted for Poland (see Table 3.7).

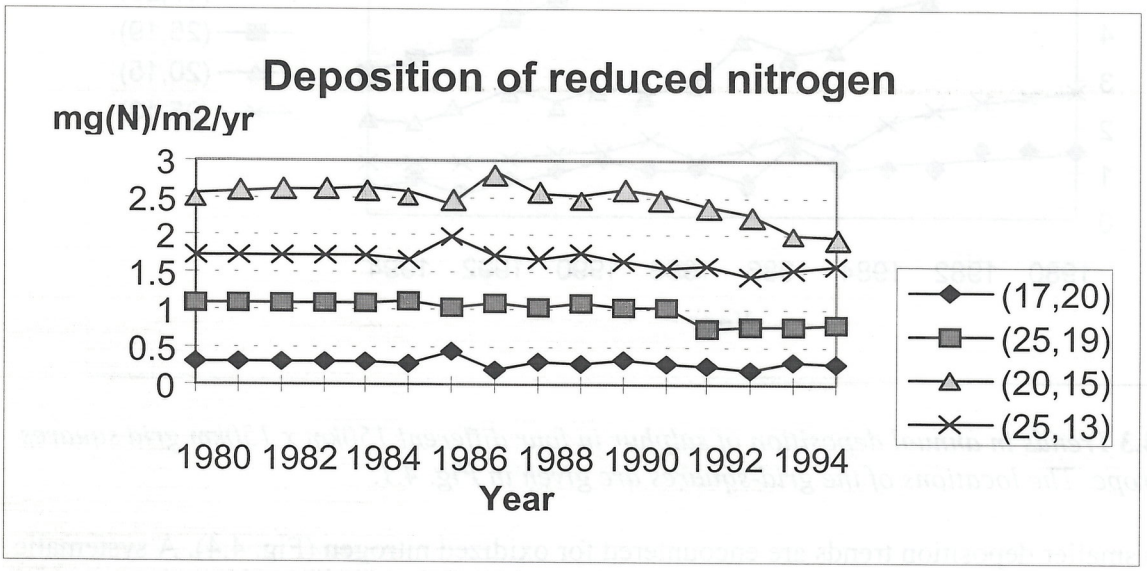

Fig. 4.5 *Trends in annual deposition of reduced nitrogen in four different 150km x 150km grid squares in Europe. The locations of the grid-squares are given in Fig. 4.1.*

4.3 Temporal evolution in source-receptor relationships.

Part 2 of this report contains all the source-receptor matrices for the period 1985 to 1995. However, it might be useful to display the tabulated information in simple diagrams in order to highlight the temporal development in transboundary fluxes of sulphur and nitrogen. Since the amount of information in the source-receptor matrices is large, we have chosen to examine the deposition apportionment for only two countries namely Finland and Poland. In Figs. 4.6 and 4.7 the four largest contributors (based on the 1995 apportionment) to sulphur and nitrogen deposition are depicted. The contribution from the other emitting areas and the indeterminate contribution are also given. Thus the sum of the contributions equal the modelled total deposition.

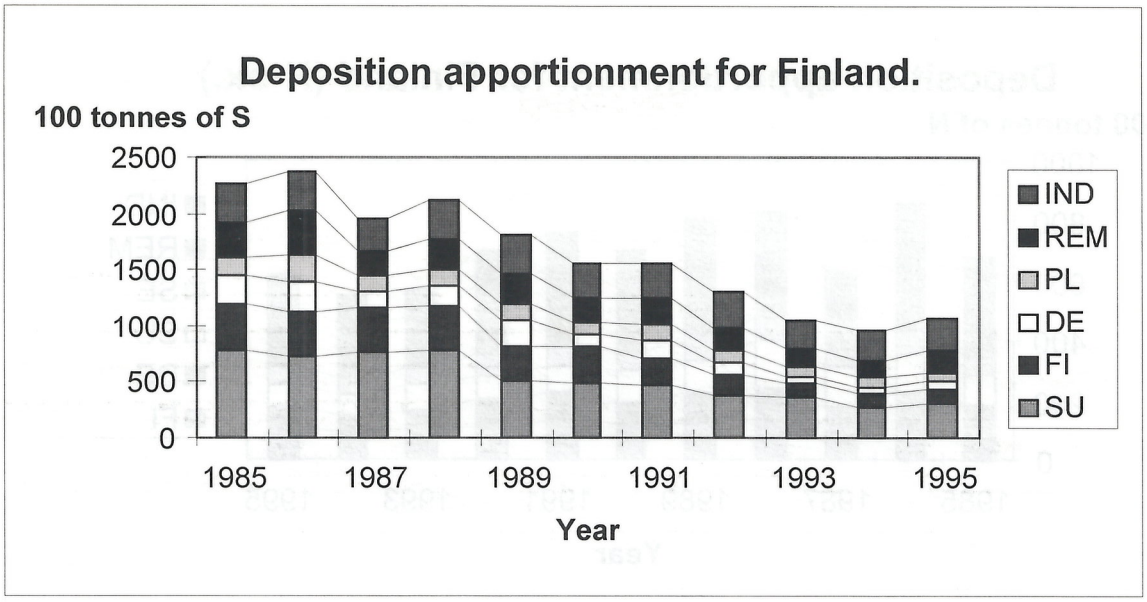

Fig. 4.6 a. *Contributions from; the European part of the area of the former Soviet Republic (SU), Finland (FI), Germany (DE), Poland (PL), all other emitting areas in the EMEP domain (REM) and indeterminate sources (IND); to total sulphur deposition in Finland.*

The contribution from any of the areas to sulphur deposition in Finland considerably decreases throughout the entire period (Fig. 4.6 a). The largest contributor to sulphur deposition in 1985 was SU, followed by Finland itself. In 1995 the area of the former SU and IND both contributed with about 30%. The deposition attributed to the Russian Federation was in 1995 approximately 18% (not shown in the figure). We observe that the share of both IND and REM to the deposition increases during the period. At the same time the share of Finland and Germany decreases while the relative contribution from Poland remains nearly constant. The variability from year to year is quite large, in particular for Poland and Germany. The transport from these country is largely influenced by the varying meteorological circulation patterns from one year to another. For emitter areas closer to Finland and in Finland itself (SU and FI) the interannual variability is smaller. Indeterminate sources also exhibit rather small variability from one year to another.

In Fig. 4.6 b and c the similar picture is given for oxidized and reduced nitrogen deposition to Finland. We observe that in 1995 the largest contributor to both oxidized and reduced nitrogen deposition in the country is Finland itself. A downward trend in total deposition is found for the nitrogen compounds as well, although it is not so pronounced as for sulphur. In 1995 the deposition apportionment for NO_X was rather similar to that of 1985 for all areas except for SU which lowered its contribution by approximately 30%. For reduced nitrogen the contributions from DE and PL are also considerably reduced during this period. Smaller changes are encountered for the other areas. The indeterminate sources accounted for about 18% and 20% of the depositions of reduced and oxidized nitrogen respectively throughout most of the period.

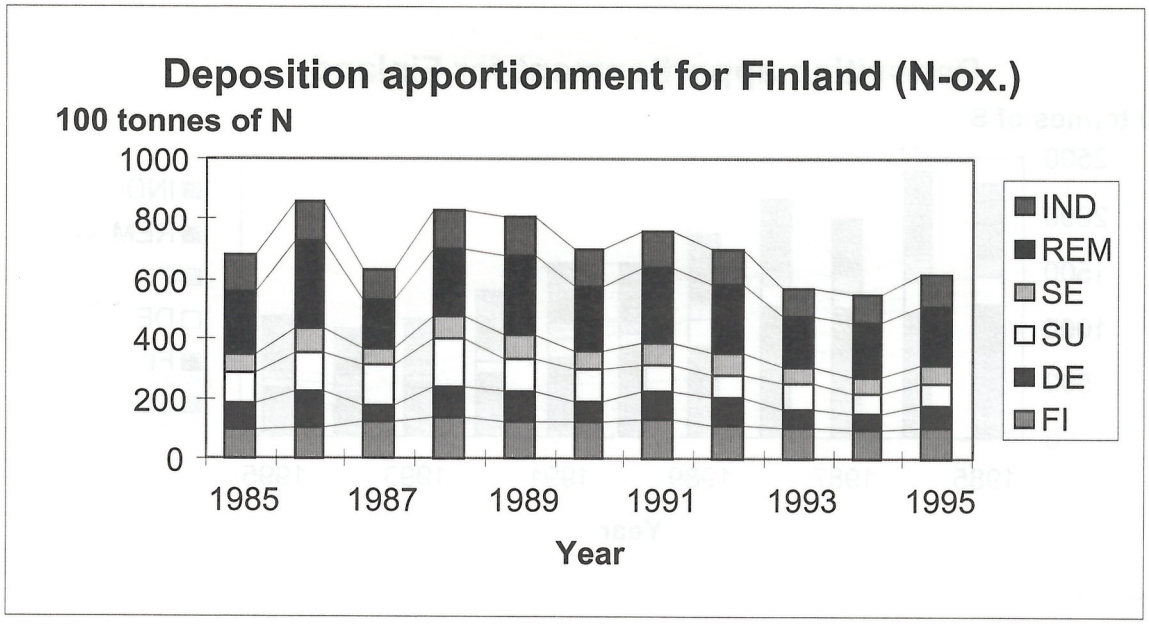

Fig. 4.6 b. *Contributions from; the European part of the area of the former Soviet Republic (SU), Finland (FI), Germany (DE), Poland (PL), all other emitting areas in the EMEP domain (REM) and indeterminate sources (IND); to total oxidized nitrogen deposition in Finland.*

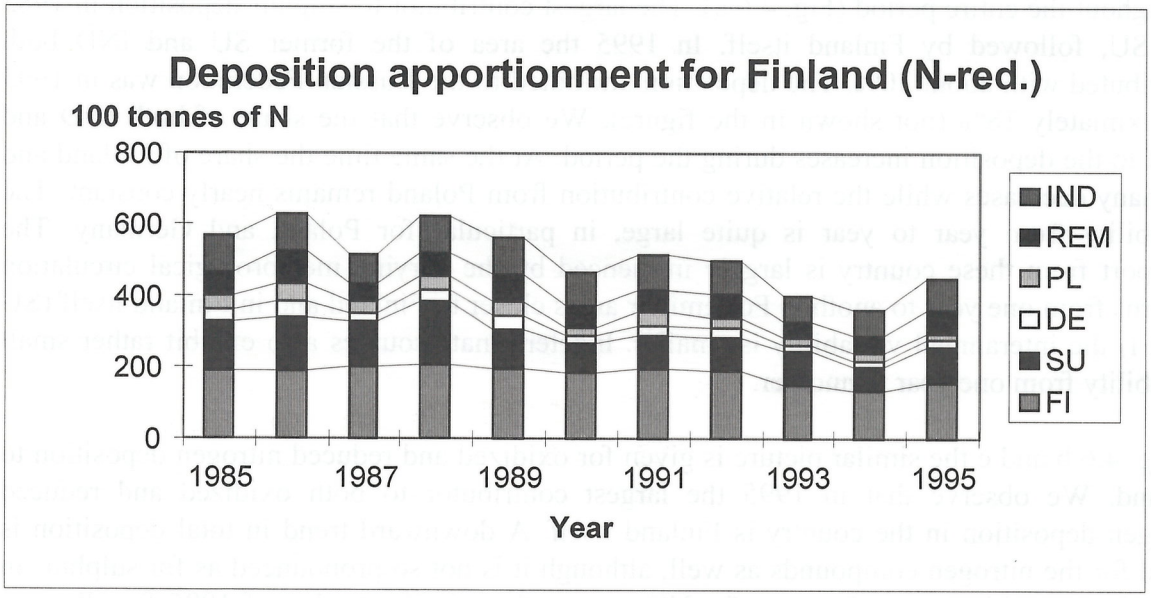

Fig. 4.6 c. *Contributions from; the European part of the area of the former Soviet Republic (SU), Finland (FI), Germany (DE), Poland (PL), all other emitting areas in the EMEP domain (REM) and indeterminate sources (IND); to total reduced nitrogen deposition in Finland.*

In contrast to Finland, Poland is in 1995 the largest contributor to its own sulphur deposition (Fig. 4.7 a). However, in 1985 the apportionment between Poland and Germany was nearly equal. Since 1990 the imported sulphur from Germany declined rapidly. On the other hand, Germany contributes more to the deposition of oxidized nitrogen in Poland than any other country for all years between 1985 and 1995. The largest decrease in export of NO_X to Poland

was from the area of former Czechoslovakia. The deposition of reduced nitrogen (Fig. 4.7 c) is largely influenced by the local Polish sources which dropped considerably from 1991 to 1992. A slight increase in the contribution from the area of the former Soviet Union can be observed. Except for this only small variations in the apportionment can be found.

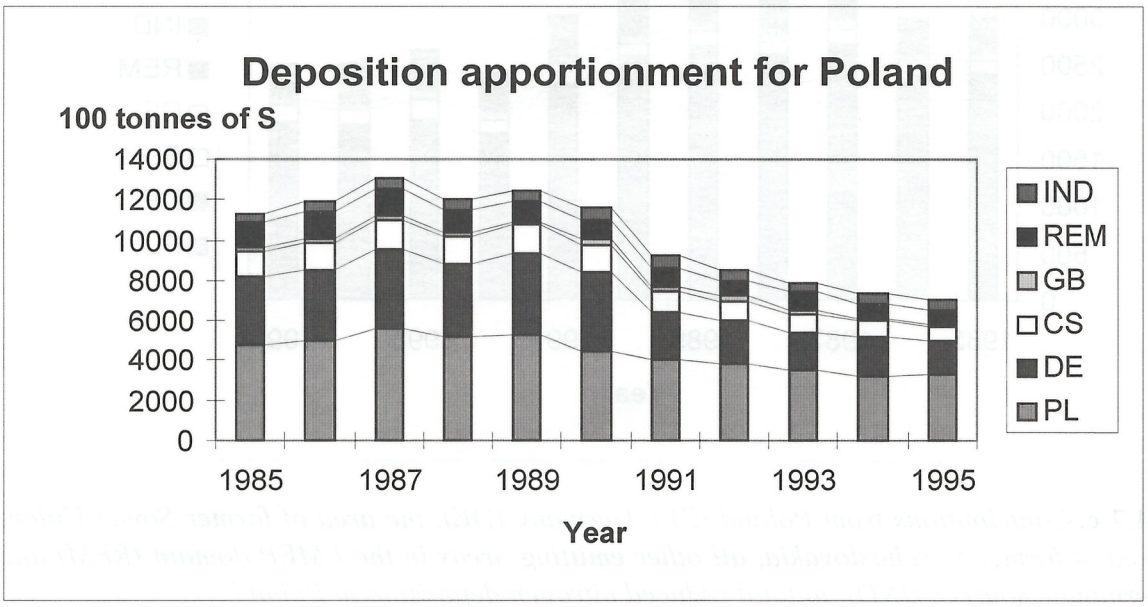

Fig. 4.7 a. *Contributions from Poland (PL), Germany (DE), the area of former Czechoslovakia, United Kingdom (GB), all other emitting areas in the EMEP domain (REM) and indeterminate sources (IND), to total sulphur deposition in Poland.*

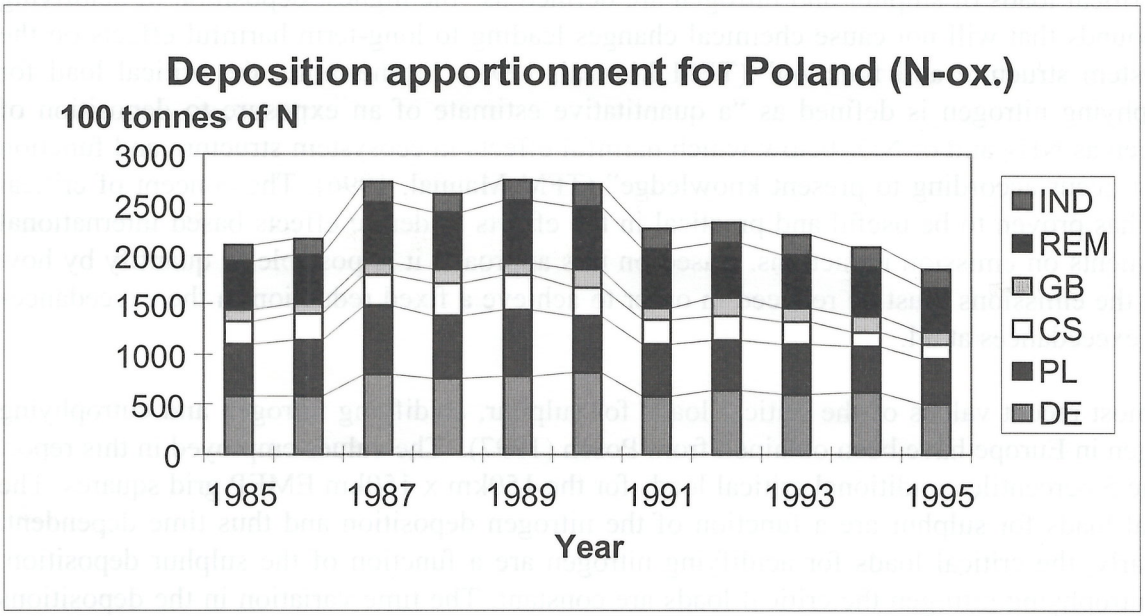

Fig. 4.7 b. *Contributions from Germany (DE), Poland (PL), the area of former Czechoslovakia, United Kingdom (GB), all other emitting areas in the EMEP domain (REM) and indeterminate sources (IND), to total oxidized nitrogen deposition in Poland.*

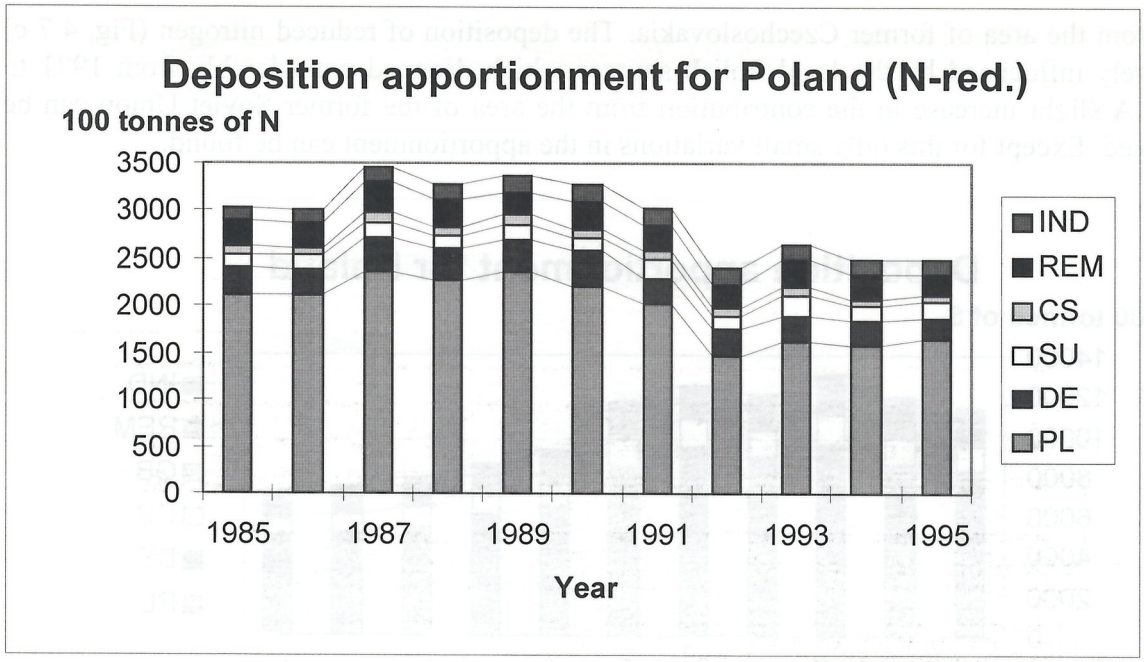

Fig. 4.7 c. *Contributions from Poland (PL), Germany (DE), the area of former Soviet Union, the area of former Czechoslovakia, all other emitting areas in the EMEP domain (REM) and indeterminate sources (IND), to total reduced nitrogen deposition in Poland.*

4.4 Trends in exceedances of critical loads.

The critical loads of sulphur and nitrogen are defined as "the highest deposition of acidifying compounds that will not cause chemical changes leading to long-term harmful effects on the ecosystem structure and function" (TFM Manual, 1996). Furthermore, the critical load for eutrophying nitrogen is defined as "a quantitative estimate of an exposure to deposition of nitrogen as NH_X and/or NO_y below which harmful effects in ecosystem structure and function do not occur according to present knowledge" (TFM Manual, 1996). The concept of critical loads has proven to be useful and practical in the efforts to derive effects based international agreements on emission reductions. Based on this approach it is possible to quantify by how much the emissions must be reduced in order to achieve a fixed reduction in the exceedances or no exceedances at all.

The most recent values of the critical loads for sulphur, acidifying nitrogen and eutrophying nitrogen in Europe have been obtained from Posch (1997). The values employed in this report are the 5 percentile conditional critical loads for the 150km x 150km EMEP grid squares. The critical loads for sulphur are a function of the nitrogen deposition and thus time dependent. Similarly, the critical loads for acidifying nitrogen are a function of the sulphur deposition. For eutrophying nitrogen the critical loads are constant. The time variation in the depositions are derived from the 150km lagrangian model. For further details on the critical loads approach the reader is referred to the TFM manual (1996).

In addition to the critical loads we have obtained the fraction of eco-system coverage in each 150km x 150km grid square (Posch, 1997). Hence, this enables us to estimate the ecosytem area with exceedances. Note that for the period 1980 to 1984 average depositions (1985-1995) are scaled according to the annual emissions. In Fig. 4.8 the critical loads are subtracted from

the sulphur and nitrogen depositions, and the total eco-system area (in km^2) with exceedance is thereby estimated. The total area of exceedance is given as a fraction of the land area of the EMEP domain where critical loads values are defined. In line with the emission reductions an improvement in the total area in Europe with recorded exceedances is observed. In fact the

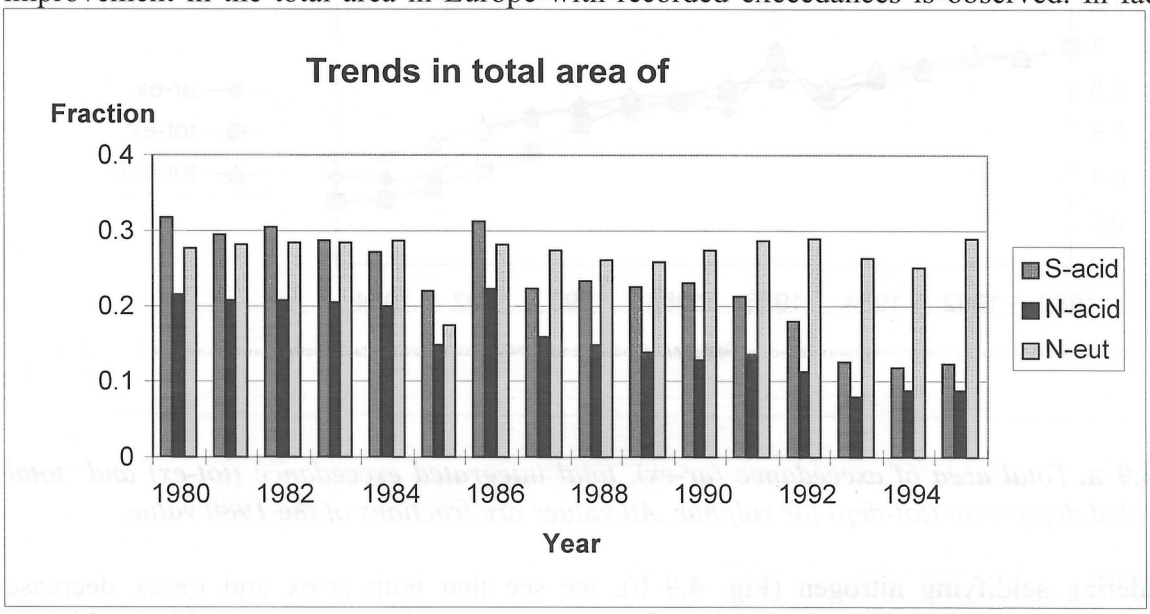

Fig. 4.8 *Trends in total area of exceedance of the conditional critical load (5 percentile) for sulphur (S-acid), for nitrogen (N-acid), and the critical load (constant) for eutrophying nitrogen (N-eutro.) Source of critical loads: CCE*

area of exceedance has decreased by more than 50% for both sulphur and acidifying nitrogen from 1980 to 1995. The downward trend from 1980 to 1984 for sulphur is due to reduced sulphur emissions. This further affects the total area of exceedance for acidifying nitrogen since the conditional critical load for nitrogen is higher when the sulphur deposition is reduced. However, the total nitrogen emissions (NO_X + NH_3) varied little during this period. This is reflected by the nearly unchanged area of exceedance for eutrophying nitrogen. In 1985, the starting year with day to day meteorology employed in the computations, a clear mimimum in the total area of exceedance is encountered for all three components. Next year 1986, on the other hand, gives a distinct maximum. Since 1986 a decline in the area of exceedance of sulphur and acidifying nitrogen has taken place. However, no such evolution is encountered for eutrophying nitrogen.

In figures 4.9 a,b and c we again present the temporal evolution of the total ecosystem area (in km^2) of exceedance as defined in the previous section, but now as a fraction of the 1980 value (ar-ex). Furthermore, we define the integrated exceedance (tot-ex), as the sum of the exceedance in all ecosystem areas (eq/yr). Finally, the total integrated deposition over the land areas as a fraction of the 1980 value is given (tot-dep). For sulphur we observe that tot-ex decrease more rapidly than ar-ex. The smallest rate of decrease is found for tot-dep. Again the regular pattern from year to year from 1980 to 1984 is noted, due to employment of the scaled average depositions. Altogether we find that tot-exc has declined with more than 70% since 1980, while ar-ex and tot-dep are reduced by approximately 60% and 50% respectively.

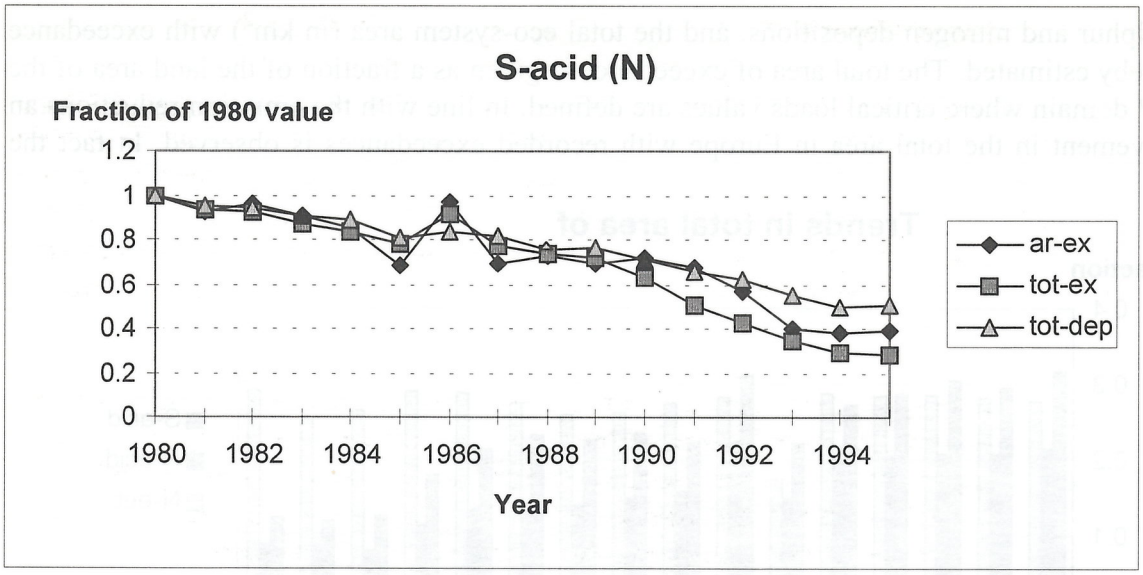

Fig. 4.9 a. *Total area of exceedance (ar-ex), total integrated exceedance (tot-ex) and total integrated deposition (tot-dep) for sulphur. All values are fractions of the 1980 value.*

Considering acidifying nitrogen (Fig. 4.9 b), we see that both ar-ex and tot-ex decrease somewhat from 1980 to 1984 due to the substantial decrease in sulphur deposition, which in turn, has influenced the critical loads of acidifying nitrogen. Although the total nitrogen deposition stays at nearly the same level from 1985 to 1990, tot-ex and ar-ex continue to decrease throughout this period. Since 1990 the total nitrogen deposition is declining and both tot-ex and ar-ex are reduced by approximately 50% and 60% respectively.

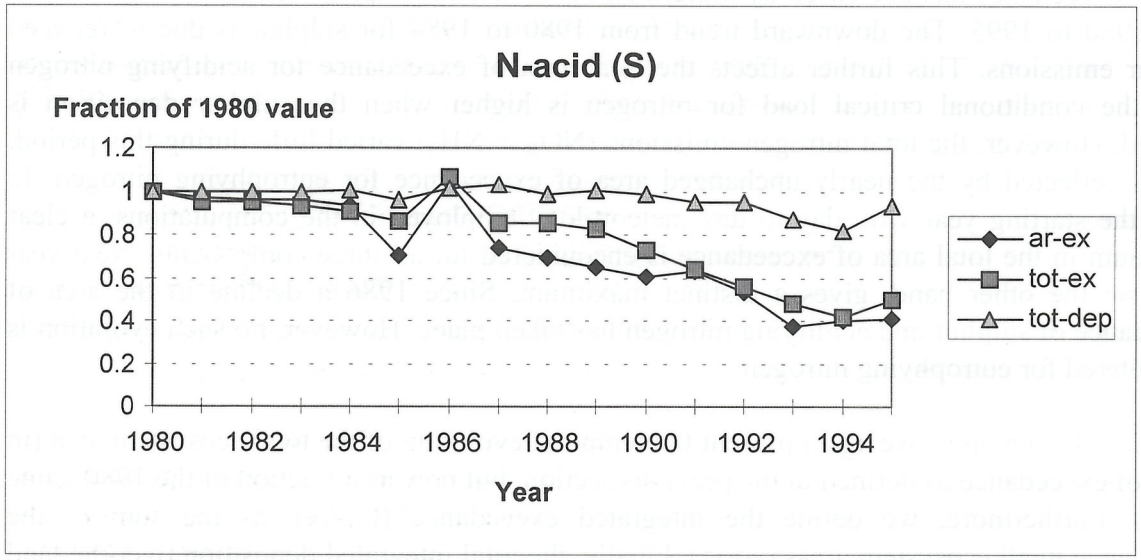

Fig. 4.9 b. *Total area of exceedance (ar-ex), total integrated exceedance (tot-ex) and total integrated deposition (tot-dep) for acidifying nitrogen. All values are fractions of the 1980 value.*

The critical load of eutrophying nitrogen is independent of the sulphur deposition. Therefore no changes in either ar-ex nor tot-ex are seen between 1980 to 1984 (Fig. 4.9 c). However, from 1985 and onward, the annual variation is evident. A very low value of ar-ex is

encountered in 1985. The exceedances map of 1995 (see Fig. 5.7) shows large areas of low exceedances in Russia. A closer scrutiny of the modelled data for 1985 reveals particular low nitrogen deposition rates over parts of Russia. This actually removes exceedances in a substantial part of Russia, and therefore explains the rather anomalous behaviour of ar-ex in 1985. Similar features are not encountered for tot-ex and tot-dep since the overall deposition in the EMEP area is not subject to such strong variations from one year to another.

For the period 1987 to 1992 only small alterations of ar-ex, tot-ex and tot-dep are found. A rather strong decrease is further seen for 1993 and 1994 in particular for tot-ex. Finally, an increase took place for all three components in 1995.

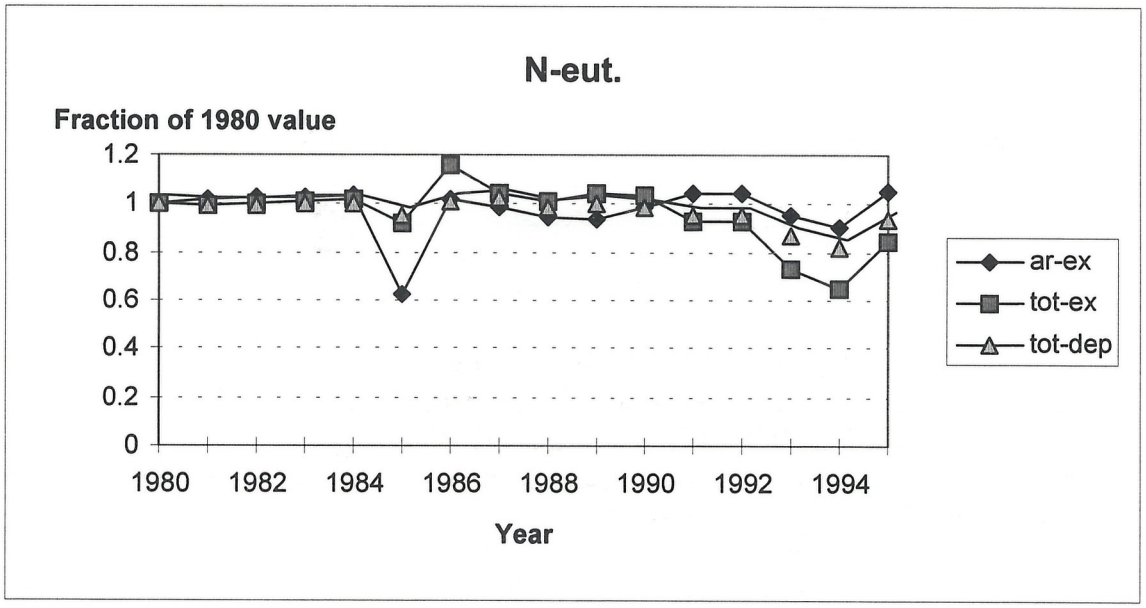

Fig. 4.9 c. *Total area of exceedance (ar-ex), total integrated exceedance (tot-ex) and total integrated deposition (tot-dep) for eutrophying nitrogen. All valus are fractions of the 1980 value.*

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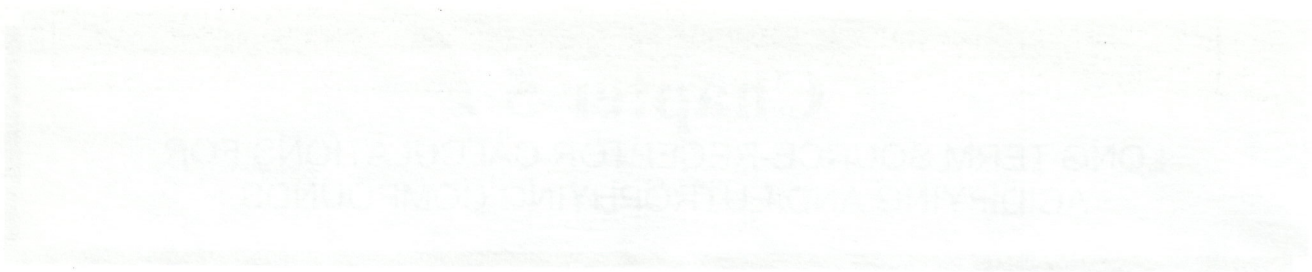
Chapter 5

LONG TERM SOURCE-RECEPTOR CALCULATIONS FOR ACIDIFYING AND EUTROPHYING COMPOUNDS



5. Long Term Source-Receptor Calculations for Acidifying and Eutrophying Compounds

Svetlana G. Tsyro

5.1. Introduction

The present section is devoted to the latest simulations of transboundary acidifying and eutrophying air pollution by use of the 150 km lagrangian model ROOT-150 (ROOT-150 = Receptor Oriented One Layer Trajectory model). A detailed description of this model is given in EMEP/MSC-W Report 1/96, Appendix 1. No major changes have been made to the model formulation during the last year. Recent runs of the EMEP model have been carried out for the years 1995 and 1996. The updated emission data for 1995 have been employed in the computations for 1995. For 1996 calculations the emission data for 1995 have been used with the only modification, i.e. inclusion of sulphur and nitrogen emissions from Cyprus. The meteorological input is available for both 1995 and 1996. As it is discussed in Chapter 2, the meteorological data for 1996 was taken from the HIRLAM model.

Firstly, we present and discuss the geographical distribution of acidifying deposition across Europe and the maps of the critical load exceedance. The concentration fields of some primary and secondary compounds are shown as well. Finally the estimated magnitude of transboundary pollutants exchange in Europe is illustrated by traditional source-receptor matrices.

5.2. Extension of the modelling domain.

The model has this year been extended in order to incorporate Cyprus and the entire Turkey in the calculations. Another modification of the model is connected with use of a new meteorological model HIRLAM (see section 2.1). The HIRLAM domain does not cover the lower right corner of the EMEP domain (see Fig.2.1). Hence, changes have been made in the model in order to exclude the area beyond the meteorological coverage from the transport calculations.

Furthermore, some computation corrections have been carried out in the postprocessing of the model results. They enable more accurate calculation of a local wet deposition factor for ammonia emissions, and result in a better correspondence of the lagrangian ROOT-150 and eulerian MADE-50 models in the distribution of reduced nitrogen.

5.3. Spatial distributions of concentration, deposition, and exceedances of critical loads for 1995-96.

The distribution of the pollutants is determined by a combination of three major elements, i.e. the emissions, the meteorology, and the chemical processes. The effect of meteorology appears through the pollutant transport after emission, as well as through deposition by the distribution of precipitation and aerodynamic resistance in the boundary layer. Various chemical reactions between the pollutants influence their respective lifetimes and deposition

maximum in the exceedances per EMEP grid square is found close to the main sources in Central Europe and the eastern United Kingdom. In parts of Scandinavia, where emissions are quite modest, the exceedances are relatively large due to the small buffering capacity of the soil. In the Mediterranean area the buffering capacity of the soils is much larger, and hence, the critical loads are higher, and the exceedances are much smaller.

The exceedances of the conditional critical load (5 percentile) of **acidifying nitrogen** (CL(N|Sdep95)) are given in Fig.5.6. In this case exceedances are encountered in Central Europe in Scandinavia alike. Finally, Fig.5.7. presents the exceedance of the critical loads for **eutrophying nitrogen** (CL(Nut)). A larger area is shown to have exceedances due to eutrophying nitrogen than acidifying nitrogen. The highest exceedances of CL(Nut) occur in Central Europe and northern Italy.

5.4. The air pollutant exchange between European countries.

An important feature of the lagrangian model is that it can allocate the concentrations and depositions in each grid square to any of the emitting regions in the domain. This calculation feature forms the basis for the transboundary air pollution budgets presented in this report.

The fields of influence of the emissions from individual countries are demonstrated in Appendix C, Part 2 by the maps of the allocated depositions averaged over the years 1985-95. In Appendix B we present the source-receptor deposition matrices for these compounds for the twelve years 1985-96. The new matrices for the years 1985-94 were obtained through a scaling procedure according to the updated emissions. This is enabled by the linearity of the governing differential equations of the model. The matrices for 1995 and 1996 (only provisional) are based on new model calculations, and Cyprus was included in the latter. Among the most noticeable changes due to updated emissions are, for instance, about 30% reduction of oxidised nitrogen deposition and 40% increase of sulphur deposition allocated to Romania. Deposition of oxidised nitrogen originating from Germany was around 34% smaller in 1995 than estimated earlier. Due to much higher updated emissions of SO_x and NO_x from the N.E.Atlantic Ocean and the North Sea, associated total depositions are found respectively 3.7 and 2.8 times larger. The countries most influenced are France, Germany (from the North Sea), the United Kingdom, and Spain for which the Atlantic Ocean becomes the main contributor to the deposition of oxidised sulphur and nitrogen. Significant decrease of depositions of all the compounds (exceeding 50-60%) from Latvia and Lithuania are registered. A large increase of about 55% of total sulphur deposition in 1995 attributed to remaining land areas results from the new volcanic emissions reported for Etna. This emission is responsible for 23% of all sulphur deposition in Italy and 17% in Albania. Turkey and the Mediterranean Sea are the main receivers of nitrogen and sulphur emissions from Cyprus. The deposition from Cyprus to itself is rather low due to its small receptor area. Cyprus also experiences deposition of oxidised sulphur and nitrogen from Turkey and Greece, but the largest contribution is of indeterminate origin.

In the present section the country-allocated depositions over 11 years are summarised as the average percentage contributions by each country to total deposition of pollutants in each country (Tables 5.2-5.4). The region codes are listed in Table 5.1. The area of the former Czechoslovakia, the former USSR, Cyprus, the Black Sea, and the Mediterranean Sea

comprised in the Table 5.1 do not appear in Tables 5.3-5.5 of this chapter, but they are included into the Country to Country allocated deposition matrices in Appendix B, Part 2.

Table 5.1 Emitting regions displayed, and their identifying codes.

Albania	AL	Norway	NO
Austria	AT	Poland	PO
Belarus	BY	Portugal	PT
Belgium	BE	Romania	RO
Bosnia and Herzegovina	BA	Russian Federation (European part)	RU
Bulgaria	BG	Slovakia	SK
Croatia	HR	Slovenia	SI
Czech Republic	CS*	Spain	ES
Czechoslovakia	CS	Sweden	SE
Denmark	DK	Switzerland	CH
Estonia	EE	Turkey	TR
Finland	FI	Ukraine	UA
France	FR	United Kingdom	GB
Germany	DE*	former USSR (European part)	SU
Greece	GR	Yugoslavia	YU
Hungary	HU	Cyprus	CY
Iceland	IS	remaining Land Areas & volcanoe	REM
Ireland	IE	the Baltic Sea	BAS
Italy	IT	the Black Sea	BLS
Latvia	LV	the Mediterranean Sea	MED
Lithuania	LT	the North Sea	NOS
Luxembourg	LU	the remaining N.E.Atlantic Ocean	ATL
the Former Yugoslav Republic of Macedonia	FYM	Natural marine sources	NAT
Republic of Moldova	MD	Total inattributable sources	IND
Netherlands	NL	Total attributable sources	SUM

Local dry deposition of SO_2 and NH_3 are accounted for by the local sub-grid deposition factor. It results in rather large portions of indigenous (country to itself) deposition in total deposition of these species. For sulphur oxides (Table 5.2) indigenous depositions constitute a major part of the total depositions in the United Kingdom (78%), Spain (67%), Germany (59%), and Bulgaria(55%). Indigenous depositions of reduced nitrogen (Table 5.4) are even more important and exceed practically all the other single contributions. It was found that for 26 of 39 country-emittors of ammonia more than a half of deposition is caused by their own emissions. In contrast, transboundary influence appears more significant in the case of oxidised nitrogen (Table 5.3).

All in all, the relative contributions of the individual countries to each other represent the attributable portion of the modelled acidifying pollutants. Pollutants transferred from the

boundary layer to the free troposphere and out of the lateral boundaries represent loss of attributable fraction from the computation domain. The fraction of the deposition of indeterminate origin (IND) comprise the pollutants which cannot be attributed to any particularly country. The indeterminate deposition of sulphur are mainly due to European anthropogenic emissions earlier transported out of the boundary layer and re-entering it. Therefore, it was suggested (Tarrason, 1992; Tarrason and Iversen, 1992) that 2/3 of indeterminate deposition may be re-allocated to each emission area proportionally to the existing relative contribution to a receiver. Re-allocation was performed for scaled depositions for 1985-94 for both sulphur and nitrogen compounds. Contributions from indeterminate sources can vary considerably depending on the compound and receiving area. However, depositions of indeterminate origin are generally more important for oxidised nitrogen and sulphur than for reduced nitrogen. From all the countries Island is the most influenced by this kind of pollution: nearly a half (45-47%) of all imported depositions of sulphur oxides and nitrogen cannot be allocated to any country within the EMEP modelling domain. Other countries, where depositions of indeterminate origin play a considerable role, are, for example, Turkey (41% of oxidised nitrogen and 37% of oxidised sulphur deposition), Albania (23 and 20%), Greece (25 and 18%), Russian Federation (24 and 23%). As discussed in chapter 6 the indeterminate part of the deposition is considerably reduced when a multi-level model is used for the source-receptor calculations. This is more pronounced for sulphur and reduced nitrogen than for the oxidised nitrogen compounds.

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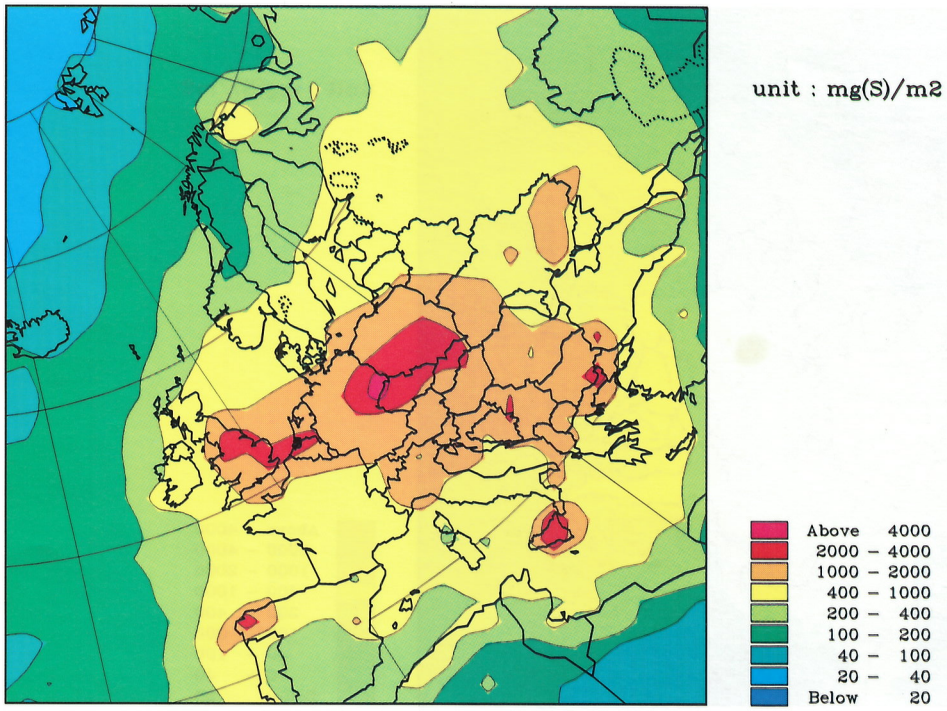

Fig.5.1. Total deposition of oxidised sulphur in 1995

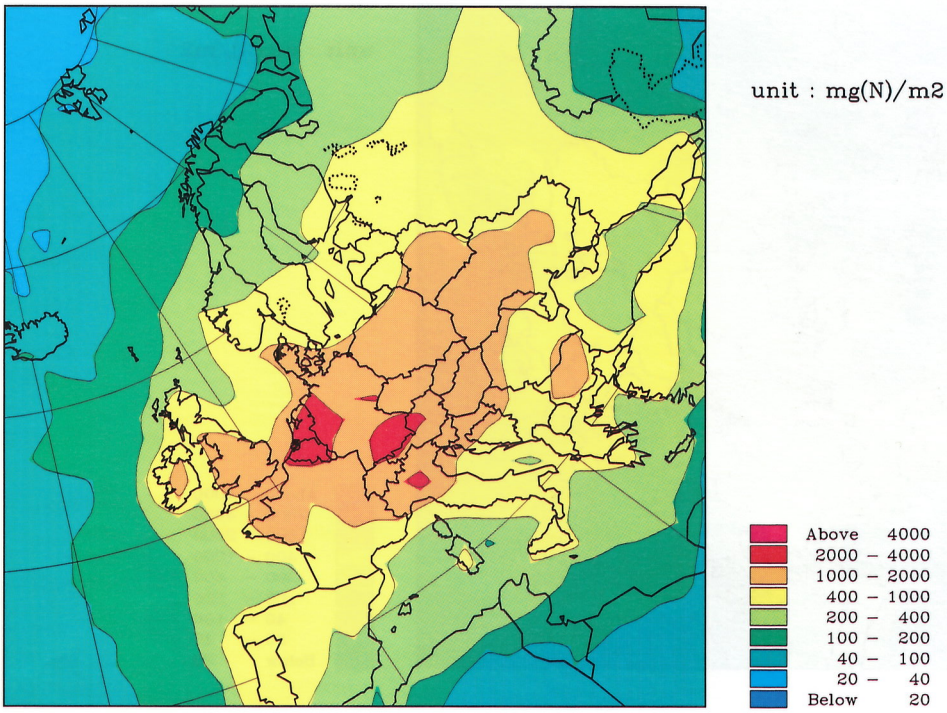

Fig.5.2. Total deposition of nitrogen in 1995

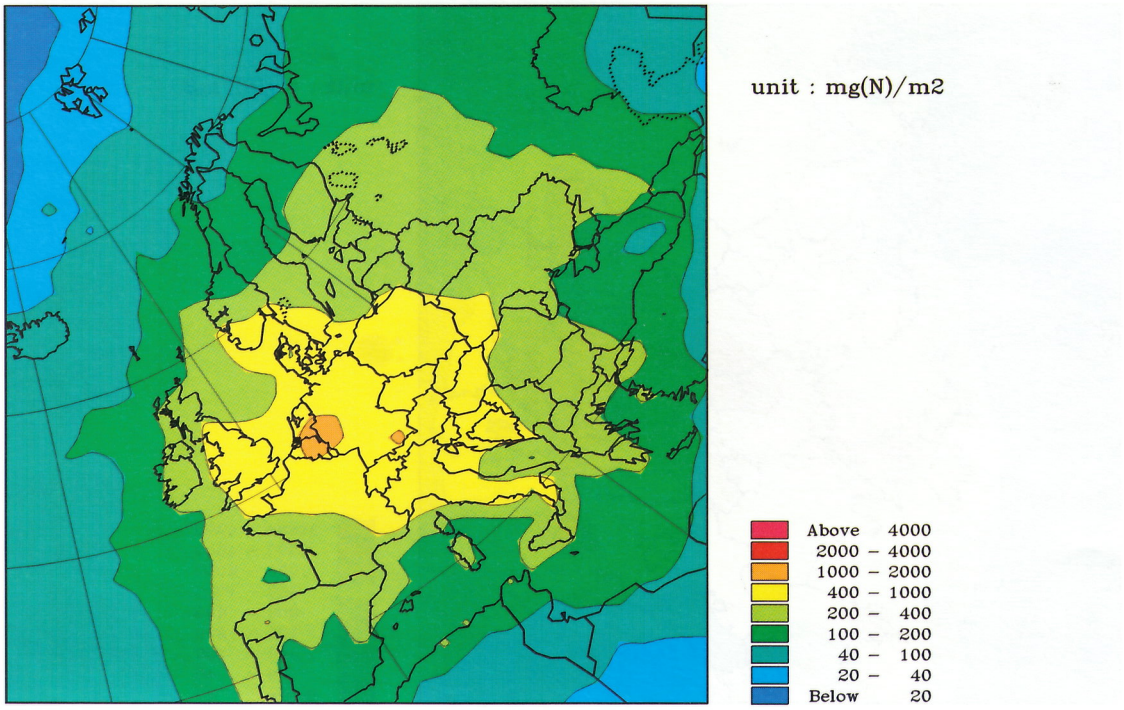

Fig.5.3. Total deposition of oxidised nitrogen in 1995

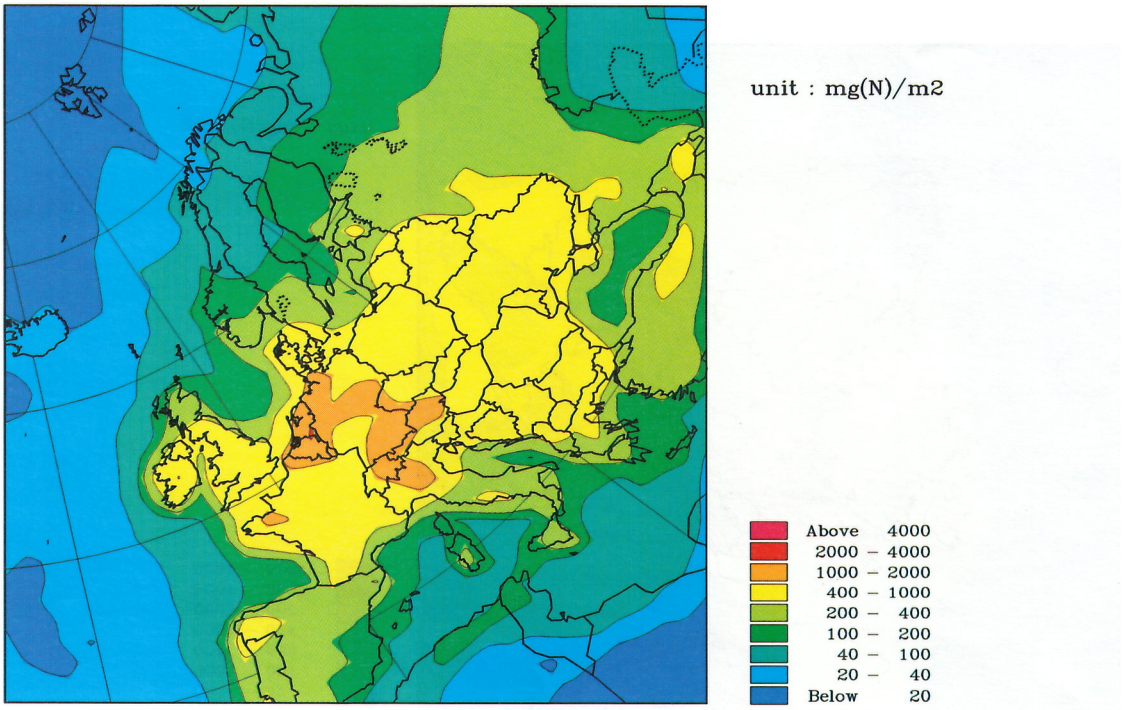

Fig.5.4. Total deposition of reduced nitrogen in 1995

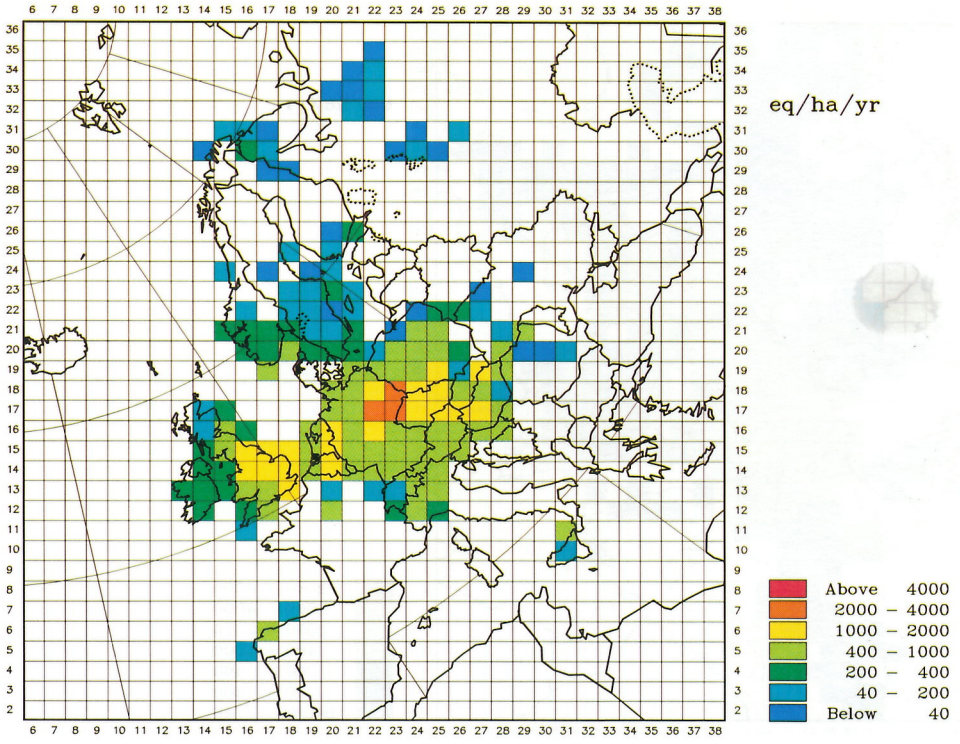

Fig.5.5. Exceedance of the 5 percentile conditional critical loads for sulphur (CL(S|Ndep95)). Source of critical loads: CCE

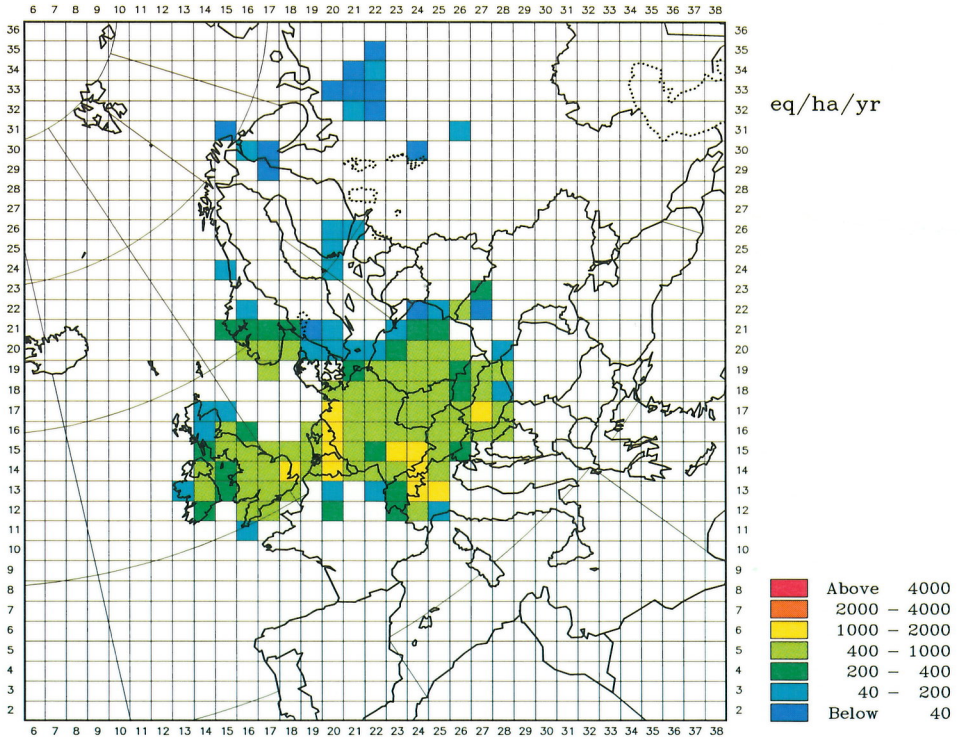

Fig.5.6. Exceedance of the 5 percentile conditional critical loads for acidifying nitrogen (CL(N|Sdep95)). Source of critical loads: CCE

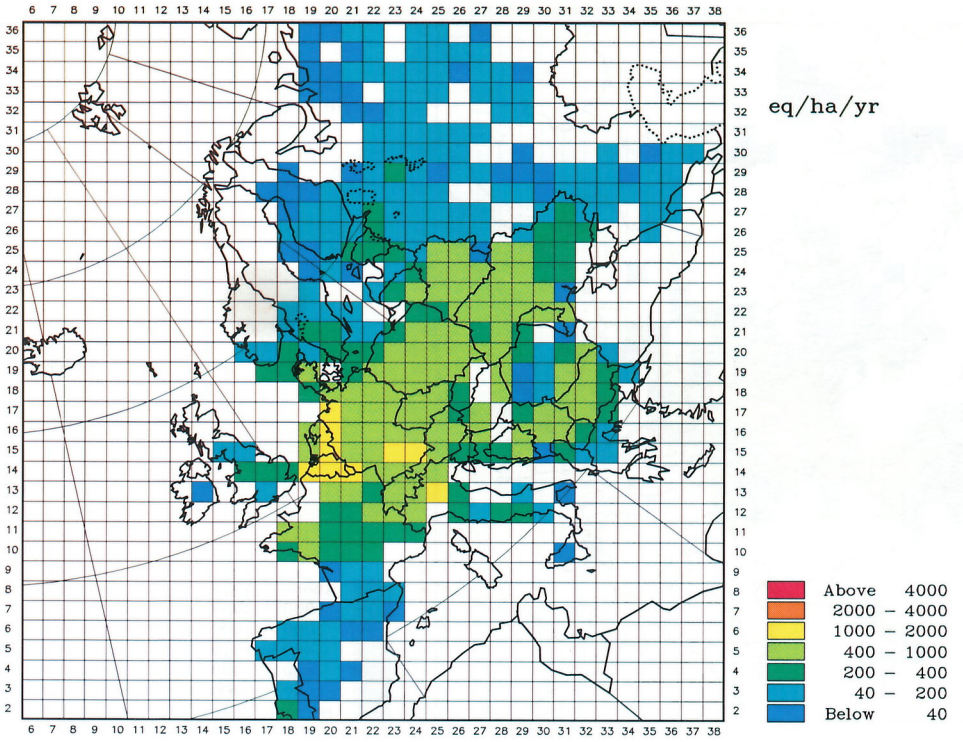

Fig.5.7. Exceedance of the 5 percentile critical loads for eutrophying nitrogen (CL(Nut)),1995. Source of critical loads: CCE

Table 5.2. Percentage contributions by modelled emission sources to total deposition of oxidised sulphur in each country, 1985-95 inclusive.

Percentage of total deposition received by each country/ area allocated between the contributing regions. SUM denotes the totals as 1000's tonnes of S. Two thirds of the indeterminate deposition is re-allocated to emitting areas.

Sources of Sulphur Emission

Areas receiving Sulphur deposition		AL	AT	BE	BG	DK	FI	FR	DE*	GR	HU	IS	IE	IT	LU	NL	NO	PL	PT	RO	ES	SE	CH	TR	
	AL	13	0	0	9	0	0	1	3	9	3	0	0	10	0	0	0	2	0	2	1	0	0	0	AL
	AT	0	6	1	1	0	0	4	25	0	5	0	0	8	0	0	0	7	0	1	1	0	1	0	AT
	BE	0	0	27	0	0	0	17	19	0	0	0	0	0	0	4	0	1	0	0	1	0	0	0	BE
	BG	0	0	0	55	0	0	0	3	1	3	0	0	1	0	0	0	2	0	10	0	0	0	0	BG
	DK	0	0	2	0	17	0	3	25	0	1	0	0	0	0	1	0	7	0	0	0	1	0	0	DK
	FI	0	0	0	0	1	17	1	9	0	1	0	0	0	0	0	0	8	0	1	0	2	0	0	FI
	FR	0	0	3	0	0	0	33	12	0	1	0	0	4	0	1	0	2	0	0	9	0	0	0	FR
	DE*	0	0	3	0	1	0	5	59	0	1	0	0	1	0	1	0	4	0	0	1	0	0	0	DE*
	GR	1	0	0	30	0	0	1	2	18	2	0	0	3	0	0	0	2	0	4	0	0	0	1	GR
	HU	0	1	0	1	0	0	1	9	0	41	0	0	3	0	0	0	8	0	5	0	0	0	0	HU
	IS	0	0	0	0	0	0	1	4	0	0	12	1	0	0	0	0	1	0	0	1	0	0	0	IS
	IE	0	0	1	0	0	0	2	5	0	0	0	28	0	0	0	0	1	0	0	1	0	0	0	IE
	IT	0	1	0	1	0	0	4	5	0	2	0	0	40	0	0	0	2	0	1	2	0	1	0	IT
	LU	0	0	6	0	0	0	30	24	0	0	0	0	1	7	2	0	2	0	0	3	0	0	0	LU
	NL	0	0	9	0	0	0	7	25	0	0	0	0	0	0	15	0	2	0	0	1	0	0	0	NL
	NO	0	0	1	0	2	1	2	15	0	1	0	1	0	0	1	4	6	0	0	0	2	0	0	NO
	PL	0	0	0	0	1	0	1	28	0	2	0	0	0	0	0	0	43	0	1	0	0	0	0	PL
	PT	0	0	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0	38	0	26	0	0	0	PT
	RO	0	0	0	8	0	0	0	6	0	9	0	0	1	0	0	0	7	0	34	0	0	0	0	RO
	ES	0	0	0	0	0	0	3	2	0	0	0	0	1	0	0	0	0	4	0	67	0	0	0	ES
	SE	0	0	1	0	5	3	2	20	0	1	0	0	0	0	1	1	11	0	1	0	8	0	0	SE
	CH	0	1	1	0	0	0	15	14	0	1	0	0	23	0	1	0	2	0	0	3	0	9	0	CH
	TR	0	0	0	13	0	0	0	2	3	2	0	0	1	0	0	0	3	0	4	0	0	0	17	TR
	GB	0	0	1	0	0	0	2	4	0	0	0	1	0	0	1	0	1	0	0	1	0	0	0	GB
	BY	0	0	0	1	0	0	1	12	0	3	0	0	1	0	0	0	21	0	2	0	0	0	0	BY
	UA	0	0	0	3	0	0	0	7	0	4	0	0	1	0	0	0	13	0	4	0	0	0	0	UA
	MD	0	0	0	6	0	0	0	6	0	4	0	0	1	0	0	0	10	0	13	0	0	0	0	MD
	RU	0	0	0	1	0	1	0	4	0	1	0	0	0	0	0	0	5	0	1	0	0	0	0	RU
	EE	0	0	0	0	1	5	1	12	0	1	0	0	0	0	0	0	12	0	1	0	2	0	0	EE
	LV	0	0	1	1	1	1	1	16	0	2	0	0	0	0	0	0	18	0	1	0	1	0	0	LV
	LT	0	0	1	1	1	0	1	16	0	2	0	0	0	0	0	0	23	0	1	0	1	0	0	LT
	SI	0	2	0	1	0	0	2	9	0	6	0	0	14	0	0	0	5	0	1	1	0	0	0	SI
	HR	0	1	0	2	0	0	2	9	0	12	0	0	12	0	0	0	7	0	2	1	0	0	0	HR
	BA	0	0	0	2	0	0	1	6	1	7	0	0	7	0	0	0	4	0	2	1	0	0	0	BA
	YU*	1	0	0	6	0	0	1	6	1	9	0	0	4	0	0	0	4	0	5	0	0	0	0	YU*
	FYM	4	0	0	21	0	0	1	3	8	4	0	0	4	0	0	0	2	0	4	0	0	0	0	FYM
	CS*	0	1	1	0	0	0	1	34	0	2	0	0	1	0	0	0	10	0	0	0	0	0	0	CS*
	SK	0	1	0	1	0	0	1	13	0	17	0	0	2	0	0	0	18	0	2	0	0	0	0	SK
	REM	0	0	0	1	0	0	1	1	0	0	0	0	2	0	0	0	1	0	0	2	0	0	0	REM
	BAS	0	0	1	0	5	4	2	25	0	1	0	0	1	0	1	0	17	0	1	0	3	0	0	BAS
	NOS	0	0	2	0	1	0	5	13	0	0	0	1	0	0	3	0	3	0	0	1	0	0	0	NOS
	ATL	0	0	1	0	0	0	3	4	0	0	0	2	0	0	1	0	1	1	0	11	0	0	0	ATL
	MED	0	0	0	6	0	0	4	4	4	2	0	0	15	0	0	0	2	0	2	5	0	0	1	MED
	BLS	0	0	0	19	0	0	0	4	1	3	0	0	1	0	0	0	5	0	7	0	0	0	3	BLS
		AL	AT	BE	BG	DK	FI	FR	DE*	GR	HU	IS	IE	IT	LU	NL	NO	PL	PT	RO	ES	SE	CH	TR	

Table 5.2. Percentage contributions by modelled emission sources to total deposition of oxidised sulphur in each country, 1985-95 inclusive.
(continuation)

Sources of Sulphur Emission

	GB	BY	UA	MD	RU	EE	LV	LT	SI	HR	BA	YU*	FYM	CS*	SK	REM	BAS	NOS	ATL	NAT	IND	SUM		
AL	1	0	1	0	0	0	0	0	0	1	5	5	3	2	1	10	0	0	0	0	20	34	AL	
AT	3	0	1	0	0	0	0	0	5	1	1	1	0	13	3	1	0	1	0	0	13	150	AT	
BE	15	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	5	1	0	7	72	BE	
BG	0	0	3	1	0	0	0	0	0	0	1	4	1	1	1	1	0	0	0	0	9	225	BG	
DK	20	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	1	5	1	1	9	56	DK	A
FI	3	2	2	0	21	4	1	1	0	0	0	0	0	3	1	0	1	1	0	1	19	161	FI	r
FR	9	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	3	2	1	16	469	FR	e
DE*	6	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	2	0	0	6	984	DE*	a
GR	0	0	2	1	0	0	0	0	0	0	2	3	2	1	1	5	0	0	0	0	18	119	GR	s
HU	1	0	1	0	0	0	0	0	1	1	2	3	0	6	7	1	0	0	0	0	7	210	HU	
IS	13	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	2	15	45	10	IS	R
IE	31	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	7	4	16	41	IE	e
IT	1	0	0	0	0	0	0	0	2	1	2	1	0	2	1	16	0	0	0	0	16	376	IT	c
LU	8	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	1	0	11	5	LU	e
NL	23	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	7	1	0	6	85	NL	i
NO	18	0	1	0	7	0	0	0	0	0	0	0	0	3	0	0	0	3	1	2	27	135	NO	v
PL	2	0	1	0	0	0	0	0	0	0	0	0	0	10	2	0	0	1	0	0	5	1008	PL	i
PT	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	13	0	17	41	PT	n
RO	1	1	6	2	1	0	0	0	0	0	2	4	0	3	3	1	0	0	0	0	10	395	RO	g
ES	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	4	1	14	282	ES	
SE	10	1	1	0	5	1	0	1	0	0	0	0	0	4	1	0	1	2	1	1	19	226	SE	S
CH	4	0	0	0	0	0	0	0	1	0	0	0	0	3	0	1	0	1	1	0	19	50	CH	u
TR	0	1	7	1	1	0	0	0	0	0	1	1	0	1	1	3	0	0	0	0	37	214	TR	l
GB	78	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	2	1	6	432	GB	p
BY	2	20	8	1	4	1	0	3	0	0	0	1	0	5	2	0	0	0	0	0	12	297	BY	h
UA	1	2	40	2	4	0	0	0	0	0	0	1	0	3	2	0	0	0	0	0	11	901	UA	u
MD	1	1	20	16	2	0	0	0	0	0	1	1	0	3	2	0	0	0	0	0	12	45	MD	r
RU	1	4	11	0	40	2	0	1	0	0	0	0	0	1	0	1	0	0	0	0	23	2069	RU	
EE	3	3	3	0	7	22	2	3	0	0	0	0	0	4	1	0	1	1	0	0	14	51	EE	D
LV	4	5	3	0	5	2	7	9	0	0	0	0	0	5	1	0	1	1	0	0	14	74	LV	e
LT	3	3	3	0	4	1	1	20	0	0	0	0	0	5	1	0	1	1	0	0	11	98	LT	p
SI	1	0	1	0	0	0	0	0	33	3	2	1	0	5	2	1	0	0	0	0	11	44	SI	o
HR	1	0	1	0	0	0	0	0	3	10	9	4	0	6	3	2	0	0	0	0	13	85	HR	s
BA	1	0	1	0	0	0	0	0	1	3	37	5	0	4	2	3	0	0	0	0	12	90	BA	i
YU*	1	0	1	0	0	0	0	0	1	1	12	25	2	3	2	3	0	0	0	0	12	161	YU*	t
FYM	0	0	1	0	0	0	0	0	0	1	4	8	10	2	1	4	0	0	0	0	18	28	FYM	i
CS*	1	0	0	0	0	0	0	0	0	0	0	0	0	40	2	0	0	0	0	0	5	338	CS*	o
SK	1	0	1	0	0	0	0	0	1	1	1	1	0	11	21	0	0	0	0	0	6	138	SK	n
REM	1	1	6	0	9	0	0	0	0	0	0	0	0	1	0	31	0	0	0	0	42	428	REM	
BAS	7	1	2	0	4	2	1	2	0	0	0	0	0	5	1	0	3	2	0	1	11	436	BAS	
NOS	48	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	7	1	2	9	858	NOS	
ATL	15	0	0	0	7	0	0	0	0	0	0	0	0	1	0	0	0	1	11	10	30	1447	ATL	
MED	1	0	1	0	0	0	0	0	0	1	2	1	0	2	1	20	0	0	0	1	21	1207	MED	
BLS	0	1	22	2	3	0	0	0	0	0	1	1	0	2	1	2	0	0	0	0	20	361	BLS	
	GB	BY	UA	MD	RU	EE	LV	LT	SI	HR	BA	YU*	FYM	CS*	SK	REM	BAS	NOS	ATL	NAT	IND	SUM		

Table 5.3. Percentage contributions by modelled emission sources to total deposition of oxidised nitrogen in each country, 1985-95 inclusive.

Percentage of total deposition received by each country/ area allocated between the contribution regions. SUM denotes the totals as 1000's tonnes of S. Two thirds of the indeterminate deposition is re-allocated to emitting areas.

Sources of Oxidised Nitrogen Emission

		AL	AT	BE	BG	DK	FI	FR	DE*	GR	HU	IS	IE	IT	LU	NL	NO	PL	PT	RO	ES	SE	CH	TR	
A	AL	4	1	0	3	0	0	4	4	11	1	0	0	28	0	0	0	2	0	2	2	0	0	0	AL
r	AT	0	6	2	0	0	0	10	26	0	1	0	0	14	0	2	0	4	0	1	1	0	3	0	AT
e	BE	1	0	13	0	0	0	18	17	0	0	0	0	1	0	9	0	1	0	0	1	0	0	0	BE
a	BG	0	1	0	22	0	0	1	7	5	3	0	0	5	0	1	0	5	0	15	0	0	0	1	BG
s	DK	0	0	3	0	10	0	5	18	0	0	0	1	0	0	7	1	4	0	0	0	2	0	0	DK
	FI	0	0	1	0	3	16	2	10	0	0	0	0	0	0	2	3	7	0	0	0	9	0	0	FI
R	FR	0	0	3	0	0	0	33	11	0	0	0	0	5	0	3	0	1	1	0	6	0	1	0	FR
e	DE*	0	1	5	0	1	0	11	39	0	0	0	0	2	0	7	0	3	0	0	1	0	1	0	DE*
c	GR	1	1	0	10	0	0	3	4	21	1	0	0	11	0	1	0	3	0	5	1	0	0	2	GR
e	HU	0	4	1	1	0	0	4	14	0	12	0	0	11	0	1	0	9	0	5	0	0	1	0	HU
i	IS	0	3	1	0	1	0	3	5	0	0	5	1	0	0	3	1	1	0	0	0	1	0	0	IS
v	IE	0	0	2	0	0	0	6	6	0	0	0	11	0	0	3	0	1	0	0	1	0	0	0	IE
i	IT	0	1	1	0	0	0	11	7	1	1	0	0	50	0	1	0	2	0	1	2	0	2	0	IT
n	LU	0	0	8	0	0	0	29	21	0	0	0	0	0	4	4	0	0	0	0	3	0	0	0	LU
g	NL	0	0	7	0	1	0	8	19	0	0	0	1	0	0	16	0	1	0	0	1	0	0	0	NL
	NO	0	0	2	0	4	1	3	12	0	0	0	1	0	0	4	9	3	0	0	0	5	0	0	NO
O	PL	0	1	2	0	2	0	4	25	0	1	0	0	2	0	3	0	24	0	1	0	1	0	0	PL
x	PT	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	23	0	19	0	0	0	PT
i	RO	0	1	1	5	0	0	2	8	1	5	0	0	5	0	1	0	9	0	23	0	0	0	0	RO
d	ES	0	0	1	0	0	0	8	3	0	0	0	0	2	0	1	0	0	6	0	45	0	0	0	ES
i	SE	0	0	2	0	6	4	3	14	0	0	0	0	0	0	4	5	6	0	0	0	12	0	0	SE
s	CH	0	1	2	0	0	0	24	14	0	0	0	0	20	0	2	0	1	0	0	2	0	11	0	CH
e	TR	0	0	0	5	0	0	1	4	6	1	0	0	3	0	0	0	3	0	4	0	0	0	12	TR
d	GB	0	0	2	0	1	0	5	6	0	0	0	2	0	0	3	0	1	0	0	1	0	0	0	GB
	BY	0	1	1	1	2	1	3	14	0	1	0	0	2	0	2	1	18	0	2	0	2	0	0	BY
N	UA	0	1	1	2	1	0	2	9	0	2	0	0	2	0	1	0	14	0	4	0	1	0	0	UA
i	MD	0	1	1	3	1	0	2	8	1	3	0	0	3	0	1	0	12	0	11	0	1	0	0	MD
t	RU	0	0	0	0	1	3	1	5	0	1	0	0	1	0	1	1	6	0	1	0	2	0	0	RU
r	EE	0	1	1	0	4	6	2	13	0	1	0	0	1	0	2	2	10	0	0	0	8	0	0	EE
o	LV	0	1	1	0	4	3	3	14	0	1	0	0	1	0	3	1	12	0	1	0	6	0	0	LV
g	LT	0	1	1	0	4	1	3	16	0	1	0	0	1	0	3	1	16	0	1	0	4	0	0	LT
e	SI	0	6	1	0	0	0	6	13	0	2	0	0	32	0	1	0	4	0	1	1	1	1	0	SI
n	HR	0	4	1	1	0	0	6	11	1	4	0	0	28	0	1	0	6	0	2	1	0	1	0	HR
	BA	0	2	1	1	0	0	5	9	1	4	0	0	27	0	1	0	5	0	2	1	0	1	0	BA
D	YU*	1	2	1	4	0	0	3	9	3	5	0	0	17	0	1	0	5	0	6	1	0	1	0	YU*
e	FYM	3	1	0	10	0	0	2	5	14	2	0	0	14	0	0	0	3	0	5	0	0	0	1	FYM
p	CS*	0	2	2	0	1	0	7	32	0	1	0	0	3	0	3	0	8	0	1	0	0	1	0	CS*
o	SK	0	4	1	1	1	0	4	17	0	7	0	0	6	0	2	0	16	0	2	0	0	1	0	SK
s	REM	0	0	0	0	0	0	4	3	1	0	0	0	5	0	1	0	2	0	1	4	0	0	0	REM
i	BAS	0	0	2	0	6	3	4	19	0	0	0	0	1	0	4	2	9	0	0	0	8	0	0	BAS
t	NOS	0	0	3	0	2	0	7	12	0	0	0	1	0	0	6	1	2	0	0	1	1	0	0	NOS
i	ATL	0	1	1	0	1	1	5	5	0	0	0	1	0	0	2	1	1	1	0	3	1	0	0	ATL
o	MED	0	1	1	2	0	0	11	6	4	1	0	0	26	0	1	0	2	0	1	7	0	1	1	MED
n	BLS	0	1	0	5	0	0	1	5	2	2	0	0	2	0	1	0	6	0	6	0	1	0	3	BLS
		AL	AT	BE	BG	DK	FI	FR	DE*	GR	HU	IS	IE	IT	LU	NL	NO	PL	PT	RO	ES	SE	CH	TR	

Table 5.3. Percentage contributions by modelled emission sources to total deposition of oxidised nitrogen in each country, 1985-95 inclusive.

(continuation)

Sources of Oxidised Nitrogen Emission

	GB	BY	UA	MD	RU	EE	LV	LT	SI	HR	BA	YU*	FY	CS*	SK	REM	BAS	NOS	ATL	IND	SUM		
AL	1	0	1	0	0	0	0	0	0	1	2	1	2	2	1	0	0	0	0	23	10	AL	
AT	4	0	0	0	0	0	0	0	1	1	0	0	0	7	1	0	0	2	1	11	68	AT	A
BE	20	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	9	3	7	32	BE	r
BG	1	1	5	1	2	0	0	0	0	1	1	2	1	3	2	0	0	1	0	16	36	BG	e
DK	26	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	9	2	8	27	DK	a
FI	7	2	2	0	7	2	1	2	0	0	0	0	0	2	0	0	2	3	1	17	7	FI	s
FR	11	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5	6	12	259	FR	
DE*	11	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5	1	7	346	DE*	R
GR	1	0	3	0	1	0	0	0	0	0	1	1	1	2	1	0	0	0	0	25	28	GR	e
HU	2	0	1	0	0	0	0	0	1	2	1	1	0	8	6	0	0	1	0	11	50	HU	c
IS	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	6	47	7	IS	e
IE	31	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5	14	20	20	IE	i
IT	2	0	0	0	0	0	0	0	1	1	1	0	0	2	1	0	0	1	1	14	149	IT	v
LU	11	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4	4	8	3	LU	i
NL	27	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	10	2	6	38	NL	n
NO	22	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	1	6	3	20	82	NO	g
PL	6	1	1	0	1	0	0	1	0	0	0	0	0	9	2	0	1	3	1	8	229	PL	
PT	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	25	26	21	PT	O
RO	2	1	6	1	2	0	0	0	0	1	1	1	0	5	4	0	0	1	0	13	87	RO	x
ES	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10	18	113	ES	i
SE	13	1	1	0	2	1	1	1	0	0	0	0	0	2	0	0	1	5	1	14	126	SE	d
CH	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	2	12	30	CH	i
TR	1	1	8	0	4	0	0	0	0	0	0	0	0	2	1	0	0	0	0	41	63	TR	s
GB	57	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	7	6	9	136	GB	e
BY	4	9	6	0	5	1	1	3	0	0	0	0	0	5	1	0	1	2	0	12	89	BY	d
UA	2	3	23	1	7	0	0	1	0	0	0	0	0	4	2	0	0	1	0	14	212	UA	
MD	2	2	17	4	4	0	0	1	0	0	0	0	0	4	2	0	0	1	0	15	10	MD	N
RU	2	3	8	0	32	1	1	1	0	0	0	0	0	2	1	1	1	1	0	24	668	RU	i
EE	8	2	2	0	5	5	3	3	0	0	0	0	0	3	1	0	2	3	1	13	19	EE	t
LV	8	3	2	0	3	2	4	5	0	0	0	0	0	4	1	0	2	3	1	12	28	LV	r
LT	7	3	2	0	3	1	2	8	0	0	0	0	0	4	1	0	1	3	1	11	33	LT	o
SI	2	0	0	0	0	0	0	0	5	2	1	0	0	5	2	0	0	1	1	12	14	SI	g
HR	2	0	1	0	0	0	0	0	1	4	3	1	0	5	2	0	0	1	0	13	28	HR	e
BA	2	0	1	0	0	0	0	0	1	3	6	2	0	5	2	0	0	1	0	16	24	BA	n
YU*	2	0	1	0	0	0	0	0	0	2	3	5	2	5	2	0	0	1	0	17	38	YU*	
FYM	1	0	2	0	0	0	0	0	0	1	2	3	5	2	2	0	0	0	0	22	7	FYM	D
CS*	5	0	0	0	0	0	0	0	0	0	0	0	0	20	1	0	0	2	1	8	73	CS*	e
SK	3	0	1	0	0	0	0	0	1	1	0	0	0	12	9	0	0	1	0	9	34	SK	p
REM	2	1	4	0	13	0	0	0	0	0	0	0	0	1	0	3	0	1	1	52	130	REM	o
BAS	12	1	1	0	2	1	1	1	0	0	0	0	0	3	1	0	2	5	1	10	167	BAS	s
NOS	39	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	9	4	10	318	NOS	i
ATL	17	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	4	15	38	668	ATL	t
MED	2	0	1	0	0	0	0	0	0	1	1	0	0	2	1	0	0	1	1	24	335	MED	i
BLS	1	1	19	1	11	0	0	0	0	0	0	0	0	3	1	1	0	1	0	25	74	BLS	o
	GB	BY	UA	MD	RU	EE	LV	LT	SI	HR	BA	YU*	FY	CS*	SK	IND	BAS	NOS	ATL	REM	SUM		

Table 5.4. Percentage contributions by modelled emission sources to total deposition of reduced nitrogen in each country, 1985-95 inclusive.

Percentage of total deposition received by each country/ area allocated between the contributing regions. SUM denotes the totals as 1000's tonnes of S. Two thirds of the indeterminate deposition is re-allocated to emitting areas.

Sources of Reduced Nitrogen

		AL	AT	BE	BG	DK	FI	FR	DE*	GR	HU	IS	IE	IT	LU	NL	NO	PL	PT	RO	ES	
A	AL	64	0	0	3	0	0	1	1	3	1	0	0	4	0	0	0	1	0	1	0	AL
r	AT	3	45	1	0	0	0	5	18	0	2	0	0	7	0	1	0	2	0	1	0	AT
e	BE	0	0	61	0	0	0	15	5	0	0	0	0	0	0	11	0	0	0	0	0	BE
a	BG	0	0	0	77	0	0	0	1	1	1	0	0	0	0	0	0	1	0	6	0	BG
s	DK	0	0	1	0	80	0	1	7	0	0	0	0	0	0	2	0	2	0	0	0	DK
	FI	0	0	0	0	2	35	1	6	0	1	0	0	0	0	2	1	7	0	1	0	FI
R	FR	0	0	2	0	0	0	81	3	0	0	0	0	2	0	1	0	0	0	0	2	FR
e	DE*	0	1	2	0	1	0	6	73	0	0	0	0	1	0	7	0	1	0	0	0	DE*
c	GR	2	0	0	10	0	0	1	1	56	1	0	0	2	0	0	0	1	0	3	0	GR
e	HU	0	2	0	1	0	0	1	3	0	66	0	0	2	0	0	0	3	0	4	0	HU
i	IS	0	0	1	0	0	0	4	4	0	0	29	3	0	0	2	0	1	0	0	0	IS
v	IE	0	0	0	0	0	0	2	1	0	0	0	88	0	0	1	0	0	0	0	0	IE
i	IT	0	1	0	0	0	0	3	2	0	1	0	0	79	0	0	0	1	0	0	1	IT
n	LU	0	0	6	0	0	0	21	7	0	0	0	0	0	55	2	0	0	0	0	0	LU
g	NL	0	0	4	0	0	0	3	6	0	0	0	0	0	0	82	0	0	0	0	0	NL
	NO	0	0	1	0	6	0	3	10	0	0	0	1	0	0	4	31	4	0	0	0	NO
R	PL	0	1	0	0	1	0	1	10	0	1	0	0	0	0	1	0	68	0	1	0	PL
e	PT	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	82	0	12	PT
d	RO	0	0	0	6	0	0	0	1	0	4	0	0	1	0	0	0	2	0	66	0	RO
u	ES	0	0	0	0	0	0	5	1	0	0	0	0	1	0	0	0	0	4	0	83	ES
c	SE	0	0	1	0	9	2	2	11	0	1	0	1	0	0	3	2	7	0	1	0	SE
e	CH	0	1	1	0	2	0	16	8	0	0	0	0	10	0	1	0	0	0	0	1	CH
d	TR	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	1	0	2	0	TR
	GB	0	0	1	0	0	0	4	2	0	0	0	5	0	0	2	0	1	0	0	0	GB
N	BY	0	0	0	0	0	0	1	3	0	1	0	0	0	0	1	0	8	0	1	0	BY
i	UA	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	4	0	3	0	UA
t	MD	0	0	0	2	0	0	0	1	0	1	0	0	0	0	0	0	2	0	8	0	MD
r	RU	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	3	0	1	0	RU
o	EE	0	0	0	0	1	1	1	5	0	1	0	0	0	0	1	0	6	0	1	0	EE
g	LV	0	0	0	0	2	0	1	5	0	1	0	0	0	0	1	0	8	0	1	0	LV
e	LT	0	0	0	0	1	0	1	4	0	1	0	0	0	0	1	0	10	0	1	0	LT
n	SI	0	7	0	0	0	0	2	5	0	4	0	0	13	0	1	0	2	0	1	0	SI
	HR	0	3	0	1	0	0	2	4	0	9	0	0	11	0	1	0	3	0	2	0	HR
D	BA	1	1	0	1	0	0	2	3	0	6	0	0	8	0	0	0	2	0	2	0	BA
e	YU*	2	1	0	5	0	0	1	2	1	6	0	0	3	0	0	0	1	0	4	0	YU*
p	FYM	6	0	0	11	0	0	0	1	6	2	0	0	2	0	0	0	1	0	3	0	FY
o	CS*	0	4	1	0	0	0	3	21	0	1	0	0	1	0	2	0	7	0	1	0	CS*
s	SK	0	3	0	1	0	0	1	6	0	9	0	0	2	0	1	0	9	0	2	0	SK
i	REM	0	0	0	0	0	0	2	1	0	0	0	0	2	0	0	0	1	0	1	2	RE
t	BAS	0	0	1	0	11	2	3	21	0	1	0	0	0	0	4	0	14	0	1	0	BAS
i	NOS	0	0	4	0	7	0	18	14	0	0	0	3	0	0	12	1	3	0	0	1	NOS
o	ATL	0	0	1	0	1	0	14	4	0	0	0	9	0	0	2	1	1	3	0	5	ATL
n	MED	1	1	0	4	0	0	12	3	3	2	0	0	20	0	1	0	1	1	2	7	ME
	BLS	0	0	0	6	0	0	0	1	1	1	0	0	1	0	0	0	2	0	7	0	BLS
		AL	AT	BE	BG	DK	FI	FR	DE*	GR	HU	IS	IE	IT	LU	NL	NO	PL	PT	RO	ES	

Table 5.4. Percentage contributions by modelled emission sources to total deposition of reduced nitrogen in each country, 1985-95 inclusive.

(continuation)

Sources of Reduced Nitrogen

	SE	CH	TR	GB	BY	UA	MD	RU	EE	LV	LT	SI	HR	BA	YU*	FYM	CS*	SK	REM	IND	SUM		
AL	0	0	0	0	0	1	0	0	0	0	0	0	1	1	3	1	0	0	0	13	16	AL	A
AT	0	2	0	1	0	1	0	0	0	0	0	2	0	0	0	0	3	1	0	7	84	AT	r
BE	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	46	BE	e
BG	0	0	1	0	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	5	123	BG	a
DK	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	57	DK	s
FI	3	0	0	1	4	3	0	9	3	2	2	0	0	0	0	0	1	0	0	19	48	FI	
FR	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	390	FR	R
DE*	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	457	DE*	e
GR	0	0	2	0	0	2	0	1	0	0	0	0	0	0	1	1	0	0	0	14	44	GR	c
HU	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	0	1	3	0	5	83	HU	e
IS	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	4	IS	i
IE	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	58	IE	v
IT	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	218	IT	i
LU	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	4	LU	n
NL	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	91	NL	g
NO	3	0	0	7	1	1	0	1	0	0	1	0	0	0	0	0	1	0	0	23	47	NO	
PL	0	0	0	1	1	2	0	1	0	0	1	0	0	0	0	0	2	1	0	5	291	PL	R
PT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	37	PT	e
RO	0	0	0	0	1	6	1	1	0	0	0	0	0	0	1	0	0	1	0	6	195	RO	d
ES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	167	ES	u
SE	33	0	0	3	2	2	0	2	1	1	1	0	0	0	0	0	1	0	0	16	78	SE	c
CH	0	55	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	45	CH	e
TR	0	0	72	0	0	4	0	1	0	0	0	0	0	0	0	0	0	0	0	15	161	TR	d
GB	0	0	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	163	GB	
BY	0	0	0	0	59	9	0	3	0	1	3	0	0	0	0	0	1	0	0	7	166	BY	N
UA	0	0	1	0	3	73	1	4	0	0	1	0	0	0	0	0	0	1	0	6	490	UA	i
MD	0	0	0	0	1	19	55	2	0	0	0	0	0	0	0	0	0	0	0	5	27	MD	t
RU	0	0	1	0	3	8	0	61	1	1	1	0	0	0	0	0	0	0	0	16	850	RU	r
EE	2	0	0	1	4	3	0	4	48	5	4	0	0	0	0	0	1	0	0	10	21	EE	o
LV	1	0	0	1	7	4	0	3	3	39	11	0	0	0	0	0	1	0	0	9	32	LV	g
LT	1	0	0	1	6	3	0	2	0	2	59	0	0	0	0	0	1	0	0	6	51	LT	e
SI	0	1	0	0	0	1	0	0	0	0	19	51	2	1	1	0	1	1	0	8	18	SI	n
HR	0	0	0	0	0	1	0	0	0	0	0	2	42	4	2	0	1	2	0	11	31	HR	
BA	0	0	0	0	0	1	0	0	0	0	0	1	6	46	5	0	1	1	0	13	27	BA	D
YU*	0	0	0	0	0	2	0	0	0	0	0	0	1	2	58	1	1	1	0	10	63	YU*	e
FYM	0	0	1	0	0	1	0	0	0	0	0	0	0	1	7	45	0	0	0	12	12	FYM	p
CS*	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	48	1	0	6	73	CS*	o
SK	0	0	0	0	0	3	0	0	0	0	0	1	1	0	1	0	4	48	0	7	40	SK	s
REM	0	0	4	0	1	4	0	16	0	0	0	0	0	0	0	0	0	0	30	34	109	REM	i
BAS	6	0	0	3	3	3	0	3	2	2	3	0	0	0	0	0	1	0	0	13	105	BAS	t
NOS	1	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	12	160	NOS	i
ATL	0	0	0	11	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	42	283	ATL	o
MED	0	1	4	1	0	2	0	0	0	0	0	0	1	1	1	0	1	0	1	30	194	MED	n
BLS	0	0	15	0	2	29	2	10	0	0	0	0	0	0	1	0	0	0	1	20	93	BLS	
	SE	CH	TR	GB	BY	UA	MD	RU	EE	LV	LT	SI	HR	BA	YU*	FYM	CS*	SK	REM	IND	SUM		

Chapter 6

SOURCE-RECEPTOR CALCULATIONS FOR ACIDIFYING COMPOUNDS BY USE OF THE MULTI-LAYER MODEL WITH 50KM RESOLUTION

6. Source - Receptor Calculations for Acidifying Compounds by use of the multi- layer model with 50km resolution.

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6.1 Introduction

In this report we are for the first time able to present a complete year (1992) calculations of source-receptor relationships in the 50 km grid obtained by use of the multi-layer model. We have therefore devoted this chapter mainly to a discussion of the new results. As pointed out earlier in this report, considerable updates of the emission data took place at MSC-W until the end of March. Due to a period of 8 to 12 weeks for the model runs, only a rather preliminary discussion of the new data was possible here. A comparison with the 150 km lagrangian model that up to present has delivered the official transfer matrices from MSC-W, is given. Since the 150 km lagrangian model has been evaluated rather extensively (see for example Barrett et al., 1995) we focus the discussion of the multi-layer model on a model intercomparison and comparisons with observational data for 1992. The validation of the results for the lagrangian 150 km model were given in last year's report. Frequent references will thus be made both to the chapter on model validation in last years report (Berge et al. (1995)) and to this years report (part 2) for source receptor relationships calculated with the lagrangian model and scaled in accordance with the new emission updates (as described in chapter 5).

The multi-layer acid deposition model for Europe has been developed primarily aiming at (1) taking better into account the physical processes with a vertical dependence (topographical effects, vertical distribution of the emissions, clouds etc.) and (2) coupling of acidification and photo-oxidants in particular through the cloud processes. When changing from the EMEP lagrangian models to an eulerian model with 50 km, additional advantages can be obtained. A finer resolution than 150km should ideally include several layers in the vertical since the assumption that the air pollutants are well mixed up to the top of the boundary layer height in a single layer model is less valid when the horizontal dimension of the grid-square is reduced. A multi-layer model will also be able to allocate the part of the emitted pollutants that is transported above the Planetary Boundary Layer (PBL) and deposited within the modelling domain. This part of the transport can not be specifically allocated in a single layer model. Finally, the multi-layer model is fully operational and contains the necessary technical features for long-range calculations. As the physical and chemical parameterizations of the model are developed the operational capabilities of the model are maintained.

A short description of the eulerian 50 km model is given in Sections 6.2.

6.2 The eulerian multi-layer model.

The eulerian multi-layer model, henceforth denoted MADE-50 (MADE = Multi-level Acid Deposition model for Europe) was initially developed for sulphur (Berge, 1993a, Jakobsen et al., 1995), but it has been extended to include nitrogen components (Jonson and Berge, 1995). The transport scheme for the chemical components is based on the Bott advection routine (Bott, 1989) in the horizontal directions, while in the vertical direction the upwind scheme is applied. Vertical diffusion is calculated through vertical eddy diffusivities derived from Louis et al. (1981). For dry deposition a resistance analogy is used (see Jakobsen et al., 1996 and Jakobsen et al., 1997). The sub-cloud scavenging of the gaseous species is based on scavenging coefficients (see Jakobsen at al., 1995). The in-cloud scavenging of gases and particles, and sub-cloud scavenging of particles, are calculated based on the parameterization scheme described by Berge (1993b). The chemistry follows Hov et al. (1988) with some modifications of the night time conversion from NO_2 to nitrate and an inclusion of the effect of the clouds on the sulphur chemistry in the air (see Jakobsen et al., 1996 and Jakobsen et al., 1997). The model is fully parallelized for massive parallel computers (see Skålin et al., 1995).

6.3 Comparison of model results and measurements.

6.3.1 Annual scatter plots.

The model comparison is focused on the annual results for 1992 and the measured data are based on the stations selected in accordance with the procedure used last year (EMEP Report 1/96). For the wet deposition estimates the requirement that the measurements should cover at least 25% of the days with model data has been used. Results are presented in so-called scatter plots. A perfect fit of the data follows the central line. The two other lines represents a factor of two deviation between the model and the observation. The definition of the statistical measures employed is found in Jakobsen et al. (1995).

For the components in air the differences between the MADE-50 and the ROOT-150 are small (see Jakobsen et al., 1997). Last year larger differences were found at some stations for SO_2 and total nitrate in air. A large underestimation was revealed for SO_2 at the surface layer in the MADE-50 . In last years report this was related to the inaccurate parameterization of the surface resistances in the dry deposition module and thus to the dry deposition fluxes. Jakobsen et al. (1997) describe how this scheme has been improved. The new results obtained this year are in better agreement with the measurements and the lagrangian model. However, both models still overestimate total nitrate in air. For NO_2, sulphate in air, ammonia and ammonium in air the differences between the two models are smaller.

In Figs. 6.1 to 6.3 the accumulated wet deposition of oxidised sulphur and oxidised and reduced nitrogen for the two models are compared with observations. In general MADE-50 gives accumulated wet depositions in reasonable agreement with the measurements. However, in general there is an underestimation of the wet deposition for all compounds. In the revised version of the wet deposition scheme (Jakobsen et al., 1997) the effectiveness of the sub-cloud scavenging of particles have been reduced. Physically, this sub-cloud scavenging should now be more realistic. Still, this has reduced the wet deposition fluxes somewhat compared to earlier calculations. Further studies and development of the wet scavenging model will be conducted.

6.4 Total deposition figures and source-receptor relationships.

6.4.1 Total depositions and exceedances of the conditional critical loads.

In Figs. 6.4 to 6.7 the total deposition of sulphur, reduced nitrogen and oxidised nitrogen species from MADE-50 are presented together with the exceedance of the critical loads of acidifying sulphur and nitrogen. Compared to the results reported last year, the new MADE-50 results show that the depositions are adjusted in reasonable accordance with the updates in the emission estimates. For oxidised sulphur the total deposition calculated with MADE-50 is very similar to the results obtained with the lagrangian 150 km model. It should however be expected that compared to the ROOT-150 model results, smaller scale features are apparent in the 50 km model results. In addition, the minor differences that can be seen on the figures 6.4. to 6.6 compared to last years result are to a great extent caused by the emission updates reported by the parties since last year. The largest discrepancies are located in the areas of the English channel and in the south of Italy due to the large updates in emission in these areas. For reduced nitrogen the discrepancies between the results from the two models are larger. The depositions in the eastern Europe, especially in the Ukraine and Belarus areas, are much larger for the lagrangian model results reported last year compared to the MADE-50 results. As described in chapter 5, corrections have been implemented in the post processing algorithms for the local part of the lagrangian model depositions. The modified algorithms applied to the lagrangian 150 km model data this year give better agreement with the eulerian model estimates (not shown). Also, the lagrangian 50 km model results reported last year are in good agreement with the MADE-50 results for these species. For oxidised nitrogen the differences between the lagrangian 150 km and the MADE-50 model plots are small. Only minor differences can be seen mostly due to the emission updates performed this year. The largest updates were made in the English channel and in the south of Italy as described in chapter 3.

This year conditional critical loads for acidifying sulphur and nitrogen have been prepared in the 50 km EMEP grid (Maximillian Posch; Personal communication, 1997). Based on these estimates we present examples on exceedance and compare with the corresponding data from the 150 km lagrangian model. Figs. 6.7 a and b show the exceedance of the 5 percentile conditional critical load for acidifying sulphur, CL(S|Ndep92), and acidifying nitrogen, CL(N|Sdep92) in the 50km grid. The corresponding figures in the 150 km grid is given in Figs. 6.8 a and b. Qualitatively, the exceedances maps are very similar for sulphur. The exceedances in the 50km grid become, however, more concentrated in smaller areas than in the 150km grid. For acidifying nitrogen the differences are larger. In particular over Poland, southern Germany and over the Alps much less exceedances are encountered by use of the 50km model. Further investigations for a better understanding of these differences are needed.

In chapter 5, the corresponding plots for 1995 in the 150 km grid are given showing similar pictures as have been discussed here for 1992.

6.4.2 The source receptor matrices.

In order to enable country allocation estimates, the MADE-50 model has been run with the individual emissions for most emitting regions listed in table 5.1. Only a few land or sea areas have been lumped together in the MADE-50 calculations to reduce the computational demand. These are: The Remaining Sea Areas (RSA) which consist of The Caspian sea, The Black sea (BLS) and The Mediterranean (MED). The Russian Federation (RU) which consists of Kola/Karelia, Leningrad/Novgo Pskov, Kalingrad and Rest of Russia. The Remaining land areas (REM) which consist of Kazachstan, Georgia, Africa and Natural land emissions from Italy. Inattributable sources (IND) are due to the boundary conditions. Imbedded in this approach (i.e. running the MADE-50 model for each country at the time) is the assumption that the possible non-linearities in the chemistry scheme are negligible, as discussed by Hass et al., 1996. To evaluate the of non-linearity problem the sum of the individual runs for each of the countries are compared to the results for a total run with all emissions included. The deviation of the total depositions in the calculation domain were found to be less than 3% for oxidised nitrogen, less than 2% for reduced nitrogen and less than 0.5% for sulphur. The variations in the percentage may indicate the influence of the non-linearities for the various species.

The source receptor matrices for oxidised sulphur and oxidised and reduced nitrogen for all years are presented in part 2 of this report. The data is based on calculations with the ROOT-150. This year we are also able to present source receptor matrices for 1992 based on the MADE-50 for all components (tables 6.1, 6.2 and 6.3). Some important differences are found between the source receptor matrices of the ROOT-150 and MADE-50. Maybe the most important feature is that the indeterminate contributions are much lower in MADE-50 for all species.

As can easily been seen, for many of the individual countries the depositions are changed markedly due to large updates in the emission data since last year. For example the NO_x emissions from Germany (DE*), Latvia (LV) and Lithuania (LT) are reduced by 20 to 50% while the emissions from BA, CS*, NOS and ATL are increased by 50 to several hundred percent. Also for oxidised sulphur and reduced nitrogen several large emission updates exist, as described in chapter 3.

In the ROOT-150 calculations it is not possible to keep track of the origin of the mass after it is transported through the top of the PBL to the free troposphere. A fraction of this mass will return and be deposited within the domain of calculations, and some will be lost through the lateral boundaries to other continents. Compared to MADE-50, ROOT-150 also estimate an indeterminate part of the depositions which originates from the upper boundary (top of the ABL) in addition to the contribution from the lateral boundaries. As a fraction of the total deposition we obtain an indeterminate contribution for respectively ox-S and ox-N of 19% and 20% for ROOT-150 and 6% and 16% for MADE-50. For reduced nitrogen the MADE-50 has been run without specifying any boundary values. Consequently, no estimate of the indeterminate could be made. But, due to the rather short lifetime of reduced nitrogen we would not expect any larger value than for sulphur (6%). The indeterminate part of the reduced nitrogen deposition from ROOT-150 is 13%. The lower percentage found for the MADE-50 calculations are mostly due to the multi-layer model keeping track of the mass transported above the atmospheric boundary layer, but also to some minor extent related to the different choice of boundary conditions. The MADE-50 results together with the official source-receptor matrix for 1992 from ROOT-150 show that the fraction of the source

allocated part of the depositions increases specially for sulphur by use of the MADE-50. This is however not so pronounced for oxidized nitrogen.

The contributions to the emitting countries themselves are generally decreased for sulphur and reduced nitrogen, while it is increased for oxidised nitrogen.

At distances beyond 1000-2000 km an increasing portion of the transport takes place above the Atmospheric boundary layer (ABL). It is therefore expected that when moving to a multi-layer approach the mass allocated to remote land areas will increase compared to the single layer model results. Comparing some of the data in tables 6.2, 6.3 and 6.4 with the corresponding results from the lagrangian 150 km model, we find that for sulphur emitted from for example GB a higher fraction of mass is allocated in remote areas. For example the contribution from GB to FI has been increased by about 150%, to NO with about 50% and about 130% to RU. The contributions from CH to FI, NO and RU have also increased, but the magnitude of these contributions are small. The contributions from the east European countries, for example PL to FI has increased by about 100%, to RU and NO the increases in the allocated mass contributions are about 50%. From RU to FI the contribution has increased by about 30% and to NO the contribution is increased by more than 150%. For sulphur the fraction of total mass allocated within the calculation domain is about 10% larger for the MADE-50 model compared to the ROOT-150 model results.

For reduced nitrogen the main trend is very similar to that of sulphur. For example, the GB contribution to FI is increased by about 80%, the contribution to NO is increased by about 50% and the contribution to RO is increased by about 25%. Also for these compounds the contributions from CH to FI, NO and RU have increased, but as for sulphur the magnitude of these contributions are small. The contributions from the east European countries, for example PL to FI has increased by about 90%, to RU and NO the increases in the allocated mass contributions are about 40%. From RU to FI the contribution has increased by about 50%. Also for reduced nitrogen, the fraction of total mass allocated within the calculation domain is about 10% larger for the MADE-50 model compared to the ROOT-150 model results. The authors' interpretation is thus, in line with the expectations, that the main reason for this trend is that contrary to the ROOT models, the MADE-50 model is capable of keeping track of the mass of the pollutants as they are transported above the ABL, advected in the free troposphere, and deposited far from its major sources.

On the other hand, for oxidised nitrogen this trend is not so pronounced. For this component there is a tendency of allocating a larger fraction of the emitted mass into the emitter country itself due to increased dry deposition fluxes. At the same time larger fractions of oxidised nitrogen are also transported out of the lateral boundaries and thus out of the calculation domain to other continents before it is deposited, probably due to the mass transport of the relatively longer lived oxidized nitrogen species in the higher air layers above the ABL, using the multi-layer approach. This means that at shorter transport distances the depositions have to be smaller at least in some areas since the total mass in the two model systems are the same. For oxidized nitrogen the contribution from GB to FI is reduced by about 10%, while the contributions to RU and NO are reduced by less than 5%. From PL the contribution to FI is increased by about 7%, while the contributions to NO and RU are reduced by 6% and 26%, respectively. The contributions from CH to FI, NO and RU have all increased by about 50%. Also the contributions from RU to FI and NO are increased. However, for oxidized nitrogen, the fraction of total mass allocated within the calculation domain is reduced by about 5% for

the MADE-50 model compared to the ROOT-150 model results. The more complex chemistry, its interactions with the transport processes and the life-times of the different NO_x compounds would need further examinations in order to better understand this issue.

At smaller distances from the emitters in central and northern Europe no pronounced trends have been found in the data for the sulphur species. For example, the sulphur transport from GB to the neighbouring countries BE and NL are reduced by 30% and 40%, respectively. The contribution from CH to AT is reduced by about 20%, while the contribution to DE has increased by more than 25%. For reduced nitrogen the transport seems to increase the contributions also for shorter range transport. For example, the dispersion of the emissions from GB to BE is increased by about 7%, the contribution to NL has increased by 30% and the contribution to DE has increased by about 10%. For oxidized nitrogen the contributions are reduced for shorter range transport. The contributions from GB to BE and NL have for example been decreased by about 20% and 10%, respectively. The transport from CH to AT and PL have decreased by about 45% and 15%, respectively.

6.5 Discussion and conclusions.

This year should be regarded as the first year for MSC-W moving from lagrangian 150 km to eulerian 50 km calculations of acid deposition in Europe. In the previous chapter we have presented the first results from our eulerian 50 km model for the whole 1992. The data has been compared with the measurements of the EMEP observational network and the well established 150km model. Source receptor matrices and total deposition fields based on the multi-layer eulerian approach have been presented. The 50km eulerian model (MADE-50) compares well with measurements and the results are consistent with the 150 km lagrangian model (ROOT-150). Total wet deposition of oxidised sulphur, oxidised nitrogen and reduced nitrogen are smaller than in the ROOT-150 model results and in the measurements. For components in air the variation from the one model to the other is small. The authors conclusion is that the model produces a reasonable picture of the depositions and concentrations in the 50 km grid for the sulphur and nitrogen components.

Comparing the source receptor matrices obtained by the lagrangian 150 km and the eulerian model, it is seen that substantial more of the emitted sulphur and reduced nitrogen pollutants are allocated within the model domain with the new model. A large part of the pollutants that are transported into the troposphere return to the surface within the modelling domain. Therefore, a larger part of the depositions can be allocated to the emitter. This trend is not so pronounced for oxidized nitrogen as for the other chemical species.

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Table 6.2 Source-receptor relationship for reduced nitrogen. Emitters along the abscissa and receivers along the ordinate.

	AL	AT	BE	BG	DK	FI	FR	DE*	GR	HU	IS	IE	IT	LU	NL	NO	PL	PT	RO	ES	SE	CH	TR	
AL	68	1	0	3	0	0	1	1	6	1	0	0	8	0	0	0	1	0	2	1	0	0	0	AL
AT	0	281	1	2	1	0	19	139	0	29	0	0	39	0	2	0	13	0	6	5	0	21	0	AT
BE	0	0	155	0	0	0	93	29	0	0	0	1	1	5	50	0	2	0	0	3	0	0	0	BE
BG	3	4	0	750	0	0	2	6	14	13	0	0	5	0	1	0	5	0	149	2	0	1	10	BG
DK	0	0	5	0	268	0	11	67	0	0	0	1	0	0	18	1	7	0	0	1	6	0	0	DK
FI	0	3	3	2	9	176	9	46	0	5	0	1	3	0	8	4	47	0	8	3	22	1	0	FI
FR	0	9	73	1	3	0	3073	150	0	5	0	7	106	9	48	1	16	9	3	166	1	36	0	FR
DE*	0	70	98	1	22	0	258	2466	0	9	0	4	16	20	336	0	79	1	5	18	2	56	0	DE*
GR	20	2	0	95	0	0	3	3	245	3	0	0	13	0	0	0	3	0	18	3	0	1	14	GR
HU	0	36	0	5	0	0	4	20	0	415	0	0	12	0	1	0	19	0	68	1	0	1	0	HU
IS	0	0	0	0	1	0	2	5	0	0	9	1	0	0	1	0	3	0	0	0	1	0	0	IS
IE	0	0	1	0	0	0	11	5	0	0	0	494	1	0	2	0	1	1	0	3	0	0	0	IE
IT	3	21	1	6	1	0	41	18	5	15	0	0	1475	0	1	0	11	3	7	43	0	38	1	IT
LU	0	0	4	0	0	0	11	6	0	0	0	0	0	8	1	0	0	0	0	0	0	0	0	LU
NL	0	0	72	0	1	0	35	85	0	0	0	1	1	1	490	0	2	0	0	2	0	0	0	NL
NO	0	2	6	0	28	3	23	53	0	2	0	5	3	0	18	92	14	1	1	5	17	2	0	NO
PL	1	18	9	6	22	1	30	375	0	37	0	2	9	1	23	2	1408	1	19	6	9	4	0	PL
PT	0	0	0	0	0	0	2	1	0	0	0	0	1	0	0	0	0	239	0	74	0	0	0	PT
RO	2	20	1	148	1	1	10	33	3	148	0	0	20	0	2	0	30	1	1398	5	1	3	4	RO
ES	0	2	3	1	0	0	75	12	0	1	0	1	19	0	3	0	2	71	1	1368	0	2	0	ES
SE	0	3	11	0	80	24	26	125	0	4	0	2	4	1	31	18	50	0	3	5	202	2	0	SE
CH	0	3	0	0	0	0	40	30	0	1	0	0	39	0	0	0	1	0	0	5	0	174	0	CH
TR	3	2	0	88	0	0	3	6	21	5	0	0	9	0	1	0	8	0	54	3	0	1	1573	TR
GB	0	1	12	0	4	0	92	37	0	1	0	118	2	1	21	1	9	2	1	14	1	1	0	GB
BY	0	5	2	6	4	3	7	39	0	12	0	0	5	0	4	1	144	0	24	2	3	2	2	BY
UA	2	12	3	54	4	2	15	64	5	59	0	0	14	0	5	1	228	1	230	6	3	3	27	UA
MD	0	0	0	6	0	0	1	2	0	2	0	0	1	0	0	0	7	0	72	0	0	0	1	MD
RU	3	19	7	69	25	67	41	146	7	34	0	2	27	1	24	8	242	1	147	17	30	8	95	RU
EE	0	1	0	1	3	4	2	10	0	2	0	0	1	0	1	0	17	0	2	0	4	0	0	EE
LV	0	1	1	1	5	2	3	19	0	2	0	0	1	0	3	0	32	0	3	1	5	0	0	LV
LT	0	2	1	1	6	1	5	27	0	3	0	0	1	0	4	0	65	0	4	1	4	1	0	LT
SI	0	17	0	1	0	0	2	4	0	9	0	0	31	0	0	0	2	0	2	1	0	1	0	SI
HR	1	13	0	2	0	0	3	8	1	38	0	0	41	0	0	0	6	0	6	3	0	2	0	HR
BA	2	8	0	3	0	0	3	7	1	20	0	0	23	0	0	0	8	0	6	3	0	1	0	BA
YU*	13	11	0	39	0	0	4	13	3	60	0	0	18	0	1	0	12	0	51	3	0	1	0	YU*
FYM	15	1	0	15	0	0	1	1	9	2	0	0	2	0	0	0	1	0	4	1	0	0	0	FYM
CS*	0	56	3	1	1	0	19	191	0	21	0	0	5	1	5	0	48	0	5	3	0	4	0	CS*
SK	0	19	1	3	1	0	4	22	0	84	0	0	5	0	1	0	41	0	13	1	0	1	0	SK
REM	4	7	1	18	1	1	35	19	9	7	0	0	76	0	2	1	12	10	16	68	1	5	87	REM
BAS	0	4	12	2	246	43	29	370	0	6	0	2	4	1	41	5	176	0	6	4	127	2	0	BAS
NOS	0	5	95	0	147	1	384	278	0	4	0	30	5	1	227	24	33	2	2	20	16	4	0	NOS
ATL	0	9	25	2	25	13	441	139	0	5	12	297	15	2	47	44	48	207	7	247	13	9	1	ATL
MED	51	21	3	110	1	0	186	35	171	23	0	0	675	0	4	1	20	16	50	282	1	14	135	MED
BLS	1	3	0	137	1	0	3	9	6	7	0	0	5	0	1	0	19	0	169	2	1	1	263	BLS
SUM	196	692	612	1582	916	346	5058	5121	511	1093	21	975	2742	53	1431	204	2889	572	2561	2402	475	408	2217	SUM

Table 6.2 Source-receptor relationship for reduced nitrogen continued. Emitters along the abscissa and receivers along the ordinate.

	GB	BY	UA	MD	RU	EE	LV	LT	SI	HR	BA	YU*	FYM	CS*	SK	REM	BAS	NOS	ATL	RSA	NAT	IND	SUM	
AL	0	0	1	0	0	0	0	0	0	1	1	11	5	0	0	1	0	0	0	0	0	0	113	AL
AT	1	1	3	0	1	0	0	0	26	4	2	3	0	24	14	0	0	0	0	0	0	0	637	AT
BE	15	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	355	BE
BG	0	3	32	6	9	0	0	0	1	2	4	54	9	3	4	1	0	0	0	0	0	0	1093	BG
DK	22	1	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	412	DK
FI	9	23	21	1	64	1	10	17	1	1	0	1	0	7	4	0	0	0	0	0	0	0	510	FI
FR	67	2	2	0	1	0	0	1	2	2	1	1	0	10	3	4	0	0	0	0	0	0	3812	FR
DE*	68	6	7	0	4	0	0	4	2	1	0	1	0	63	7	0	0	0	0	0	0	0	3624	DE*
GR	0	1	13	2	4	0	0	0	1	1	2	9	19	1	1	2	0	0	0	0	0	0	479	GR
HU	1	2	14	0	1	0	0	0	14	22	6	28	0	15	53	0	0	0	0	0	0	0	738	HU
IS	5	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	IS
IE	47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	566	IE
IT	1	1	3	0	1	0	0	0	21	15	8	7	1	6	6	9	0	0	0	0	0	0	1769	IT
LU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	LU
NL	31	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	723	NL
NO	49	2	3	0	6	0	1	2	0	0	0	0	0	3	1	0	0	0	0	0	0	0	342	NO
PL	17	74	87	2	21	0	3	21	4	3	2	7	0	94	57	0	0	0	0	0	0	0	2375	PL
PT	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	319	PT
RO	1	14	146	43	17	0	1	2	6	9	10	59	3	16	30	1	0	0	0	0	0	0	2189	RO
ES	6	0	0	0	0	0	0	0	1	1	0	1	0	1	0	8	0	0	0	0	0	0	1579	ES
SE	36	9	7	0	17	0	5	10	1	0	0	1	0	8	2	0	0	0	0	0	0	0	687	SE
CH	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	295	CH
TR	0	6	88	9	36	0	0	1	1	1	2	8	3	2	2	15	0	0	0	0	0	0	1951	TR
GB	1058	2	2	0	2	0	0	1	0	0	0	0	0	2	1	0	0	0	0	0	0	0	1386	GB
BY	4	997	223	7	61	0	22	88	1	1	1	3	0	10	9	1	0	0	0	0	0	0	1693	BY
UA	4	224	3207	117	220	0	4	19	4	4	5	16	2	27	39	5	0	0	0	0	0	0	4635	UA
MD	0	4	86	90	4	0	0	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	280	MD
RU	26	439	916	33	6559	2	64	101	3	5	6	18	3	28	24	164	0	0	0	0	0	0	9411	RU
EE	2	11	8	0	13	2	20	13	0	0	0	0	0	2	1	0	0	0	0	0	0	0	120	EE
LV	4	33	13	1	16	1	73	77	0	0	0	1	0	3	2	0	0	0	0	0	0	0	303	LV
LT	4	60	17	1	17	0	16	221	0	0	0	1	0	4	3	0	0	0	0	0	0	0	470	LT
SI	0	0	1	0	0	0	0	0	60	10	1	1	0	2	2	0	0	0	0	0	0	0	147	SI
HR	0	0	2	0	0	0	0	0	16	75	33	12	0	5	6	1	0	0	0	0	0	0	274	HR
BA	0	1	3	0	1	0	0	0	3	23	73	23	1	4	6	1	0	0	0	0	0	0	224	BA
YU*	1	1	8	1	2	0	0	0	3	15	33	292	11	8	12	1	0	0	0	0	0	0	617	YU*
FYM	0	0	2	0	1	0	0	0	0	0	1	15	33	0	1	0	0	0	0	0	0	0	105	FYM
CS*	2	2	4	0	1	0	0	1	3	2	1	2	0	224	31	0	0	0	0	0	0	0	636	CS*
SK	1	2	16	0	1	0	0	0	4	3	2	5	0	25	128	0	0	0	0	0	0	0	383	SK
REM	2	8	48	2	372	0	1	1	3	4	5	7	2	5	3	589	0	0	0	0	0	0	1432	REM
BAS	35	24	17	1	37	2	36	42	1	1	1	2	0	14	5	0	0	0	0	0	0	0	1298	BAS
NOS	664	5	4	0	6	0	1	3	1	1	0	0	0	9	3	0	0	0	0	0	0	0	1975	NOS
ATL	544	19	19	1	121	0	3	8	1	1	0	1	0	13	4	4	0	0	0	0	0	0	2347	ATL
MED	5	5	42	6	13	0	0	1	19	45	32	36	11	10	9	124	0	0	0	0	0	0	2157	MED
BLS	1	20	555	36	154	0	1	3	1	1	2	10	2	3	3	14	0	0	0	0	0	0	1434	BLS
SUM	2733	2008	5623	362	7788	11	263	641	204	254	238	637	107	659	479	948	0	0	0	0	0	0	56032	SUM

Table 6.3 Source-receptor relationships for oxidized sulphur. Emitters along the abscissa and receivers along the ordinate.

	AL	AT	BE	BG	DK	FI	FR	DE*	GR	HU	IS	IE	IT	LU	NL	NO	PL	PT	RO	ES	SE	CH	TR	
AL	42	0	0	11	0	0	2	5	19	5	0	0	18	0	0	0	5	0	2	6	0	0	0	AL
AT	1	71	6	7	1	0	38	139	1	50	0	0	72	1	2	0	77	0	7	22	0	7	0	AT
BE	0	0	173	0	0	0	108	54	0	1	0	1	3	2	51	0	8	0	0	13	0	0	0	BE
BG	4	3	1	905	1	0	5	43	20	53	0	0	17	0	0	0	40	0	107	7	0	0	9	BG
DK	0	0	13	0	124	0	21	76	0	2	0	2	1	0	8	1	25	0	0	7	4	0	0	DK
FI	0	2	12	11	17	285	25	249	1	24	0	2	9	1	6	4	219	0	10	19	28	1	1	FI
FR	0	5	132	3	4	0	1641	384	1	21	0	11	218	10	44	0	98	11	5	487	1	17	0	FR
DE*	0	22	221	3	21	0	446	3269	0	36	0	10	48	19	111	0	338	1	6	93	2	23	0	DE*
GR	20	1	1	239	0	0	6	20	365	18	0	0	31	0	0	0	20	0	23	13	0	0	13	GR
HU	1	13	3	12	1	0	12	93	1	694	0	0	33	0	1	0	125	0	47	8	0	1	0	HU
IS	0	0	1	0	1	0	4	19	0	1	20	1	1	0	0	0	8	0	0	5	0	0	0	IS
IE	0	0	3	0	0	0	11	13	0	1	0	208	1	0	1	0	5	1	0	15	0	0	0	IE
IT	5	11	3	23	1	0	80	68	13	46	0	0	1616	0	1	0	63	4	11	141	0	8	2	IT
LU	0	0	4	0	0	0	9	7	0	0	0	0	0	4	0	0	1	0	0	2	0	0	0	LU
NL	0	0	95	0	1	0	62	73	0	1	0	2	2	1	150	0	12	0	0	9	0	0	0	NL
NO	0	1	21	1	34	4	47	183	0	8	0	9	10	1	10	62	62	1	2	34	16	1	0	NO
PL	1	10	40	16	34	2	76	1830	3	157	0	4	27	2	19	1	3706	0	23	31	7	2	1	PL
PT	0	0	1	0	0	0	4	4	0	0	0	0	3	0	0	0	1	231	0	116	0	0	0	PT
RO	4	13	6	231	2	1	26	190	12	354	0	0	54	0	2	0	202	1	728	22	1	1	6	RO
ES	1	1	8	2	1	0	86	47	2	5	0	2	45	0	3	0	17	77	2	2414	0	1	0	ES
SE	0	2	37	2	111	37	66	440	0	16	0	5	11	1	19	20	205	1	4	33	178	1	0	SE
CH	0	2	2	1	0	0	38	24	0	2	0	0	81	0	1	0	6	0	0	23	0	44	0	CH
TR	5	2	2	263	1	0	9	50	65	36	0	0	31	0	1	0	62	0	60	16	0	0	495	TR
GB	0	0	24	0	4	0	87	93	0	3	0	69	5	1	12	0	30	3	1	62	1	0	0	GB
BY	1	3	9	22	9	6	23	275	2	53	0	1	15	0	4	1	509	0	24	14	4	1	2	BY
UA	3	8	15	188	9	5	41	491	18	245	0	1	46	1	5	1	1010	1	187	32	4	2	27	UA
MD	0	0	0	18	0	0	2	18	1	9	0	0	2	0	0	0	39	0	35	2	0	0	2	MD
RU	8	14	43	336	48	123	124	1119	41	249	0	6	112	1	18	7	1462	2	217	110	32	4	71	RU
EE	0	1	2	3	5	11	5	52	0	8	0	0	2	0	1	0	72	0	3	3	4	0	0	EE
LV	0	1	5	5	9	5	10	90	1	12	0	1	3	0	3	0	121	0	4	6	4	0	0	LV
LT	0	1	6	5	9	3	12	125	1	17	0	1	4	0	3	0	193	0	5	7	3	0	0	LT
SI	0	6	0	2	0	0	5	15	1	17	0	0	55	0	0	0	17	0	2	7	0	0	0	SI
HR	2	6	1	8	0	0	9	37	2	66	0	0	74	0	0	0	42	0	8	14	0	1	0	HR
BA	3	4	1	9	0	0	8	34	4	43	0	0	49	0	0	0	34	0	7	13	0	0	0	BA
YU*	12	6	2	56	1	0	11	69	11	130	0	0	46	0	1	0	67	0	45	13	0	1	1	YU*
FYM	12	0	0	30	0	0	1	6	17	7	0	0	7	0	0	0	6	0	5	3	0	0	1	FYM
CS*	0	15	14	3	2	0	43	616	1	65	0	1	16	1	6	0	348	0	6	15	0	2	0	CS*
SK	1	8	3	6	1	0	10	114	1	249	0	0	17	0	1	0	213	0	12	6	0	1	0	SK
REM	4	3	3	54	1	1	45	80	22	25	0	0	149	0	1	0	74	10	22	165	0	1	13	REM
BAS	0	3	52	7	244	125	85	991	1	39	0	5	13	2	30	6	821	1	9	33	140	1	1	BAS
NOS	0	3	172	2	106	1	490	572	0	15	1	54	20	3	189	28	155	3	3	125	19	2	0	NOS
ATL	1	6	91	10	30	24	529	654	2	33	62	307	58	4	32	31	243	863	13	1493	15	4	1	ATL
MED	81	17	16	549	3	0	522	234	752	146	0	2	1851	1	5	0	193	27	90	1006	1	7	201	MED
BLS	3	3	3	437	2	1	10	124	25	80	0	0	24	0	1	0	216	0	200	11	1	0	163	BLS
SUM	216	268	1245	3481	838	639	4894	13089	1407	3041	85	706	4901	60	744	165	11170	1244	1935	6674	467	137	1011	SUM

Table 6.3 Source-receptor relationships for oxidized sulphur continued. Emitters along the abscissa and receivers along the ordinate.

	GB	BY	UA	MD	RU	EE	LV	LT	SI	HR	BA	YU*	FYM	CS*	SK	REM	BAS	NOS	ATL	RSA	NAT	IND	SUM	
AL	1	0	2	0	1	0	0	0	1	1	9	11	17	4	2	42	0	0	0	0	1	12	219	AL
AT	29	1	7	1	2	0	0	0	89	8	14	10	1	131	23	21	0	2	0	0	1	13	855	AT
BE	76	0	1	0	0	0	0	0	0	0	0	0	0	10	1	1	0	20	1	0	1	5	530	BE
BG	7	5	54	15	14	1	0	1	6	4	44	98	31	36	17	26	0	0	0	0	1	25	1600	BG
DK	108	1	1	0	2	0	0	1	0	0	1	0	0	11	1	1	12	29	1	0	5	6	464	DK
FI	116	38	46	4	329	87	10	24	3	1	5	6	1	92	15	6	18	8	2	0	5	54	1796	FI
FR	386	3	7	1	2	0	0	2	11	4	8	6	1	128	12	91	1	105	36	0	20	107	4024	FR
DE*	514	5	15	1	8	0	0	4	11	3	6	6	0	648	24	23	9	83	6	0	7	46	6088	DE*
GR	5	2	30	6	7	0	0	0	3	2	17	25	40	15	6	117	0	0	0	0	4	54	1103	GR
HU	13	2	14	1	2	0	0	1	22	20	34	51	1	105	130	20	0	1	0	0	0	6	1468	HU
IS	31	1	1	0	3	0	0	0	0	0	0	0	0	5	1	2	0	1	2	0	14	33	155	IS
IE	119	0	0	0	1	0	0	0	0	0	0	0	0	4	0	1	0	4	12	0	12	28	440	IE
IT	23	1	8	1	2	0	0	1	66	32	46	21	4	53	18	1154	0	1	3	0	9	73	3612	IT
LU	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	32	LU
NL	142	1	1	0	1	0	0	0	0	0	0	0	0	11	1	1	0	48	2	0	2	6	624	NL
NO	364	3	7	0	171	3	1	3	2	1	2	2	0	43	5	6	3	41	13	0	22	99	1298	NO
PL	206	31	88	6	40	3	2	20	15	7	24	26	2	793	133	23	10	22	2	0	3	28	7476	PL
PT	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6	0	0	25	0	4	19	420	PT
RO	28	15	199	55	27	2	0	3	22	16	90	164	9	164	111	49	0	2	0	0	1	45	2858	RO
ES	57	0	1	0	1	0	0	0	3	1	4	2	1	22	2	76	0	5	57	18	12	80	3056	ES
SE	321	15	18	1	100	21	5	15	3	1	4	4	0	110	9	5	33	43	5	0	12	60	1974	SE
CH	13	0	0	0	0	0	0	0	3	1	2	1	0	10	1	13	0	1	0	0	0	9	278	CH
TR	11	10	206	25	50	1	0	2	5	3	26	30	9	33	13	112	0	1	0	0	5	295	1935	TR
GB	3158	2	3	0	5	1	0	1	1	0	1	1	0	25	2	5	1	121	31	0	30	58	3841	GB
BY	61	530	210	20	93	20	12	73	7	3	14	13	1	114	32	16	4	5	1	0	1	28	2236	BY
UA	77	201	3325	214	290	12	4	30	18	10	57	60	8	290	144	61	3	6	1	0	6	121	7278	UA
MD	2	4	74	81	7	0	0	1	1	0	3	3	0	11	5	3	0	0	0	0	0	6	329	MD
RU	399	794	2841	130	9402	369	52	149	36	15	96	91	18	484	135	366	19	22	7	0	21	1426	21019	RU
EE	23	13	16	1	27	82	11	15	1	0	2	2	0	22	5	3	9	2	0	0	1	7	414	EE
LV	39	26	25	2	27	16	26	49	2	1	3	3	0	32	8	4	5	4	0	0	2	9	563	LV
LT	41	25	28	3	29	6	7	114	2	1	3	4	0	47	11	4	4	4	0	0	1	8	737	LT
SI	2	0	1	0	0	0	0	0	98	19	6	4	0	16	6	13	0	0	0	0	0	4	296	SI
HR	6	1	4	1	1	0	0	0	25	82	84	24	1	38	17	47	0	0	0	0	1	10	612	HR
BA	7	1	5	1	1	0	0	0	8	14	381	34	2	31	14	61	0	0	0	0	1	15	785	BA
YU*	12	2	14	3	3	0	0	0	11	15	243	394	29	64	34	67	0	1	0	0	1	21	1386	YU*
FYM	1	0	4	1	1	0	0	0	1	1	10	17	61	5	2	14	0	0	0	0	0	6	219	FYM
CS*	46	2	8	1	2	0	0	1	11	4	7	8	0	1093	61	8	0	4	1	0	0	8	2419	CS*
SK	14	2	12	1	2	0	0	1	12	7	14	15	1	149	270	13	0	1	0	0	0	5	1162	SK
REM	31	15	243	9	480	2	0	2	11	5	24	16	5	45	11	1222	0	1	14	6	15	844	3674	REM
BAS	356	34	43	4	117	101	25	53	4	2	7	7	1	229	25	9	188	63	3	0	27	48	3955	BAS
NOS	4793	5	7	1	16	2	1	4	3	1	4	3	0	131	10	12	11	1289	39	0	192	131	8618	NOS
ATL	2588	32	58	4	1242	23	3	11	8	2	9	7	1	205	20	72	4	261	2081	10	2025	2928	16100	ATL
MED	117	9	123	23	25	1	0	2	86	107	193	110	43	155	49	4370	0	7	58	50	220	473	11925	MED
BLS	18	43	1173	151	182	4	1	7	7	4	34	52	7	75	29	65	1	1	0	0	33	187	3378	BLS
SUM	14372	1877	8925	768	12715	760	165	588	619	399	1532	1330	298	5691	1414	8230	337	2212	2406	88	2719	7447	13330	SUM

Table 6.4 Source-receptor relationships for oxidized nitrogen. Emitters along the abscissa and receivers along the ordinate.

	AL	AT	BE	BG	DK	FI	FR	DE*	GR	HU	IS	IE	IT	LU	NL	NO	PL	PT	RO	ES	SE	CH	TR	
AL	4	1	0	2	0	0	2	2	7	1	0	0	24	0	0	0	1	0	1	2	0	0	0	AL
AT	0	69	2	1	1	0	23	69	0	6	0	0	55	0	3	0	17	0	3	5	1	11	0	AT
BE	0	0	118	0	1	0	62	56	0	0	0	1	3	2	38	0	2	0	0	4	0	1	0	BE
BG	1	4	1	110	1	1	5	13	8	6	0	0	15	0	2	0	9	0	42	3	1	1	3	BG
DK	0	0	8	0	55	1	14	38	0	0	0	1	1	0	17	2	7	0	0	2	10	0	0	DK
FI	0	3	6	1	16	157	14	68	0	3	0	2	6	0	13	16	46	0	5	4	60	2	0	FI
FR	0	9	87	1	5	1	1280	280	1	3	0	7	236	8	72	3	23	13	4	201	4	32	0	FR
DE*	0	27	129	1	15	2	263	1508	0	5	0	5	41	13	165	4	71	2	3	25	7	42	0	DE*
GR	3	2	1	24	1	0	8	9	121	3	0	0	45	0	1	0	5	1	11	7	1	1	4	GR
HU	0	17	2	2	1	0	9	32	1	83	0	0	30	0	3	0	32	0	14	2	1	2	0	HU
IS	0	0	1	0	2	0	3	9	0	0	5	1	1	0	2	1	3	0	0	1	1	0	0	IS
IE	0	0	2	0	1	0	11	11	0	0	0	50	2	0	4	0	2	2	0	7	0	0	0	IE
IT	1	17	4	5	2	1	97	35	8	7	0	1	1236	0	5	1	18	5	7	69	2	16	1	IT
LU	0	0	3	0	0	0	6	6	0	0	0	0	0	4	1	0	0	0	0	0	0	0	0	LU
NL	0	0	47	0	1	0	32	67	0	0	0	1	2	0	208	0	3	0	0	3	1	1	0	NL
NO	0	2	11	0	23	7	30	78	0	1	1	5	7	1	23	99	16	1	1	8	29	2	0	NO
PL	0	12	23	3	26	5	48	393	1	17	0	2	23	2	36	6	715	1	10	8	20	6	0	PL
PT	0	0	1	0	0	0	5	3	0	0	0	0	4	0	1	0	0	87	0	50	0	0	0	PT
RO	1	13	3	33	2	2	18	52	5	37	0	0	45	0	5	1	42	1	210	6	2	4	2	RO
ES	0	3	8	1	2	1	85	34	1	1	0	2	67	1	9	1	5	49	2	825	1	4	0	ES
SE	0	3	20	0	66	32	36	166	0	2	0	4	7	1	40	51	48	1	2	7	226	2	0	SE
CH	0	3	1	0	0	0	24	16	0	0	0	0	51	0	1	0	1	0	0	6	0	56	0	CH
TR	1	4	2	29	2	1	10	20	32	4	0	0	32	0	3	1	16	1	27	6	2	2	95	TR
GB	0	1	20	0	6	1	71	68	0	1	0	27	5	1	35	3	10	3	1	21	4	2	0	GB
BY	0	4	5	3	10	7	13	65	1	6	0	1	11	0	10	3	106	0	10	3	11	2	1	BY
UA	1	11	9	29	11	8	29	121	7	26	0	1	39	1	14	5	216	1	69	9	13	5	11	UA
MD	0	1	0	3	0	0	2	5	1	1	0	0	2	0	1	0	8	0	9	1	0	0	1	MD
RU	2	21	27	37	57	154	80	285	12	23	1	7	77	2	56	37	280	2	93	25	100	12	21	RU
EE	0	1	1	0	5	11	3	16	0	1	0	0	2	0	3	2	17	0	1	1	10	0	0	EE
LV	0	1	3	1	10	6	6	29	0	1	0	1	3	0	6	2	29	0	2	1	12	1	0	LV
LT	0	2	4	1	10	3	8	39	0	2	0	1	3	0	7	2	43	0	2	2	10	1	0	LT
SI	0	7	0	0	0	0	4	6	0	2	0	0	53	0	0	0	4	0	1	2	0	1	0	SI
HR	1	7	1	1	0	0	8	13	2	7	0	0	81	0	1	0	11	0	3	5	0	2	0	HR
BA	1	4	1	1	0	0	6	11	2	5	0	0	50	0	1	0	9	0	3	4	0	1	0	BA
YU*	2	7	1	8	1	0	8	22	4	15	0	0	42	0	2	0	17	0	19	4	1	2	0	YU*
FYM	1	1	0	3	0	0	1	2	5	1	0	0	7	0	0	0	1	0	2	1	0	0	0	FYM
CS*	0	17	6	1	1	0	25	126	0	7	0	0	13	1	8	1	61	0	3	4	1	5	0	CS*
SK	0	9	2	1	1	0	7	29	0	26	0	0	14	0	2	0	48	0	5	2	1	2	0	SK
REM	2	9	5	9	4	4	69	43	15	5	0	1	197	1	8	3	21	12	14	95	5	8	5	REM
BAS	0	3	18	1	77	46	34	202	0	3	0	3	8	1	43	12	99	0	3	5	116	2	0	BAS
NOS	0	4	58	0	40	2	171	190	0	2	1	18	11	1	171	25	26	3	1	25	22	4	0	NOS
ATL	0	11	51	2	38	33	300	259	1	4	15	82	43	3	88	62	54	137	7	235	44	13	1	ATL
MED	8	18	9	29	3	2	248	66	142	9	0	2	843	1	13	3	25	16	27	256	4	14	25	MED
BLS	1	3	2	34	2	2	6	21	7	5	0	0	15	0	3	1	24	0	46	2	3	1	23	BLS
SUM	31	332	702	378	497	490	3182	4583	390	334	26	228	3451	48	1122	348	2192	345	666	1953	727	264	197	SUM

Table 6.4 Source-receptor relationships for oxidized nitrogen continued. Emitters along the abscissa and receivers along the ordinate.

	GB	BY	UA	MD	RU	EE	LV	LT	SI	HR	BA	YU*	FYM	CS*	SK	REM	BAS	NOS	ATL	RSA	NAT	IND	SUM	
AL	1	0	1	0	0	0	0	0	0	0	2	1	3	1	1	1	0	0	1	0	0	22	81	AL
AT	7	1	1	0	1	0	0	0	10	2	2	1	0	34	6	0	0	2	1	0	0	31	365	AT
BE	58	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	22	4	0	0	12	386	BE
BG	4	2	14	2	9	0	0	0	1	1	3	6	4	8	5	1	0	1	1	0	0	44	332	BG
DK	96	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	6	36	3	0	0	15	316	DK
FI	47	9	10	0	37	14	5	7	0	0	0	0	0	17	4	0	13	14	5	0	0	79	683	FI
FR	260	2	2	0	2	0	0	1	3	2	1	1	0	32	4	4	1	135	99	2	0	242	3063	FR
DE*	295	3	5	0	5	0	0	2	2	1	0	0	0	183	7	0	5	89	16	0	0	108	3049	DE*
GR	5	1	8	1	5	0	0	0	1	1	2	2	3	4	2	2	0	1	2	0	0	77	365	GR
HU	6	1	3	0	2	0	0	0	4	6	4	3	0	34	37	0	0	2	1	0	0	17	351	HU
IS	20	0	1	0	1	0	0	0	0	0	0	0	0	2	0	0	0	4	5	0	0	40	103	IS
IE	84	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	12	32	0	0	51	274	IE
IT	16	1	4	0	3	0	0	1	13	9	10	2	2	18	7	9	0	5	12	2	0	173	1825	IT
LU	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	23	LU
NL	114	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	47	4	0	0	12	546	NL
NO	187	2	2	0	8	1	1	1	0	0	0	0	0	10	2	0	3	47	16	0	0	119	744	NO
PL	95	15	18	1	18	1	2	6	2	2	2	2	0	228	30	1	8	27	6	0	0	73	1894	PL
PT	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	45	2	0	38	245	PT
RO	11	5	36	7	16	0	0	1	3	5	8	10	3	35	28	1	0	3	2	0	0	80	738	RO
ES	39	1	1	0	1	0	0	0	1	1	1	0	0	7	1	8	0	12	80	10	0	201	1466	ES
SE	173	4	4	0	16	4	3	5	0	0	0	0	0	23	3	0	20	57	11	0	0	110	1147	SE
CH	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	1	0	0	19	184	CH
TR	10	4	55	4	37	0	0	1	1	1	2	2	2	9	4	7	0	3	3	0	0	236	671	TR
GB	1357	1	1	0	3	0	0	1	0	0	0	0	0	8	1	0	1	140	64	0	0	109	1966	GB
BY	26	97	40	3	35	3	5	18	1	1	1	1	0	25	9	1	3	8	2	0	0	47	598	BY
UA	38	42	491	23	140	2	3	10	3	3	5	4	2	73	38	6	3	12	5	0	0	162	1701	UA
MD	1	1	13	11	4	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	8	78	MD
RU	180	142	495	15	2477	44	27	50	3	3	5	5	3	94	32	101	21	53	25	0	0	1224	6410	RU
EE	12	3	3	0	7	15	3	3	0	0	0	0	0	5	1	0	5	4	1	0	0	13	149	EE
LV	23	6	5	0	9	4	8	12	0	0	0	0	0	7	2	0	5	7	1	0	0	19	222	LV
LT	25	8	5	0	9	1	3	25	0	0	0	0	0	11	3	0	4	8	1	0	0	18	261	LT
SI	1	0	0	0	0	0	0	0	11	4	2	0	0	5	2	0	0	0	0	0	0	10	115	SI
HR	3	0	1	0	1	0	0	0	4	11	11	2	0	12	5	1	0	1	1	0	0	24	220	HR
BA	3	0	1	0	1	0	0	0	1	4	19	2	1	8	4	1	0	1	1	0	0	30	176	BA
YU*	5	1	3	0	2	0	0	0	2	5	14	18	8	17	10	1	0	1	1	0	0	41	284	YU*
FYM	1	0	1	0	1	0	0	0	0	0	1	1	6	1	1	0	0	0	0	0	0	12	50	FYM
CS*	15	1	2	0	1	0	0	0	2	1	1	1	0	220	13	0	0	4	1	0	0	21	563	CS*
SK	5	1	3	0	1	0	0	0	2	2	2	1	0	43	47	0	0	1	1	0	0	13	271	SK
REM	30	6	42	2	183	1	1	2	3	3	5	2	2	15	5	162	1	9	33	6	0	704	1752	REM
BAS	126	7	7	0	17	10	5	9	0	0	0	0	0	27	4	0	39	42	6	0	0	63	1038	BAS
NOS	969	2	2	0	4	0	1	2	0	0	0	0	0	19	2	0	4	353	53	0	0	175	2361	NOS
ATL	962	11	14	1	104	4	3	7	1	1	1	0	0	41	6	4	6	199	837	4	0	2405	6094	ATL
MED	43	3	22	2	15	0	0	1	8	11	14	5	5	22	8	35	1	13	47	12	0	504	2534	MED
BLS	9	7	135	8	84	0	1	2	1	1	2	2	1	10	5	7	1	3	1	0	0	121	602	BLS
SUM	5367	391	1450	84	3265	106	74	171	85	85	123	78	48	1324	339	355	152	1383	1430	38	0	7522	46356	SUM

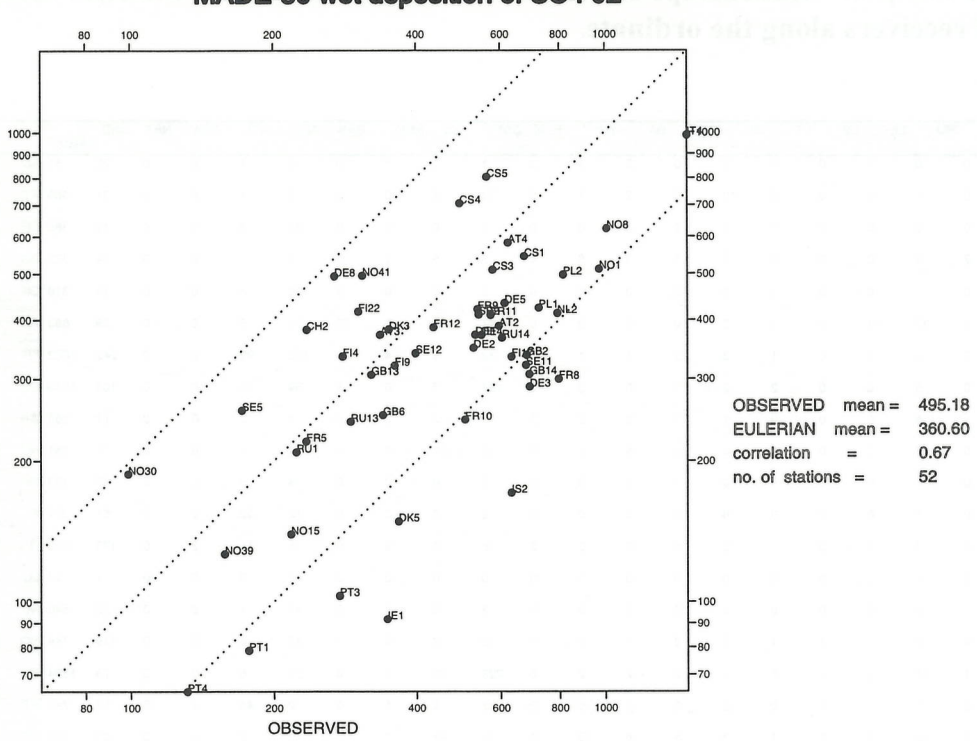

Fig. 6.1 *Observed versus calculated accumulated wet deposition of sulphate in mg (S)/m^2*

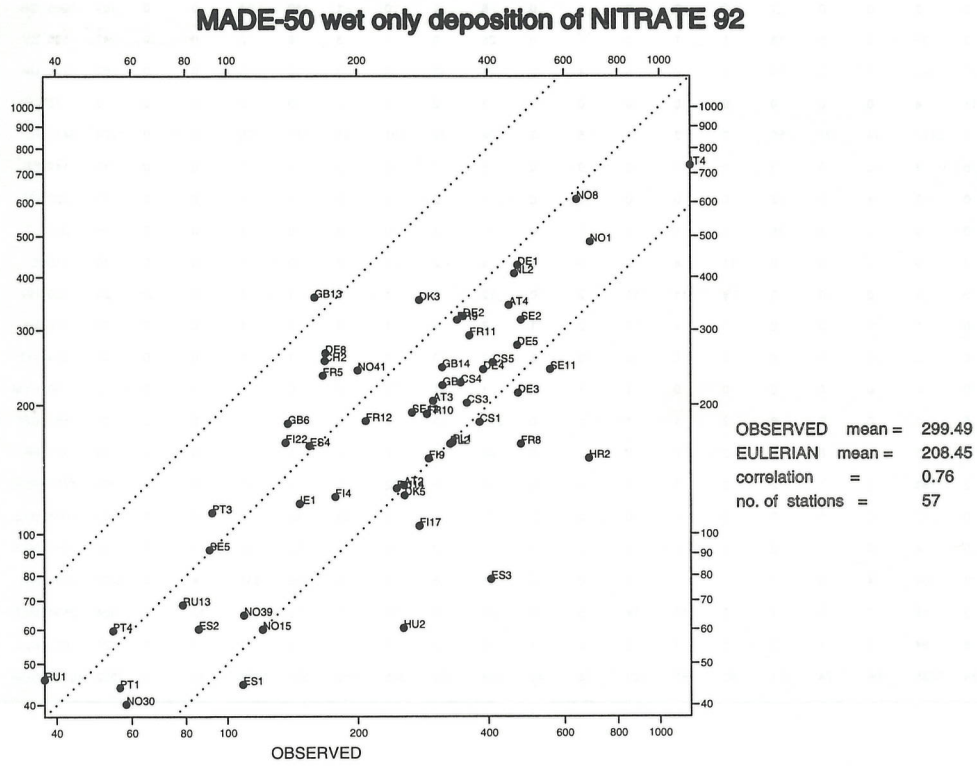

Fig. 6.2 *Observed versus calculated accumulated wet deposition of nitrate in mg (N)/m^2*

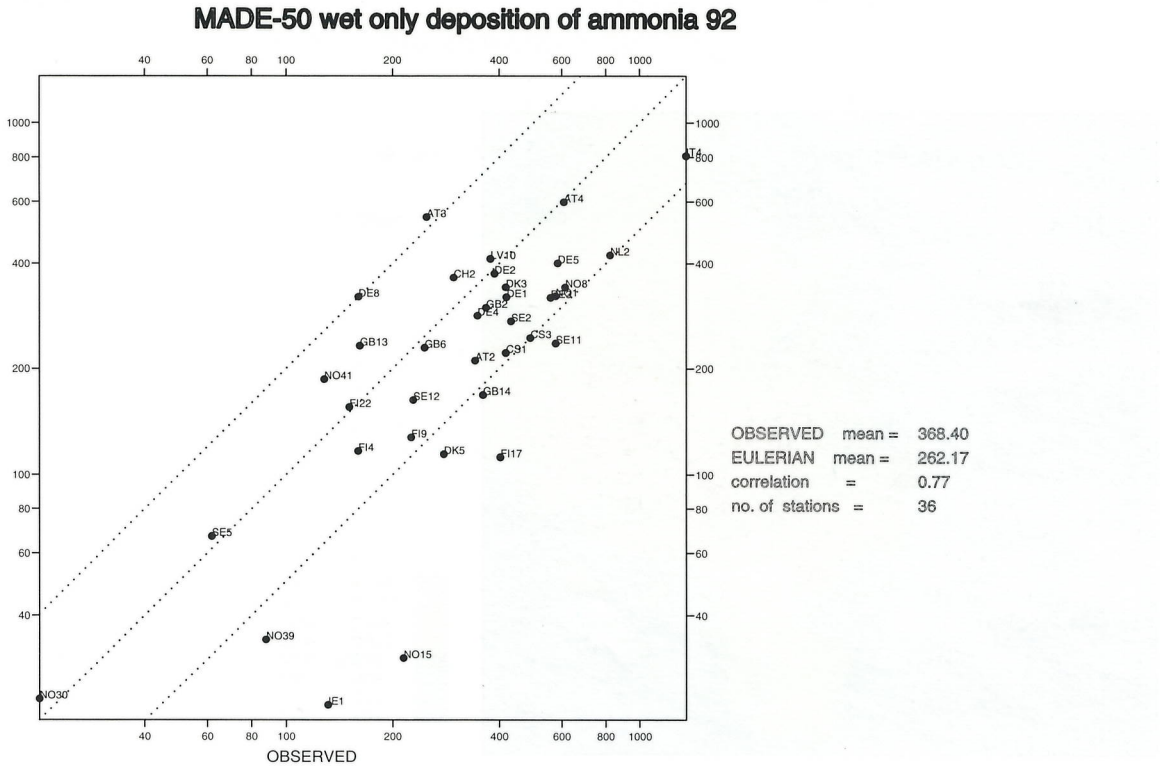

Fig. 6.3 *Observed versus calculated accumulated wet deposition of ammonia + ammonium in mg (N)/m^2*

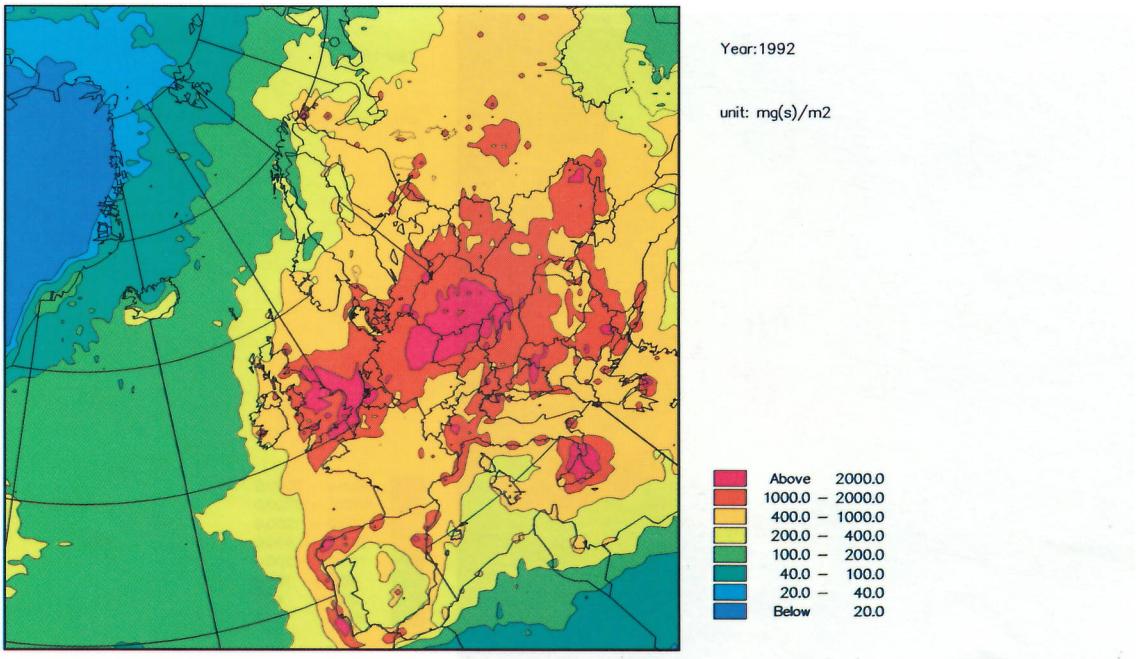

Fig. 6.4 *Total deposition of oxidized sulphur calculated by MADE-50.*

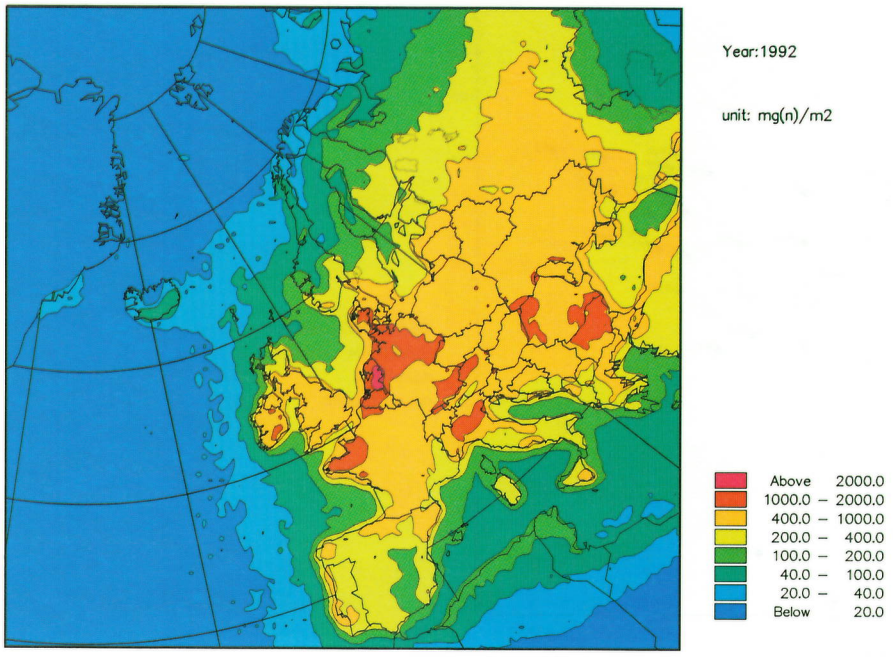

Fig. 6.5 *Total deposition of reduced nitrogen calculated by MADE-50.*

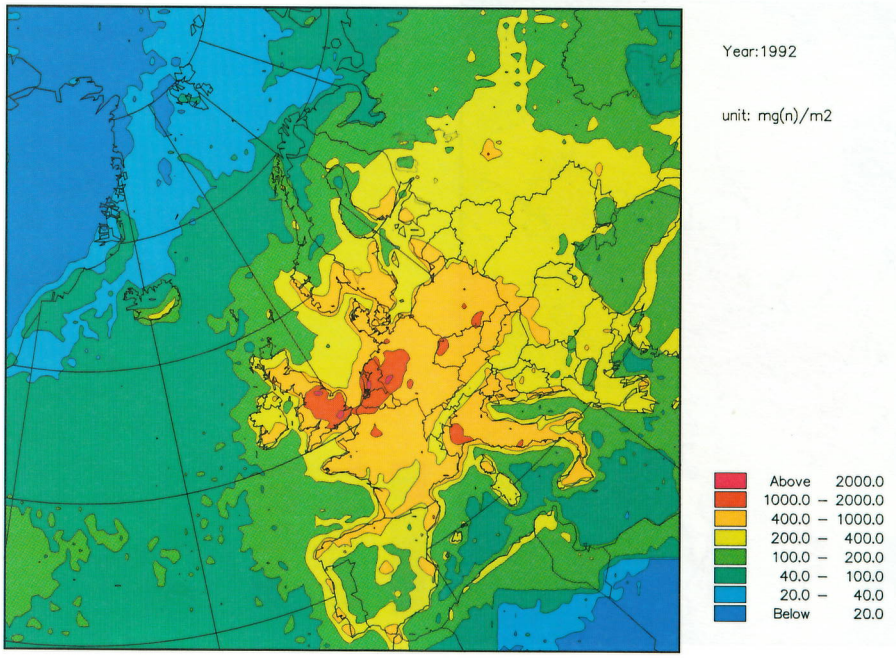

Fig. 6.6 *Total deposition of oxidised nitrogen calculated by MADE-50.*

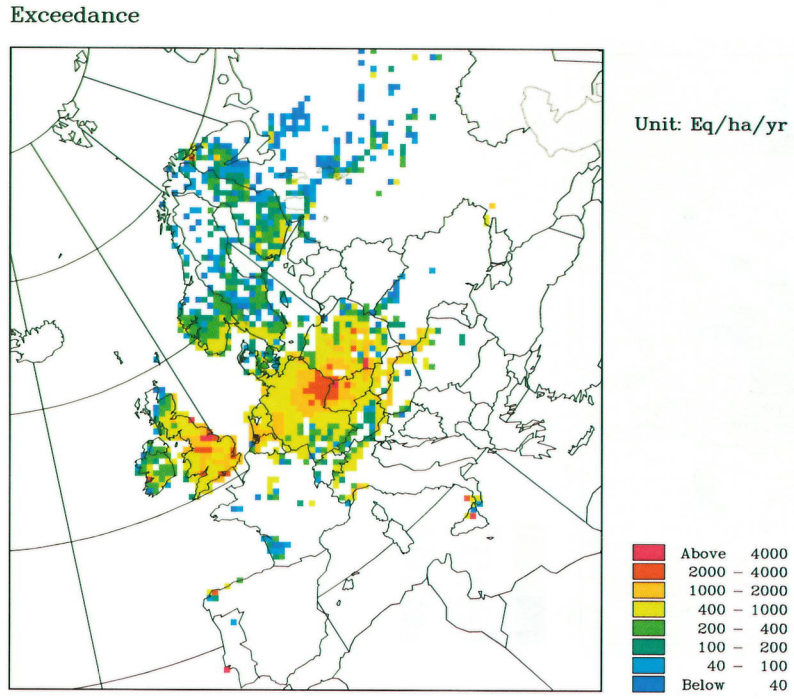

Fig. 6.7a *Exceedance of the 5 percentile sulphur conditional critical load CL(S|Ndep92) in Eq/ha/yr, MADE-50. Source for critical loads: Co-ordination centre for effects (CCE).*

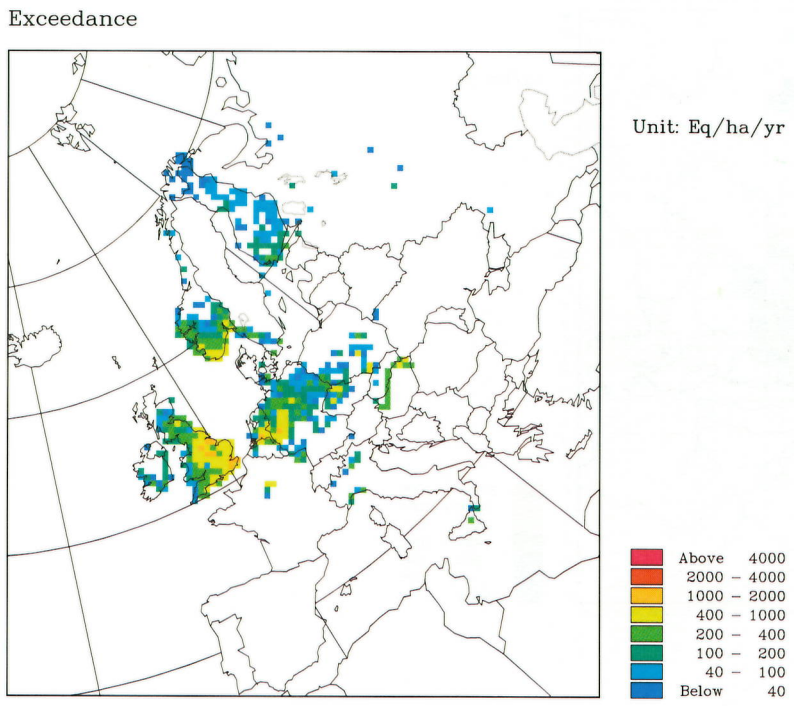

Fig. 6.7b *Exceedance of the 5 percentile nitrogen conditional critical load CL (N|Sdep92) in Eq/ha/yr, MADE-50. Source for critical loads: Co-ordination centre for effects (CCE).*

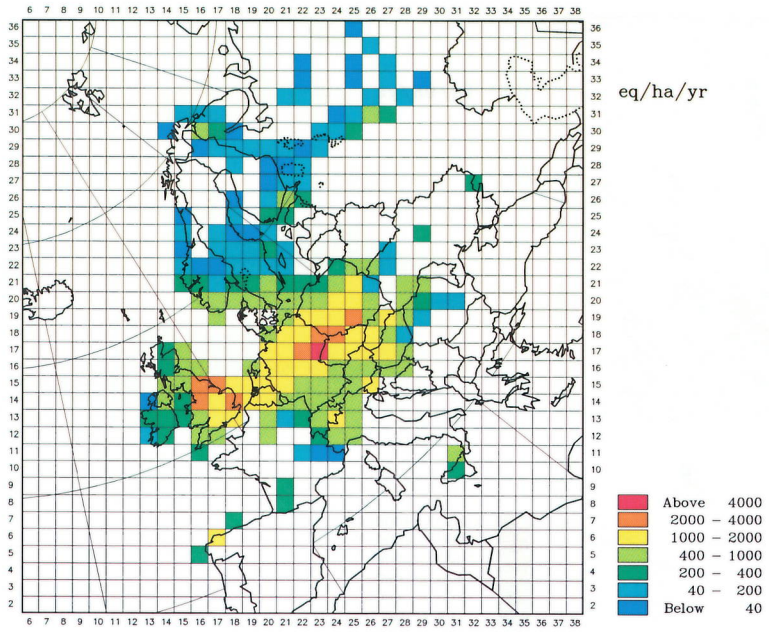

Fig. 6.8a *Exceedance of the 5 percentile sulphur conditional critical load CL (S|Ndep92) in Eq/ha/yr, ROOT-150. Source for critical loads: Co-ordination centre for effects (CCE).*

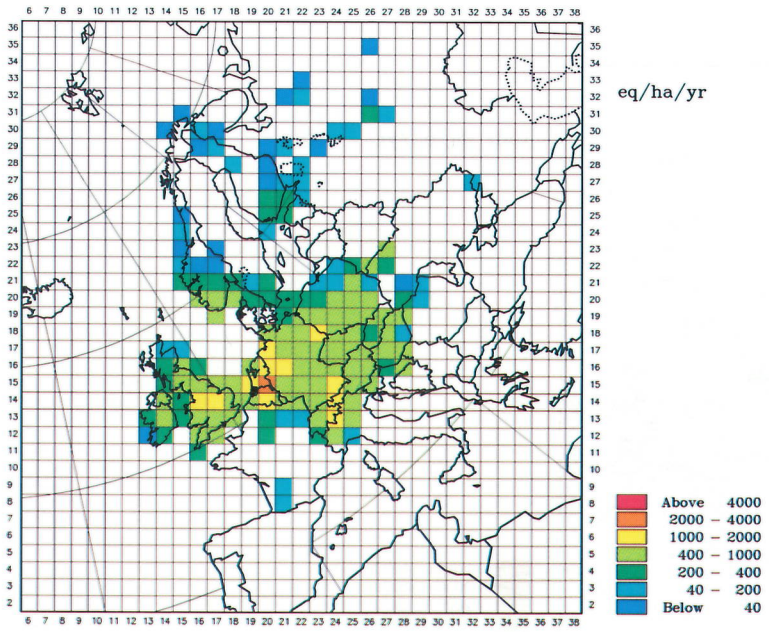

Fig. 6.8b *Exceedance of the 5 percentile nitrogen conditional critical load CL (N|Sdep92) in Eq/ha/yr, ROOT-150. Source for critical loads: Co-ordination centre for effects (CCE).*

Appendix 1
THE EMEP GRID SYSTEM

A.1 The EMEP grid system.

In original definition of the EMEP grid system has been given earlier in Saltbones and Dovland (EMEP/CCC Report 1/1986). For the **150km grid** network, the latitude, ϕ, and longitude, λ, of any point (x,y) on the grid may be calculated from the following:

$$\Phi = 90 - \frac{360}{\pi}\arctan\left[\frac{r}{M}\right] \qquad \text{(A1)}$$

$$\lambda = -32 + \frac{180}{\pi}\arctan\left[\frac{x - xpol}{ypol - y}\right] \qquad \text{(A2)}$$

in which:

xpol	=	3.	(x coordinate of the North Pole)
ypol	=	37.	(y coordinate of the North Pole)
d	=	150km	(grid length at 60°N)
$\pi/3$	=	60°N	(defining latitude)
R	=	6370km	(radius of the earth)
M	=	R/d[1 + sin(π/3)]	(Number of grid distances between the North Pole and the equator).
r	=	$\sqrt{[(x - xpol)^2 + (y - ypol)^2]}$	(grid distance from the North Pole to point (x,y))

The number -32 in eq. (A2) arises in determination of the longitude as the y-axis is oriented parallel to 32°W (defined as a negative longitude if west of Greenwich).

The x and y coordinate in the EMEP grid of any given latitude and longitude can be found from:

$$x = xpol + M\tan\left[\frac{\pi}{4} - \frac{\phi}{2}\right]\sin(-32 + \lambda) \qquad \text{(A3)}$$

$$y = ypol - M\tan\left[\frac{\pi}{4} - \frac{\phi}{2}\right]\cos(-32 + \lambda) \qquad \text{(A4)}$$

The definition of the **50km grid** network follows also from the equations A1-A4 simply by redefining xpol, ypol and d to:

xpol = 43.
ypol = 121.
d = 50km

As the 50km grid is a 3x3 subdivision of the 150km grid, conversion from the 150km coordinates to the 50km coordinates can be obtained from:

$x_{50} = 3(x_{150}) + 34.$
$y_{50} = 3(y_{150}) + 10.$

Throughout, it should be noted that integer coordinates i, j are derived from real coordinates x, y, as nearest integer, and thus refer to the centres of the grid squares. Coordinate i in the x-direction, therefore, represents from (x-0.5) to (x+0.5), and j represents (y-0.5) to (y+0.5).