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NONLINEAR EFFECTS IN THE SOURCE-RECEPTOR MATRICES COMPUTED WITH THE EMEP EULERIAN ACID DEPOSITION MODEL

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Preface and acknowledgements

This document was prepared for the twenty fourth Session of the Steering Body of EMEP (Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe). It presents the role of non-linear effects on computed source-receptor matrices with the EMEP Eulerian Acid Deposition model. Two different aspects are analysed. Firstly, nonlinear effects related to the transport from one single country-emitter to individual countries-receptors are presented and discussed. Secondly, the influence of nonlinear effects of the deposition projections for the year two 2010 are described. Both aspects illustrate the implications on non-linear effects in the EMEP model computations on the emission reduction strategies in Europe.

I would like to thank my colleagues from MSC-W of EMEP in Oslo for valuable discussions and suggestions on the presented results. Huge computational task, which required a 27 day model run on CRAY T3E, would not be possible without support from the Norwegian University of Science and Technology (NTNU) in Trondheim.

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1. Introduction

The source-receptor matrices provide the important connection between the emissions and depositions of a pollutant over different time and spatial scales. They play a very important role in the air pollution policy, especially in developing strategies for the reduction of sulphur and nitrogen emissions in Europe. The country-to-grid and country-to-country source-receptor matrices for sulphur, oxidized nitrogen and reduced nitrogen are computed annually at the Meteorological Synthesizing Centre - West (MSC-W) in Oslo within the framework of EMEP (Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe).

The source-receptor matrices for sulphur, oxidized nitrogen and reduced nitrogen are presently computed with the Eulerian Acid Deposition model developed at MSC-W. In 1999 this model was applied for the first time for routine computations of the concentrations, depositions, source-receptor matrices and country budgets for Europe in the 50 km grid. A description of the latest model version and comparison of the model results with the measurements for 1998 can be found in Olendrzynski (2000). A description of the model application for computing country budgets and source-receptor matrices for Europe is given by Bartnicki (1999). The most recent information about the Eulerian Acid Deposition model and its results can be found on the internet at: **www.emep.int**.

The country-to-grid source-receptor matrices serve as a crucial input to the Regional Acidification INformation and Simulation (RAINS) model (Alcamo *et al.*, 1990), which operates in the EMEP Centre for Integrating Assessment Modelling (CIAM) located in the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria. The RAINS model is used for analysing different emission reduction scenarios for Europe and for the analysis of the cost related to each scenario. Optimal emission reduction scenarios are the main products of the analysis. More information on the RAINS model and CIAM activities can be found on internet at: **www.iiasa.ac.at/~rains**.

In general there exist two major problems when computing source-receptor matrices with the Eulerian model. The first one is caused by nonlinearities in the model chemistry. The second is created by nonlinearities imposed by the numerical methods and especially by the numerical algorithm used for the advection equation. In addition, these nonlinearities can interact amplifying the unwanted effects. In practical applications these problems arise during the computations of depositions resulting from the emissions in European countries, when the sum of individual contributions is not necessary equal to the total deposition from all the European sources (Bartnicki, 1999). Another effect of the non-linearities can be observed in the process called scaling, when depositions are computed not directly from the model but as a product of modified emissions and source-receptor matrices. The second one is especially important when computing future depositions based on the projected emissions.

Non-linear effects can create errors in the computed depositions related to the emissions from individual countries, and in general, in the source-receptor matrices. Presentation and analysis of such effects and the errors created by them is the main subject of this note.

The presented here study of non-linear effects is organized in two major parts. In the first part, non-linear effects related to a single country as the emitter-source are analysed based on the model results for 1997. The main questions to be answered in this part are:

- What is the departure from a linear relationship between emissions and depositions of sulphur, oxidized nitrogen and reduced nitrogen?
- How strong is the interaction between different compounds in the source-receptor relationships?
- Is the non-linear effect stronger in dry or wet deposition?
- Is there any geographical pattern in nonlinear effects on total (dry+wet) deposition?
- What are the nonlinear effects on the depositions computed for individual countries-receptors?

The second part of the study deals with an important practical problem of estimating non-linear effects in the future deposition projections. In this part, depositions computed directly from the model using 1998 meteorology and projected 2010 emission data are compared with the depositions obtained from the linear scaling (product of the 1998 source-receptor matrices and projected 2010 emission data). The differences in the results are used for the estimation of errors caused by the non-linear effects in the projected depositions.

2. Non-Linear Terms in the Model Chemistry

The first source of the non-linear effects in the model computations is the algorithm applied for the numerical solution of the advection terms in the model equations. As an example let us consider, the transport of pollutant, without any chemistry involved, from the two different emission sources A and B. We run the model, first with the emissions from source A only, then with the emissions from source B only, and finally with the emissions from both sources A and B. For a linear model, the sum of computed depositions from the first two runs should be exactly equal to the depositions computed from the last run. This is not true for the EMEP Eulerian Acid Deposition model, because of the artificial nonlinear effects introduced by the advection algorithm. In practical applications, these effects are relatively small differences (below 3%) and occur mainly on the borders between the source areas.

The second source of the of the non-linear effects is related to the model chemistry. An illustration of the chemical scheme of the EMEP Eulerian Acid Deposition model is shown in Figure 1. The major source of non-linear effects in the model chemistry is in the production of ammonium nitrate from nitric acid and ammonia, because this production depends on the actual air concentrations of nitric acid and ammonia, as well as on temperature and relative humidity (details in Bartnicki *et al.*, 1998). Following the example with two emission sources A and B, the sum of the depositions computed in the runs with single sources will be again different from the deposition computed in the run with sources A and B. This applies to both, oxidized nitrogen and reduced nitrogen depositions (sulphur deposition is also affected). The differences in the depositions are caused by different proportions of the concentrations of nitric acid, ammonia and ammonium nitrate. For example, the dry deposition of ammonium nitrate, which is in the aerosol form, is lower then the dry depositions of nitric acid and ammonia which occur as gases. On the other hand, wet deposition of ammonium nitrate is more efficient than wet depositions of nitric acid and ammonia.

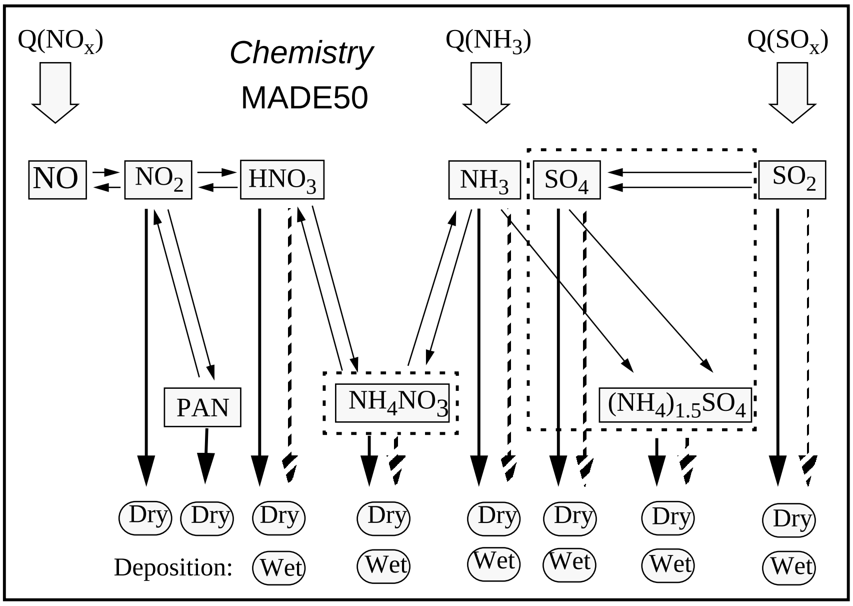

***Figure 1*:** Illustration of the chemical scheme of the EMEP Eulerian Acid Deposition model. Dashed boxes denote nitrate and sulphate particles occurring in two forms. Solid and dashed thick arrows represent dry and wet deposition, respectively.

The non-linear effects have to be taken into account when computing depositions resulting from individual EMEP countries as emitters. In order to reduce them, the depositions resulting from one emitter country are calculated using so called "reverse method" (Bartnicki, 1999). In this method, depositions from all sources are calculated first. Then depositions are calculated with the emissions from all sources, except for the emissions from the country of interest. Finally, the deposition from the emitter country is calculated as a difference between depositions obtained in step one and two. In this way, the level of nitric acid and ammonia air concentrations are more realistic than in the computations with only one country as an emitter.

The combined non-linear effects created by the numerical algorithm applied to advection term and the model chemistry has some influence on the computed source-receptor matrices and depositions. Before estimating and discussing these effects, the definitions of the source-receptor matrices are given in the next Chapter.

3. Definitions and Applications of the Source-Receptor and the Blame Matrices

Different types of the source-receptor matrices are useful for the purpose of policy. At present the most general, grid-to-grid source-receptor matrix can not be computed with the three-dimensional Eulerian model because of the excessive demands for computer resources and problems with the artificial numerical diffusion. Therefore, only country-to-grid and country-to-country source-receptor matrices are computed routinely at MSC-W of EMEP with the EMEP Eulerian Acid Deposition model.

3.1 Definitions of the Source Receptor Matrices and the Blame Matrices

Different types of the source-receptor, and the so called, blame matrices are calculated at MSC-W based on the results of the EMEP Eulerian Acid Deposition Model. Concerning the time scale, it is possible to calculate monthly and even daily matrices. However, the annual matrices are most often used for scientific and policy applications and the annual matrices will be the ones analysed in this study.

In terms of spatial resolution, it is theoretically possible to achieve grid-to-grid resolution, but here we will focus on the country-to-country matrices, which are calculated from the country-to-grid matrices. Finally, source-receptor matrices can be calculated for the concentrations and dry, wet and total deposition. For practical applications the most important are source-receptor matrices for total (dry+wet) deposition. The annual country-to-grid source-receptor matrices are defined in the following way:

$$
\begin{aligned}
SR_{ijk}^{sox} &= \left[S_{ox}\right]_{ijk} / \left[SO_2\right]_k \\
SR_{ijk}^{nox} &= \left[N_{ox}\right]_{ijk} / \left[NO_2\right]_k \\
SR_{ijk}^{nrd} &= \left[N_{rd}\right]_{ijk} / \left[NH_3\right]_k
\end{aligned}
\qquad (1)
$$

where: SR_{ijk}^{sox}, SR_{ijk}^{nox}, SR_{ijk}^{nrd} are the source-receptor matrices from country k to the grid *(i,j)* for sulphur, oxidized nitrogen and reduced nitrogen, respectively; $[S_{ox}]_{ijk}$, $[N_{ox}]_{ijk}$, $[N_{rd}]_{ijk}$ are annual depositions of sulphur, oxidized nitrogen and reduced nitrogen, respectively to the grid *(i,j);* $[SO_2]_k$, $[NO_2]_k$, $[NH_3]_k$ are annual total emissions of SO_2, NO_2 and NH_3 from country k.

The country-to-grid source-receptor matrices are calculated by computing, in the first step, annual depositions (dry + wet) in the model domain resulting from the emissions in each individual country or another emission source (e.g. ship traffic, volcanoes etc.). In the second step, the deposition fields are divided by the total annual emissions from a given source. At MSC-W, only the first step of this process is performed producing country-to-grid deposition matrices $[S_{ox}]_{ijk}$, $[N_{ox}]_{ijk}$, $[N_{rd}]_{ijk}$. The second step is performed, at CIAM, where the country-to-grid source-receptor matrices are directly used in the RAINS model for analysing different emission reduction scenarios. Based on the country-to-grid source-receptor matrices, the so called country-to-country blame matrices are computed each year by the MSC-W of EMEP. The country-to-country blame matrices $BL_{ie,ir}^{sox}$, $BL_{ie,ir}^{nox}$, $BL_{ie,ir}^{nrd}$, for sulphur, oxidized nitrogen and reduced nitrogen, respectively, give the deposition in country *ir* due to emissions in country *ie* and are calculated in the following way:

$$BL_{ie,\,ir}^{sox} = \sum_{ij \subset R_{ir}} \left[S_{ox}\right]_{ij,\,ie}$$
$$BL_{ie,\,ir}^{nox} = \sum_{ij \subset R_{ir}} \left[N_{ox}\right]_{ij,\,ie} \qquad (2)$$
$$BL_{ie,\,ir}^{nrd} = \sum_{ij \subset R_{ir}} \left[N_{rd}\right]_{ij,\,ie}$$

where *ie* is the emitters index, *ir* is the receptor index; $\left[S_{ox}\right]_{ij,\,ie}$, $\left[N_{ox}\right]_{ij,\,ie}$ and $\left[N_{rd}\right]_{ij,\,ie}$ are depositions of sulphur, oxidized nitrogen and reduced nitrogen, respectively, in the grid *(i,j)* due to emissions in the country *ie*. The summation is done over all grids *(i,j)* belonging to the receptor R_{ir}. The country-to-country blame matrices are also often called transfer matrices, or simply source-receptor matrices, and the blame matrices are routinely reported to the Steering Body of EMEP every year.

3.2 Applications of the Source Receptor and the Blame Matrices

An important assumption in calculating source receptor matrices is the linearity of the model equations. This assumption is not entirely fulfilled in the EMEP Eulerian Acid Deposition model because of the non-linear chemical reactions. Although departure from the linear relationship is relatively small in the model, it creates a problem when computing source-receptor matrices.

An important additional assumption in calculations and applications of the source-receptor matrices states that there is no interaction between different compounds. It means that, for example, reduction of the nitrogen oxides emissions effects only the deposition of oxidized nitrogen, and has no effect on the deposition of sulphur and reduced nitrogen. This assumption is also not entirely fulfilled and the implications of this fact will be further discussed in the paper.

With the above assumptions, the source-receptor matrices can be used for analysing different emissions scenarios. For given emission scenario with the new total emissions $[SO_2]_k^{new}$, $[NO_2]_k^{new}$, $[NH_3]_k^{new}$ from the emitter *k*, new depositions $[S_{ox}]_{ijk}^{new}$, $[N_{ox}]_{ijk}^{new}$, $[N_{rd}]_{ijk}^{new}$ in the model grid can be calculated as:

$$\left[S_{ox}\right]_{ijk}^{new} = SR_{ijk}^{sox} \cdot \left[SO_2\right]_k^{new}$$
$$\left[N_{ox}\right]_{ijk}^{new} = SR_{ijk}^{nox} \cdot \left[NO_2\right]_k^{new} \qquad (3)$$
$$\left[N_{rd}\right]_{ijk}^{new} = SR_{ijk}^{nrd} \cdot \left[NH_3\right]_k^{new}$$

Following Equation (3), the source-receptor matrices computed with the EMEP Eulerian Deposition model are used in the integrated model RAINS (Regional Acidification INtegration and Simulation Model) developed at IIASA (International Institute for Applied Systems Analysis) in Vienna, Austria (Alcamo *et al.*, 1989) for calculating costs of different emission reduction scenarios and also for developing the optimal emission reduction scenarios for Europe.

The blame matrices are used routinely at MSC-W for scaling the depositions to individual receptors following updated emissions from the EMEP countries and other sources. The linear scaling is done according to the following equations:

$$\begin{aligned} \left[S_{ox}\right]_{ir}^{new} &= \sum_{ie} BL_{ie,\,ir}^{sox} \cdot \left[SO_2\right]_{ie}^{new} \big/ \left[SO_2\right]_{ie}^{old} \\ \left[N_{ox}\right]_{ir}^{new} &= \sum_{ie} BL_{ie,\,ir}^{sox} \cdot \left[NO_2\right]_{ie}^{new} \big/ \left[NO_2\right]_{ie}^{old} \\ \left[N_{rd}\right]_{ir}^{new} &= \sum_{ie} BL_{ie,\,ir}^{sox} \cdot \left[NH_3\right]_{ie}^{new} \big/ \left[NH_3\right]_{ie}^{old} \end{aligned} \tag{4}$$

where $\left[S_{ox}\right]_{ir}^{new}$, $\left[N_{ox}\right]_{ir}^{new}$, $\left[N_{rd}\right]_{ir}^{new}$ are the new total depositions in the receptor country *ir*, "*new*" means new emissions, and "*old*" means old emissions.

4. Non-Linearities Related to a Single Country as a Source

Although departure from the linear relationship is relatively small in the model, it creates a problem when computing source-receptor matrices. In order to estimate the departure from the linear relationship in practical applications, a simple numerical test was performed (Bartnicki, 2000).

In the numerical experiment, Germany was chosen as an emitter of SO_2, NO_2 and NH_3 for the entire year 1997. For each compound the latest version of the EMEP Eulerian Acid Deposition model was run, first with the complete emissions and then 10 times with German total emission reduced by 10%, from 90% to 0% of the initial value. Reductions were applied to each model grid cell belonging to Germany. Annual 1997 depositions of oxidized sulphur, oxidized nitrogen and reduced nitrogen to all individual EMEP countries and other receptors, were computed for each run. For each run and for each receptor, the departure from linearity was computed in percent of the deposition to the receptor.

4.1 Non-Linear Effects on Country-to-Country Relations

Computed deposition reduction in the receptor country can be presented as a function of emission reduction in Germany. Examples for Germany, Poland and Portugal as receptors are shown in Figure 2. The dotted lines in Figure 2 represent the model results and straight lines represent a perfect linear relationships between emissions and depositions.

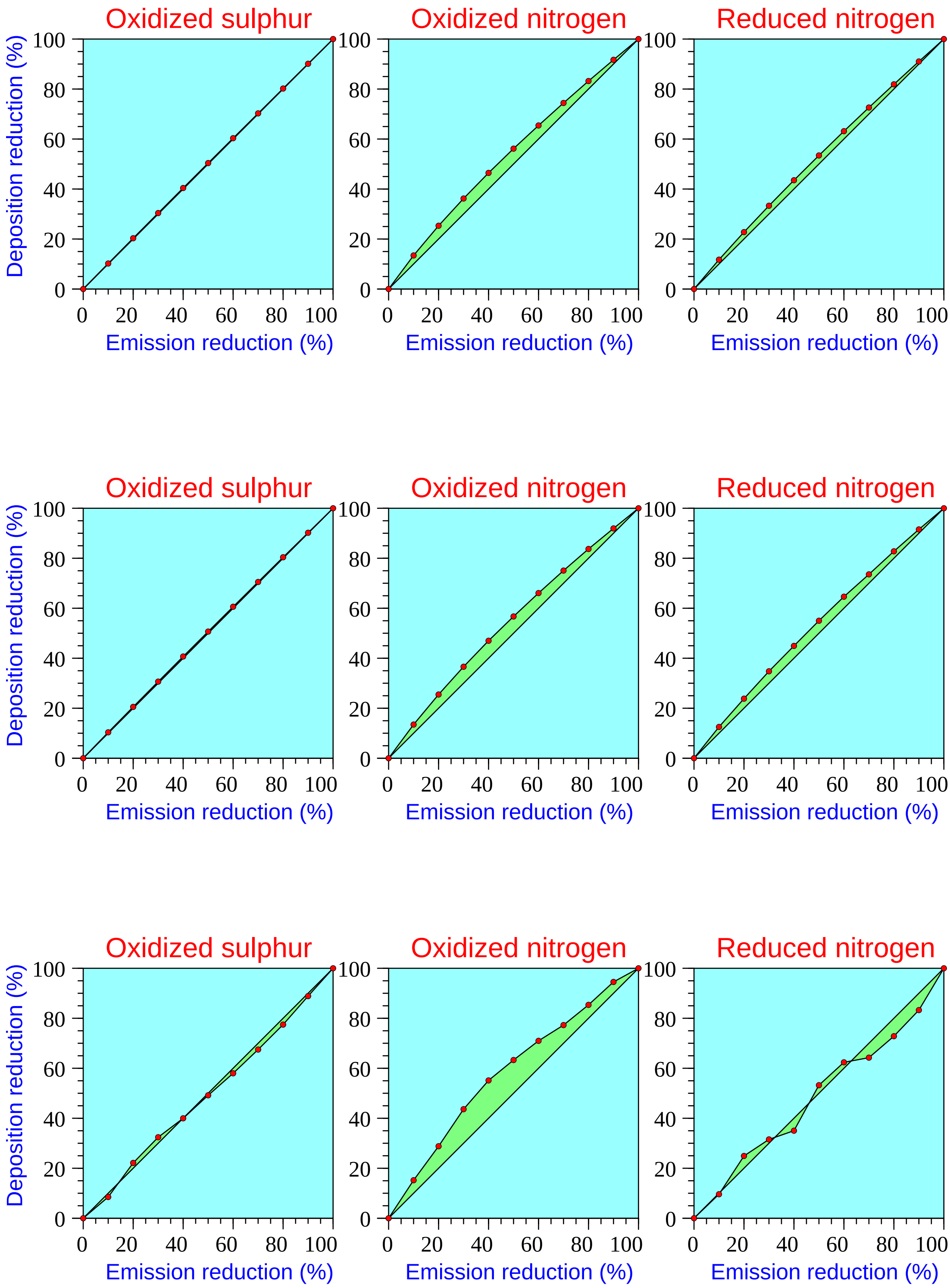

***Figure 2*:** Departure from the linear relationship between emissions in Germany and depositions of oxidized sulphur, oxidized nitrogen and reduced nitrogen in the three receptor countries: Germany, Poland and Portugal (from the top).

In case of Portugal as a receptor, the departure from linearity is largest (in absolute terms) for oxidized nitrogen (maximum 15.1%) and smallest for oxidized sulphur (maximum 2.5%). Also for Germany and Poland as receptors, the departure from linearity is largest (in absolute terms) for oxidized nitrogen (maximum 6.4% and 7.0%, respectively) and smallest for oxidized sulphur (maximum 0.4% and 0.7%, respectively).

Similar results to those presented in Figure 2 have been examined for all other European countries as receptors, and the results are shown in Table 1. For oxidized sulphur the largest (in absolute terms) departure (8%) can be noticed for Cyprus as a receptor. For oxidized nitrogen and reduced nitrogen maximum departures, 48.7% and 123.8%, occur for Italy as a receptor. For all European countries as receptors, large departures from the linear relationship between deposition and emission can be noticed for oxidized nitrogen (on average 11.7% in absolute terms) and for reduced nitrogen (on average 11.3% in absolute terms). For oxidized sulphur, departures are relatively small, on average 1.1% in absolute terms. For all compounds, the departure from linearity increases with the distance between the emitter and receptor. It is also larger for receptors with relatively small depositions.

The maxima of the departure from linearity, marked in Bold-Italics font in Table 1, can be misleading, because they occur in the receptor countries where contribution from Germany is low or very low, in all cases less then 2%. Therefore, in Table 2 only those countries were included to which contribution from Germany to total deposition was at least 5%. This table shows clearly that the non-linear effects are the most important for oxidized nitrogen, less important for reduced nitrogen, and practically not important for oxidized sulphur.

4.2 Comparison of Non-Linear Effects on Dry and Wet Deposition

The departures from the linear behaviour were examined separately for the wet and dry deposition. The results are presented only for the countries to which the contribution from Germany to the total deposition was at least 5%. The departures from linearity for these countries are shown in Table 3 and Table 4, for the dry and wet deposition, respectively.

The comparison of average non-linear effects on the dry, wet and total depositions of three compounds in the EMEP countries is given in Figure 3. Wet deposition shows clearly a more non-linear behaviour than dry in the case of oxidized nitrogen and slightly more in the case of sulphur. Non-linear effects in the dry deposition are slightly more visible than in the wet deposition in case of reduced nitrogen.

For all types of the deposition, the non-linear effects are most pronounced in the case of oxidized nitrogen, because of the non-linearities involved in the production of ammonium nitrate, as explained in Chapter 2. Since the wet deposition of aerosol, compared to the dry deposition, is very rapid and it prevails farther away from the source, non-linear effects are more significant for the wet deposition of oxidized nitrogen, than for the dry deposition.

Table 1: Maximum absolute departure (in %) from the linear relationship between the 1997 emissions in Germany and the annual 1997 depositions in the receptor countries.

Receptor country	**Compound**		
	Sulphur	**Oxidized N**	**Reduced N**
Austria	1.0	12.4	6.3
Belgium	0.6	8.3	4.9
Bulgaria	0.9	9.9	6.2
Denmark	0.8	8.2	8.3
Finland	0.5	15.2	5.5
France	0.3	6.0	2.3
Germany	0.4	6.4	3.5
Greece	1.5	11.7	49.9
Hungary	0.2	13.0	0.5
Iceland	2.3	6.8	16.5
Ireland	1.7	4.5	5.2
Italy	1.4	***48.7***	***123.8***
Luxembourg	0.4	7.9	5.3
Netherlands	0.2	10.1	6.9
Norway	0.8	9.5	5.0
Poland	0.7	7.0	5.0
Portugal	2.5	15.1	7.2
Romania	0.5	6.2	9.4
Spain	1.4	15.6	5.8
Sweden	1.1	11.1	3.9
Switzerland	1.0	13.7	8.4
Turkey	1.6	11.8	3.3
United Kingdom	0.6	7.9	8.3
Remaining Land Areas	1.9	9.3	1.9
Baltic Sea	0.7	15.5	6.7
North Sea	0.1	13.1	8.8
Remaining NE Atlantic Ocean	1.2	4.6	4.3
Mediterranean Sea	1.7	9.9	13.1
Black Sea	1.2	10.4	4.0
Russian Federation	0.8	5.3	3.0
Belarus	0.2	37.8	9.9
Ukraine	0.2	1.6	10.9
Republic of Moldova	1.3	8.2	45.5
Estonia	0.4	16.4	6.8
Latvia	0.9	14.4	5.2
Lithuania	0.6	15.0	5.6
Czech Republic	1.7	7.4	5.1
Slovakia	0.4	16.4	7.4
Slovenia	0.6	6.3	3.8
Croatia	0.6	1.2	3.3
Bosnia and Hercegovina	0.1	13.3	5.2
Yugoslavia	0.3	5.5	9.1
The Former Yugoslav Republic of Macedonia	1.0	10.5	9.0
Cyprus	***8.0***	15.7	23.9
Armenia	3.3	22.4	10.6
EMEP Average	**1.1**	**11.7**	**11.3**

Table 2: Maximum absolute departure (in %) from the linear relationship between the 1997 emissions in Germany and the annual 1997 depositions in the receptor countries. Only countries with a not less than 5% contribution to the total deposition are shown.

Receptor country	**Compound**		
	Sulphur	**Oxidized N**	**Reduced N**
Austria	1.0	12.4	6.3
Belgium	0.6	8.3	4.9
Denmark	0.8	8.2	8.3
Finland	0.5	15.2	5.5
France	0.3	6.0	2.3
Germany	0.4	6.4	3.5
Hungary	0.2	13.0	0.5
Iceland		6.8	***16.5***
Ireland		4.5	
Luxembourg	0.4	7.9	5.3
Netherlands	0.2	10.1	6.9
Norway	0.8	9.5	5.0
Poland	0.7	7.0	5.0
Romania		6.2	
Sweden	1.1	11.1	3.9
Switzerland	1.0	13.7	8.4
Baltic Sea	0.7	15.5	6.7
North Sea	0.1	13.1	8.8
Remaining NE Atlantic Ocean		4.6	4.3
Belarus		***37.8***	
Ukraine		1.6	
Estonia	0.4	16.4	6.8
Latvia	0.9	14.4	5.2
Lithuania	0.6	15.0	5.6
Czech Republic	***1.7***	7.4	5.1
Slovakia	0.4	16.4	7.4
Slovenia	0.6	6.3	3.8
Croatia	0.6	1.2	
Bosnia and Hercegovina	0.1	13.3	5.2
Yugoslavia		5.5	
EMEP Average	**0.6**	**13.7**	**6.1**

Table 3: Maximum absolute departure (in %) from the linear relationship between the 1997 emissions in Germany and the annual 1997 dry depositions in the receptor countries. Only countries with a not less than 5% contribution to the total deposition are shown.

Receptor country	**Compound**		
	Sulphur	**Oxidized N**	**Reduced N**
Austria	0.6	0.8	6.3
Belgium	0.1	5.5	4.9
Denmark	0.1	2.3	8.3
Finland	3.1	7.2	5.5
France	0.5	1.6	2.3
Germany	0.3	1.8	3.5
Hungary		8.1	0.5
Iceland		17.1	***16.5***
Ireland		1.7	
Luxembourg	0.7	3.7	5.3
Netherlands	0.3	7.5	6.9
Norway	***4.5***	1.9	5.0
Poland	0.1	0.7	5.0
Romania		26.9	
Sweden	0.6	5.6	3.9
Switzerland	1.0	11.2	8.4
Baltic Sea	0.1	12.9	6.7
North Sea	0.5	67.9	8.8
Remaining NE Atlantic Ocean		5.7	4.3
Belarus		24.4	
Ukraine		***106.3***	
Estonia	1.1	4.9	6.8
Latvia	0.4	4.3	5.2
Lithuania	0.5	1.3	5.6
Czech Republic	1.1	4.1	5.1
Slovakia	0.2	0.6	7.4
Slovenia	1.5	0.3	3.8
Croatia	1.1	0.1	
Bosnia and Hercegovina	0.7	8.9	5.2
Yugoslavia		39.5	
EMEP Average	**0.9**	**12.8**	**5.9**

Table 4: Maximum absolute departure (in %) from the linear relationship between the 1997 emissions in Germany and the annual 1997 wet depositions in the receptor countries. Only countries with a not less than 5% contribution to the total deposition are shown.

Receptor country	Compound		
	Sulphur	**Oxidized N**	**Reduced N**
Austria	1.9	22.6	4.9
Belgium	2.9	14.2	6.3
Denmark	1.6	12.7	3.6
Finland	0.7	20.8	4.5
France	0.2	12.6	4.0
Germany	3.7	17.8	3.5
Hungary		44.0	3.2
Iceland		6.6	***7.0***
Ireland		13.1	
Luxembourg	2.7	13.7	4.7
Netherlands	2.8	13.3	2.9
Norway	0.6	11.8	4.0
Poland	1.8	29.6	3.4
Romania		4.3	
Sweden	1.4	17.1	3.9
Switzerland	1.7	19.6	4.5
Baltic Sea	1.7	16.3	3.8
North Sea	1.1	11.6	5.5
Remaining NE Atlantic Ocean		5.0	3.7
Belarus		***52.4***	
Ukraine		7.7	
Estonia	0.4	37.9	5.7
Latvia	1.2	33.4	4.3
Lithuania	1.0	36.8	4.7
Czech Republic	***3.3***	27.5	3.8
Slovakia	0.6	0.6	4.0
Slovenia	0.5	0.3	2.3
Croatia	0.2	0.1	
Bosnia and Hercegovina	0.4	41.9	3.3
Yugoslavia		4.7	
EMEP Average	**1.9**	**22.6**	**4.9**

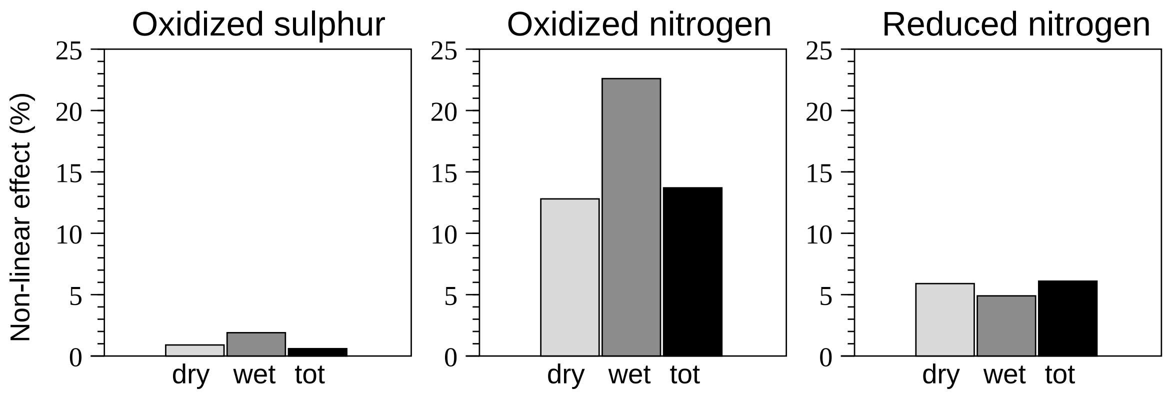

Figure 3: Nonlinear effects in the relationship between emissions in Germany and dry, wet and total (dry+wet) depositions of oxidized sulphur, oxidized nitrogen and reduced nitrogen. Nonlinear effect means departure from linearity in percent of the deposition to the receptor, averaged over all countries with at least 5% contribution from Germany.

4.3 Interactions Between the Compounds

In the computations and applications of the source-receptor the assumptions are made that:

- deposition of sulphur is independent of the emissions of NO_2 and NH_3,
- deposition of oxidized nitrogen is independent of the emissions of SO_2 and NH_3,
- deposition of reduced nitrogen is independent of the emissions of SO_2 and NO_2.

Because of the non-linear chemical reactions in the model. Therefore, we expect some interactions between emissions and depositions different compounds the above assumptions are not entirely fulfilled in the practical applications. To illustrate this problem, the results of the model simulations (described in Section 2) of the transport and deposition of sulphur, oxidized nitrogen and reduced nitrogen in 1997 are shown in Figure 4. In this figure, all depositions in Hungary are given as functions of the 1997 emission reduction in Germany. The units of the emission reduction are percents of the annual total German emissions for 1997. The units of the deposition reduction are percents of the depositions to Hungary due to emissions in Germany (German contributions) of each of the three compounds.

Solid lines in Figure 4 represent a perfect case with fulfilled assumptions and lack of interactions between different compounds. The dotted lines show the model results. When SO_2 emissions are reduced in Germany, deposition of sulphur in Hungary is reduced in an almost proportional way, but deposition of oxidized nitrogen in Hungary increases while deposition of reduced nitrogen slightly declines. Deposition of sulphur in Hungary is practically independent of NO_2 and NH_3 emissions. Deposition of reduced nitrogen in Hungary is rising when the German NO_2 emission decreasing. Also, the deposition of oxidized nitrogen in Hungary is increasing, when the German NH_3 emissions are falling.

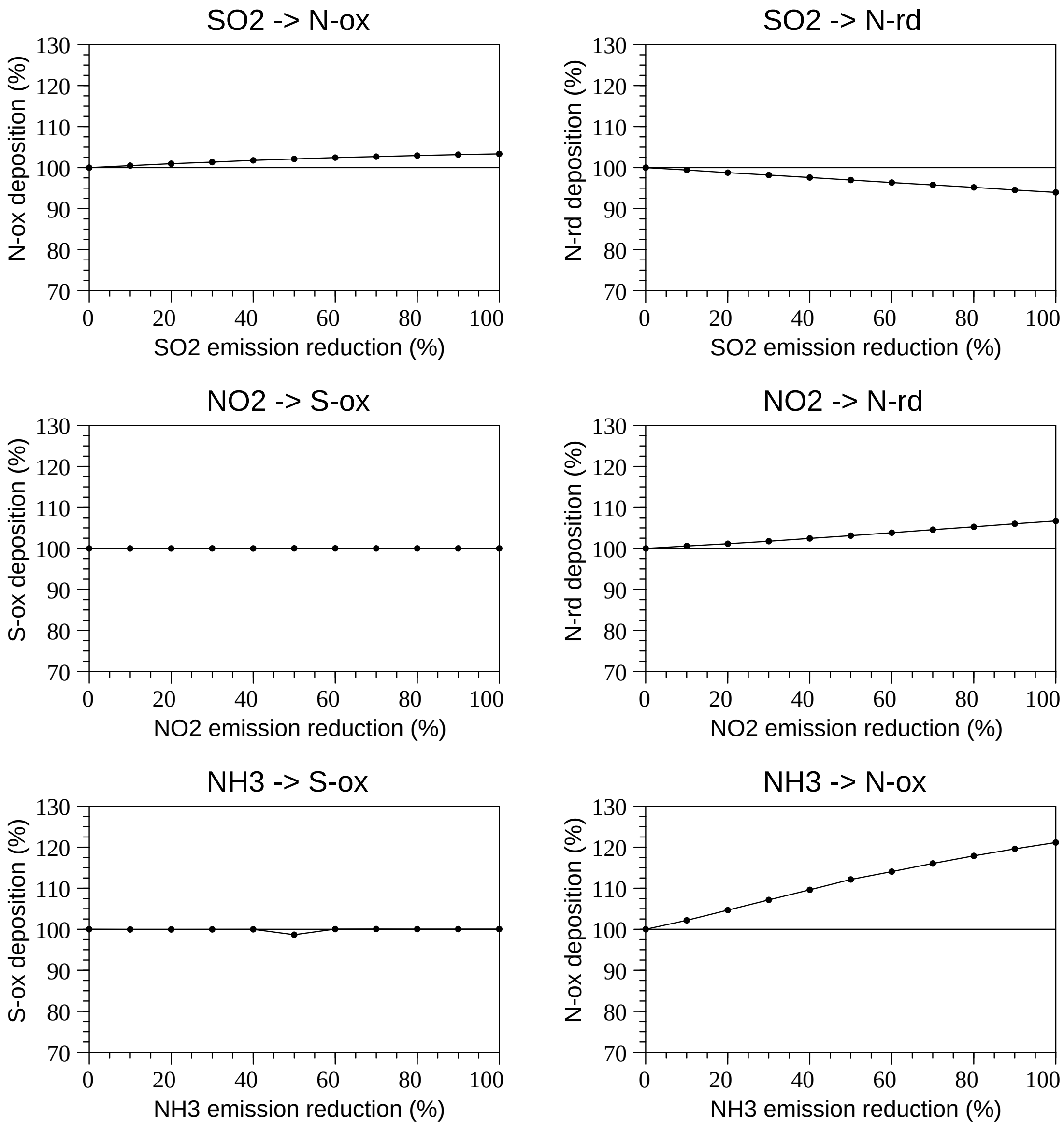

Figure 4: Interactions between SO_2, NO_2 and NH_3 emissions in Germany and depositions of oxidized sulphur, oxidized nitrogen and reduced nitrogen in Hungary in 1997. A more detailed explanation of this figure is in the text.

A similar analysis, like for Hungary, was performed for all other EMEP countries as receptors. The results of this analysis are summarized in Table 5. The country codes used in Table 5 and the following tables are explained in Appendix A.

The numbers in Table 5 indicate an increase (plus sign) or a decrease (minus sign) of respective depositions corresponding to a 100% reduction of the emissions in Germany. The maximum (or minimum) values in each column, which correspond to the deposition of one of the six compounds, are marked in Bold-Italics face.

Table 5: Interactions between the emission reductions of different compounds in Germany and the deposition reductions (in percent of the compound deposition) in individual EMEP countries. The numbers indicate increase (plus sign) or a decrease (minus sign) of respective depositions corresponding to a 100% reduction of emissions in Germany.

Receptor	SO_2 emission		NO_2 emission		NH_3 emission	
	S dep	N-ox dep	S dep	N-rd dep	S dep	N-ox dep
AT	5	1	0	3	0	25
BE	7	-7	0	-13	0	-4
BG	-11	15	0	19	0	13
DK	6	-1	0	-4	0	-3
FI	6	14	0	19	0	25
FR	5	-5	0	-6	0	4
DE	5	-3	0	-4	0	-22
GR	-15	4	0	12	0	7
HU	3	-6	0	7	0	21
IS	8	14	0	18	0	5
IE	8	10	0	13	0	7
IT	-1	0	0	3	0	13
LU	4	-4	0	-8	0	-5
NL	4	-4	0	-10	0	-3
NO	9	11	0	23	0	13
PL	12	-4	0	0	0	13
PT	-8	31	-1	***34***	0	7
RO	-4	7	0	17	0	21
ES	-6	25	0	19	0	8
SE	11	6	0	13	0	10
CH	4	1	0	1	0	17
TR	-18	38	0	23	0	8
GB	12	8	0	14	0	1
REM	-15	39	0	29	0	5
BAS	7	1	0	0	0	21
NOS	9	1	0	1	0	16
ATL	2	18	0	22	0	9
MED	-12	-5	0	24	0	7
BLS	-14	15	0	20	0	11
RU	-6	21	0	22	0	18
BY	2	4	0	10	0	27
UA	-4	6	0	12	0	22
MD	-10	-2	0	10	0	17
EE	7	8	0	21	0	27
LV	10	9	0	18	0	17
LT	9	7	0	15	0	23
CZ	13	-3	0	-1	0	4
SK	5	2	0	9	0	***26***
SI	1	-3	0	4	0	19
HR	2	-5	0	8	0	17
BA	1	8	0	16	0	20
YU	-3	8	0	16	0	21
MK	-12	15	0	15	0	14
CY	-19	-50	0	50	0	3
AM	***-22***	***120***	0	20	0	4

It should be stressed that the values for Armenia and Cyprus in Table 5 are rather uncertain because German contributions to the deposition, and total depositions, in these countries are very low and small changes in absolute values of the deposition can lead to a large percentage.

Reduction of NO_2 emission in Germany leads to the increase of reduced nitrogen depositions in most (38 out of 45) of the EMEP countries. The same applies to the reduction of NH_3 emission in Germany and depositions of oxidized nitrogen in the EMEP countries (increase in 40 out of 45 countries). There is no such pattern for emissions of sulphur and depositions of oxidized and reduced nitrogen, where increases and decreases are equally spread among EMEP countries.

The results presented in this Section show, that as expected, in practical applications, there exist problem with the interactions between emissions and depositions of different compounds. However, errors due to such interactions are not significant compared to other sources of uncertainties, for example, lack of meteorological data in the case of long term projections of the depositions.

5. Errors in the Deposition Projections Caused by the Non-Linear Effects

In order to analyse errors caused by the non-linear effects on the future deposition projections, depositions of sulphur, oxidized nitrogen and reduced nitrogen in the year 2010 were calculated with two methods: linear scaling and direct application of the EMEP Eulerian Acid Deposition model. Differences between depositions calculated with these two methods are a good measure of the error related to non-linear effects. However, it should be mentioned that this error is only one of the possible sources of the uncertainties in computed depositions, and other important sources (e.g. lack of actual meteorology for the year 2010) are not taken into account in this analysis.

5.1 Emission Projections for the Year 2010

The 2010 emission projections of SO_2, NO_2 and NH_3 are taken from the MSC-W database (Venstreng, 2000) in the form of annual total emissions. The annual total emissions for the year 1998 are also shown in Table 6, as well as, the ratios between 2010 and 1998 emissions.

Compared to the 1998 emissions, the 2010 emissions, for all compounds and many European countries, are much lower, following the Gothenburg Protocol. However, if we take into account the entire EMEP domain, the 2010 emissions are 7% and 8% higher for sulphur dioxide and nitrogen dioxide, respectively. The ammonia emissions remain on the same level (0.1% higher in 2010 than in 1998).

Table 6 shows that compared to 1998 emissions the most significant increase of SO2 emissions in 2010 (in absolute terms) is expected in the Russian Federation, Ukraine and Spain. Concerning NO2 emissions, significant increase in 2010 (in absolute terms) is expected in Turkey, the Russian Federation and Ukraine.

Table 6: The annual total SO_2, NO_2 and NH_3 emissions for the years 1998 and 2010 in 100 tonnes (S, N), and ratios (R1, R2, R3) between 2010 and 1998 emissions for EMEP sources.

Country (region)	Emissions and emission ratios								
	SO_2			NO_2			NH_3		
	1998	2010	R1	1998	2010	R2	1998	2010	R3
AL	360	360	1.0	73	73	1.0	255	255	1.0
AM	17	360	21.8	33	140	4.2	206	206	1.0
AT	230	195	0.8	517	326	0.6	593	544	0.9
BY	950	2400	2.5	499	548	1.1	1804	1804	1.0
BE	1015	530	0.5	916	551	0.6	815	609	0.7
BA	2400	2400	1.0	243	243	1.0	255	255	1.0
BG	6255	4280	0.7	679	810	1.2	544	889	1.6
HR	447	350	0.8	231	265	1.1	192	247	1.3
CY	245	195	0.8	67	70	1.0	33	33	1.0
CZ	2215	1415	0.6	1257	870	0.7	659	1285	2.0
DK	385	250	0.6	703	405	0.6	856	848	1.0
EE	550	1260	2.3	140	207	1.5	239	239	1.0
FI	450	580	1.3	767	682	0.9	311	189	0.6
FR	4185	2000	0.5	5028	2617	0.5	6811	6424	0.9
GE	165	1240	7.5	166	396	2.4	799	799	1.0
GR	2700	2730	1.0	1163	1047	0.9	609	601	1.0
HU	2955	2750	0.9	660	603	0.9	609	741	1.2
IS	134	145	1.1	84	91	1.1	25	25	1.0
IE	880	210	0.2	371	198	0.5	1046	955	0.9
IT	5105	4210	0.8	5128	4370	0.9	3846	3698	1.0
KZ	700	700	1.0	231	231	1.0	148	148	1.0
LV	200	785	3.9	128	247	1.9	107	362	3.4
LT	470	725	1.5	183	335	1.8	288	692	2.4
LU	20	20	1.0	52	33	0.6	58	58	1.0
NL	565	250	0.4	1342	810	0.6	1458	1054	0.7
NO	150	110	0.7	682	475	0.7	222	189	0.9
PL	9485	6985	0.7	3016	2675	0.9	3055	3854	1.3
PT	1670	1470	0.9	1138	931	0.8	799	807	1.0
MD	160	675	4.2	66	274	4.1	206	346	1.7
RO	4560	6555	1.4	968	1662	1.7	1820	2471	1.4
SK	895	1050	1.2	396	685	1.7	286	519	1.8
SI	615	135	0.2	195	137	0.7	156	165	1.1
ES	7490	10715	1.4	3634	2715	0.7	4258	3887	0.9
SE	245	335	1.4	782	450	0.6	486	469	1.0
CH	138	130	0.9	376	240	0.6	581	519	0.9
MK	85	85	1.0	18	18	1.0	140	140	1.0
TR	6441	4975	0.8	2588	6221	2.4	2644	2644	1.0
UA	5662	11550	2.0	1385	3330	2.4	6004	6004	1.0
GB	8077	4250	0.5	5337	3533	0.7	2886	3014	1.0
YU	2605	5675	2.2	201	447	2.2	741	741	1.0
BAS	1142	1140	1.0	1072	1071	1.0	0	0	1.0
BLS	284	285	1.0	261	262	1.0	0	0	1.0
MED	5944	5945	1.0	4988	4988	1.0	0	0	1.0
NOS	2268	2270	1.0	1971	1972	1.0	0	0	1.0
ATL	4504	4505	1.0	3852	3853	1.0	0	0	1.0
NAT	3715	3715	1.0	0	0	1.0	0	0	1.0
ASI	4347	4345	1.0	645	645	1.0	2495	2495	1.0
REM	2065	2065	1.0	292	292	1.0	1935	1935	1.0
VOL	10000	10000	1.0	0	0	1.0	0	0	1.0
FFR	1796	785	0.4	4323	2833	0.7	4133	3640	0.9
FGD	4664	2040	0.4	1094	718	0.7	1014	889	0.9
RUA	86	168	2.0	70	102	1.5	53	94	1.8
RUO	2421	4714	1.9	156	226	1.4	38	67	1.8
RUP	613	1195	1.9	474	686	1.4	213	377	1.8
RUR	7916	15411	1.9	6872	9943	1.4	5253	9271	1.8

There are additional important contributors to the deposition, which are not strictly emission sources, namely boundary and initial conditions applied in the model computations. The contribution of boundary and initial conditions to the depositions will be discussed in the next Section.

5.2 Contribution of Initial and Boundary Conditions

In the computations of the source-receptor matrices for 1998, the boundary and initial conditions applied in the model calculations were taken into account as additional sources. The contribution of these sources to the depositions of sulphur and nitrogen oxides in the receptor countries in 1998 is shown in Table 7. The largest contribution from boundary and initial conditions, 49% and 55% for sulphur and oxidized nitrogen can be noticed for Denmark as a receptor. The reason for such a large value is a relatively large contribution of boundary conditions to the deposition in Greenland, which has a large territory and is located close to the lateral boundaries of the model domain. For all countries, the contribution of boundary conditions to the deposition of oxidized nitrogen is higher than to the deposition of sulphur. The contribution of boundary conditions to the depositions in the entire EMEP domain are 14% and 23%, for sulphur and nitrogen oxides, respectively.

5.3 Blame Matrices and Import-Export Budgets for 1998

The Blame matrices for 1998 were used in the scaling procedure, for estimating 2010 depositions in the EMEP receptors. Two types of the blame matrices, the original blame matrices and aggregated blame matrices for 1998 were computed with the EMEP Eulerian Acid Deposition model, using 1998 gridded emission data compiled at MSC-W and 1998 meteorological data.

The original 1998 blame matrices, for sulphur, oxidized nitrogen and reduced nitrogen, respectively were calculated using sub-regions of certain EMEP countries (e.g. Germany and the Russian Federation).

The aggregated matrices, which are routinely reported to the Steering Body of EMEP, include only the entire EMEP countries and are calculated by integrating original blame matrices. These matrices are shown in Appendix B.

When compared to 1997 (Bartnicki, 1999), total 1998 depositions in the EMEP area, resulting from the emissions in each individual source-country, followed closely the changes in emissions between 1997 and 1998. For most of the countries, local deposition (country to itself) was smaller in 1998 than in 1997, for oxidized nitrogen (more long-range transport) and larger in 1998 than in 1997, for reduced nitrogen (less long-range transport).

In addition to different meteorological and emission data, the main reasons for the differences between 1997 and 1998 blame matrices were: underestimation of convective precipitation in the 1997 meteorology and improvements of the dry deposition parameterization in the model version used for the 1998 computations.

Based on the blame matrices for 1998, the import-export budgets for 1998 were also calculated. The import-export budgets for 1998 are given in Appendix C.

Table 7: Contribution of initial and boundary conditions (BIC) to the annual deposition of sulphur and oxidized nitrogen in the EMEP receptors in 1998.

Receptor	Sulphur			Oxidized nitrogen		
	Tot-dep	BIC-dep	BIC/Tot %	Tot-dep	BIC-dep	BIC/Tot %
AL	362	16	4.4	158	35	22.2
AT	707	33	4.7	501	64	12.8
BE	555	15	2.7	410	24	5.9
BG	2215	36	1.6	507	68	13.4
DK	759	370	48.7	585	320	54.7
FI	1195	101	8.5	624	95	15.2
FR	3925	265	6.8	3694	453	12.3
FGD	1887	37	2.0	958	60	6.3
FFR	2749	113	4.1	2694	183	6.8
GR	1850	41	2.2	606	82	13.5
HU	1520	18	1.2	605	40	6.6
IS	111	51	45.9	74	50	67.6
IE	528	51	9.7	236	65	27.5
IT	3685	130	3.5	2420	272	11.2
LU	35	1	2.9	31	2	6.5
NL	607	15	2.5	503	23	4.6
NO	983	191	19.4	536	158	29.5
PL	6555	68	1.0	2340	123	5.3
PT	585	44	7.5	497	73	14.7
RO	3945	72	1.8	1011	132	13.1
ES	3199	256	8.0	2315	436	18.8
SE	1412	119	8.4	1029	154	15.0
CH	302	30	9.9	293	57	19.5
TR	5894	1000	17.0	2530	907	35.8
GB	3303	139	4.2	1696	185	10.9
REM	10884	3085	28.3	5241	2308	44.0
BAS	2690	72	2.7	1270	103	8.1
NOS	5333	250	4.7	3002	323	10.8
ATL	19735	8691	44.0	9754	5322	54.6
MED	16844	787	4.7	7849	1227	15.6
BLS	2857	132	4.6	1017	140	13.8
RUO	1296	145	11.2	318	85	26.7
RUP	1155	61	5.3	518	70	13.5
RUA	168	3	1.8	76	5	6.6
BY	1952	54	2.8	703	80	11.4
UA	5796	195	3.4	1871	263	14.1
MD	318	10	3.1	99	15	15.2
RUR	13887	2565	18.5	6541	1640	25.1
EE	279	11	3.9	137	14	10.2
LV	472	16	3.4	237	26	11.0
LT	663	16	2.4	295	29	9.8
CZ	1462	24	1.6	649	43	6.6
SK	941	12	1.3	358	24	6.7
SI	273	8	2.9	163	16	9.8
HR	705	19	2.7	345	41	11.9
BA	1100	26	2.4	307	57	18.6
YU	1889	35	1.9	437	76	17.4
MK	296	11	3.7	102	25	24.5
CY	50	7	14.0	31	6	19.4
AM	164	61	37.2	71	41	57.7
MT	9	0	0.0	2	0	0.0

5.4 Scaling Versus Direct Model Results for the Year 2010

Two methods were used to calculate depositions in the EMEP receptors in the year 2010. In the first method the EMEP Eulerian Acid Deposition model was run with the emission projections for the year 2010 described in Section 5.1, and with 1998 meteorology. The depositions in the EMEP receptor countries were calculated by integrating the computed depositions in the model grids belonging to these receptors.

In the second method, depositions for the year 2010 in individual EMEP receptors were calculated by scaling 1998 emissions according to the following equations:

$$
\begin{aligned}
\left[S_{ox}\right]_{ir}^{2010} &= \sum_{ie} BL_{ie,\,ir}^{sox} \cdot R1 \\
\left[N_{ox}\right]_{ir}^{2010} &= \sum_{ie} BL_{ie,\,ir}^{sox} \cdot R2 \\
\left[N_{rd}\right]_{ir}^{2010} &= \sum_{ie} BL_{ie,\,ir}^{sox} \cdot R3
\end{aligned}
\qquad (5)
$$

where $\left[S_{ox}\right]_{ir}^{2010}$, $\left[N_{ox}\right]_{ir}^{2010}$, $\left[N_{rd}\right]_{ir}^{2010}$ are the total depositions in 2010 in the receptor country *ir*, for sulphur, oxidized nitrogen and reduced nitrogen, respectively. The *R1, R2* and *R3* denote ratios between 2010 and 1998 emissions given in Table 6. Depositions calculated by means of Equation (5) are used in various policy applications concerning environmental impact related to emission projections for the year 2010.

Comparison of the depositions calculated directly from the model run and by scaling is given in Table 8. The “Dif. (%)” in Table 8 denotes the difference between depositions calculated from the model run and scaling, in percent of the depositions calculated from the model run for each receptor.

The largest differences between the model run and scaling can be noticed for Luxembourg as a receptor country, 34.8% and 30.0%, for sulphur and oxidized nitrogen, respectively. The largest differences for reduced nitrogen, 14.3% can be observed for Iceland, as a receptor. For most of the receptors differences between the model run and scaling do not exceed 10%. Only in 2, 3 and 2 countries, differences are larger than 10%, for sulphur, oxidized nitrogen and reduced nitrogen respectively.

For most of the countries and for all compounds scaling slightly underestimates modelled depositions. The largest differences between model results and scaling can be noticed for oxidized nitrogen, but also in this case the differences are relatively small for most of the countries, including large emitters.

The results presented in Table 8 indicate that the errors related to nonlinear effects, and introduced in the computed depositions by scaling are relatively small compared to the other sources of uncertainty.

Table 8: Comparison of the depositions calculated directly from the model run and by scaling. Units: 100 tonnes of S or N.

Receptor	Sulphur			Oxidized nitrogen			Reduced nitrogen		
	Model	Scaling	Dif. (%)	Model	Scaling	Dif. (%)	Model	Scaling	Dif. (%)
AL	397	378	-4.8	153	141	-7.8	142	133	-6.3
AM	266	267	0.4	115	107	-7.0	190	193	1.6
AT	534	504	-5.6	384	379	-1.3	656	647	-1.4
BY	2501	2454	-1.9	763	764	0.1	1849	1854	0.3
BE	336	314	-6.5	271	249	-8.1	410	372	-9.3
BA	1180	1133	-4.0	295	284	-3.7	246	241	-2.0
BG	2118	2062	-2.6	612	615	0.5	746	716	-4.0
HR	703	674	-4.1	315	308	-2.2	299	289	-3.3
CY	44	38	-13.6	42	38	-9.5	13	12	-7.7
CZ	1031	982	-4.8	466	476	2.1	1031	962	-6.7
DK	660	638	-3.3	511	490	-4.1	388	364	-6.2
EE	392	376	-4.1	143	129	-9.8	183	176	-3.8
FI	1660	1662	0.1	610	611	0.2	306	313	2.3
FR	3029	2999	-1.0	2501	2510	0.4	5096	4969	-2.5
DE	2824	2681	-5.1	2496	2506	0.4	4041	3868	-4.3
GR	1790	1744	-2.6	615	618	0.5	416	394	-5.3
HU	1542	1504	-2.5	580	577	-0.5	705	680	-3.5
IS	105	100	-4.8	71	64	-9.9	14	12	-14.3
IE	250	235	-6.0	180	163	-9.4	591	565	-4.4
IT	3442	3369	-2.1	2091	2094	0.1	2269	2236	-1.5
LV	637	607	-4.7	237	238	0.4	365	363	-0.5
LT	707	671	-5.1	285	281	-1.4	638	633	-0.8
LU	23	15	-34.8	20	14	-30.0	37	33	-10.8
NL	377	355	-5.8	343	318	-7.3	692	671	-3.0
NO	1013	1015	0.2	443	446	0.7	230	237	3.0
PL	4985	4836	-3.0	1905	1983	4.1	3495	3367	-3.7
PT	601	596	-0.8	423	419	-0.9	448	442	-1.3
MD	468	459	-1.9	156	140	-10.3	308	306	-0.6
RO	4997	4942	-1.1	1327	1319	-0.6	2011	2008	-0.1
RU	25565	25827	1.0	9765	9827	0.6	10286	10305	0.2
SK	885	832	-6.0	349	344	-1.4	468	450	-3.8
SI	201	182	-9.5	136	130	-4.4	153	140	-8.5
ES	4070	4082	0.3	1919	1877	-2.2	2529	2550	0.8
SE	1418	1400	-1.3	834	852	2.2	595	617	3.7
CH	251	237	-5.6	220	212	-3.6	437	434	-0.7
MK	322	306	-5.0	105	94	-10.5	130	123	-5.4
TR	5456	5398	-1.1	4002	4026	0.6	2047	2038	-0.4
UA	8246	8225	-0.3	2634	2517	-4.4	5139	5231	1.8
GB	2009	1961	-2.4	1207	1229	1.8	1842	1754	-4.8
YU	2753	2701	-1.9	497	475	-4.4	624	634	1.6
EU	23023	22555	-2.0	14405	14329	-0.5	20316	19795	-2.6
BAS	2635	2575	-2.3	1072	1138	6.2	1127	1160	2.9
BLS	3511	3497	-0.4	1495	1555	4.0	1074	1070	-0.4
MED	16506	16520	0.1	7666	7916	3.3	2422	2429	0.3
NOS	3857	3770	-2.3	2208	2374	7.5	1864	1902	2.0
BAS	2635	2575	-2.3	1072	1138	6.2	1127	1160	2.9
BLS	3511	3497	-0.4	1495	1555	4.0	1074	1070	-0.4
MED	16506	16520	0.1	7666	7916	3.3	2422	2429	0.3
NOS	3857	3770	-2.3	2208	2374	7.5	1864	1902	2.0
ATL	19897	19989	0.5	9005	9088	0.9	1954	2044	4.6
REM	11647	11665	0.2	5851	5807	-0.8	4160	4154	-0.1

6. Conclusions

From the numerical experiment with Germany as a single country-source in the EMEP domain and individual EMEP countries as receptors, the following conclusions can be drawn:

- The non-linear effects are most important for oxidized nitrogen, less important for reduced nitrogen, and practically not important for oxidized sulphur. Averaged over all countries, with the contribution of German sources not lower than 5%, departures from a linear relationship between emissions and total (dry+wet) depositions are 0.6%, 13.7% and 6.1%, for sulphur, oxidized nitrogen and reduced nitrogen, respectively.

- As expected, for most of the countries and all compounds, non-linear effects amplifies with the distance between the emitter and receptor. These effects are also larger for the receptors with a relatively small deposition.

- Concerning dry and wet deposition, nonlinear effects are definitely more visible in the wet deposition of sulphur and oxidized nitrogen. For reduced nitrogen, nonlinear effects are slightly more visible in the dry deposition, but for this compound there is not much difference in non-linear effects on the dry, wet and the total (wet + dry) depositions.

- As anticipated, there are some interactions between emissions and depositions of different compounds. Emission reduction of SO_2 has the effect not only on deposition of sulphur but also on both nitrogen compounds. Emission reduction of one of the nitrogen compounds effects the depositions of both nitrogen compounds, but does not effect the deposition of sulphur.

The above conclusions are, in principle, limited to one emitter only - Germany. However, experience with running the EMEP model shows that the results obtained for other emitter-countries in Europe should be similar. Some exceptions can only be expected for the countries located close to the model boundaries.

The subject of the second part of this note was the influence of the non-linear effects on the depositions in the year 2010. A comparison of the 2010 depositions to individual countries (receptors) estimated from scaling with source-receptor matrices and computed directly from the model leads to the following conclusions:

- In the computations of source-receptor matrices and import-export budgets for 1998, boundary and initial conditions applied in the model calculations were taken into account as additional emission sources. These sources contributed significantly to the depositions of sulphur and nitrogen oxides. The largest contribution of these sources, 49% and 55% for sulphur and oxidized nitrogen can be noticed for Denmark as a receptor. The reason for such a large contribution is a relatively large contribution of the boundary conditions to the deposition in Greenland. For all countries, contribution of boundary conditions to the deposition of oxidized nitrogen is higher than to the deposition of sulphur. The contribution of boundary conditions to the depositions in the entire EMEP domain are 14% and 23%, for sulphur and nitrogen oxides, respectively.

- When compared to 1997, total 1998 depositions in the EMEP area, resulting from the emissions in each individual country-source, followed closely the changes in emissions between

1997 and 1998. For most of the countries, local deposition (country to itself) was smaller in 1998 than in 1997, for oxidized nitrogen (more long range transport) and larger in 1998 than in 1997, for reduced nitrogen (less long range transport).

- The largest differences between the model run and scaling can be noticed for Luxembourg as a receptor country, 34.8% and 30.0%, for sulphur and oxidized nitrogen, respectively. The largest differences for reduced nitrogen, 14.3% can be observed for Iceland, as a receptor. For most of the receptors differences between the model run and scaling do not exceed 10%. Only in 2, 3 and 2 countries, differences are larger than 10%, for sulphur, oxidized nitrogen and reduced nitrogen respectively.

- Scaling slightly underestimates modelled depositions for most of the countries and for all compounds. The largest differences between model results and scaling can be noticed for oxidized nitrogen, but also in this case the differences are relatively small for most of the countries, including large emitters.

Generally, the results of this study indicate that the influence of non-linear effects on country-to-grid source-receptor matrices and computed depositions is relatively small compared to other sources of uncertainty in the model computations, like for example inter-annual changes of meteorological conditions and uncertainties in the emission data. This conclusion justifies the scaling procedure. However, the analysis of the non-linear effects in country-to-grid source-receptor matrices remains to be done. This analysis is planned for next year, in co-operation with CIAM, who is the main user of the country-to-grid source-receptor matrices computed at MSC-W.

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Appendix A: Names and Codes of the EMEP Emitter and Receptor Countries

Code	Name	Code	Name
AL	Albania	RU	Russian Federation
AM	Armenia	SK	Slovakia
AT	Austria	SI	Slovenia
BY	Belarus	ES	Spain
BE	Belgium	SE	Sweden
BA	Bosnia and Hercegovina	CH	Switzerland
BG	Bulgaria	MK	The former Yugoslav Republic of Macedonia
HR	Croatia	TR	Turkey
CY	Cyprus	UA	Ukraine
CZ	Czech Republic	GB	United Kingdom
DK	Denmark	YU	Yugoslavia
EE	Estonia	EU	European Community
FI	Finland	BAS	Baltic Sea
FR	France	BLS	Black Sea
GE	Georgia	MED	Mediterranean Sea
DE	Germany	NOS	North Sea
GR	Greece	ATL	Remaining North-East Atlantic Ocean
HU	Hungary	BIC	Boundary and initial conditions
IS	Iceland	NAT	Natural marine emissions
IE	Ireland	NOA	North Africa
IT	Italy	ASI	Remaining Asian areas
KZ	Kazakhstan	REM	Remaining Land Areas
LV	Latvia	SUM	Sum of all attributable sources
LT	Lithuania	VOL	Volcanic emissions
LU	Luxembourg	FCS	Former Czechoslovakia
MT	Malta	FFR	Former Federal Republic of Germany
NL	Netherlands	FGD	Former German Democratic Republic
NO	Norway	FSU	Former USSR
PL	Poland	RUA	Kaliningrad
PT	Portugal	RUO	Kola/Karelia
MD	Republic of Moldova	RUP	St.Petersburg/Novgorod-Pskov
RO	Romania	RUR	Rest of the Russian Federation

Appendix B: Blame Matrices for 1998 Computed with the EMEP Eulerian Acid Deposition Model

Table 8: The 1998 country-to-country blame matrices computed with the EMEP Eulerian Acid Deposition model for sulphur.

EMITTERS

		AL	AM	AT	BY	BE	BA	BG	HR	CY	CZ	DK	EE	FI	FR	GE	DE	GR	HU	IS	IE	IT	KZ	LV	LT	LU	NL	NO	
	AL	53	0	0	0	0	16	28	1	0	1	0	0	0	3	0	3	19	6	0	0	28	0	0	0	0	0	0	AL
	AM	0	5	0	0	0	0	2	0	1	0	0	0	0	0	3	0	1	0	0	0	0	1	0	0	0	0	0	AM
	AT	1	0	55	0	7	14	3	12	0	49	0	0	0	30	0	96	2	39	0	0	81	0	0	0	0	3	0	AT
	BY	1	0	4	322	6	26	47	4	0	60	4	10	3	14	0	141	5	80	0	1	19	2	12	50	0	3	0	BY
	BE	0	0	0	0	183	0	0	0	0	3	0	0	0	121	0	23	0	1	0	2	2	0	0	0	1	44	0	BE
	BA	4	0	3	0	1	503	17	18	0	13	0	0	0	8	0	16	6	46	0	0	65	0	0	0	0	0	0	BA
	BG	10	0	2	1	0	48	1281	4	0	8	0	0	0	4	0	12	50	34	0	0	32	1	0	0	0	0	0	BG
	HR	2	0	5	0	1	120	12	80	0	15	0	0	0	10	0	19	3	57	0	0	70	0	0	0	0	0	0	HR
	CY	0	0	0	0	0	0	1	0	16	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	CY
	CZ	1	0	15	0	11	18	8	7	0	453	1	0	0	30	0	313	1	69	0	1	24	0	0	1	0	4	0	CZ
	DK	0	0	0	1	8	2	0	0	0	9	59	0	0	13	0	56	0	3	1	2	2	0	0	1	0	5	1	DK
	EE	0	0	0	8	1	2	3	0	0	8	2	54	7	2	0	24	0	4	0	0	1	0	11	10	0	1	0	EE
	FI	0	0	1	12	5	4	7	1	0	16	8	63	205	9	0	63	1	10	0	1	3	1	9	15	0	2	3	FI
	FR	0	0	3	0	80	7	4	3	0	28	2	0	0	1648	0	111	1	10	0	17	96	0	0	0	3	23	0	FR
	DE	0	0	19	2	234	15	5	5	0	206	17	0	0	425	0	2012	3	34	0	10	68	0	0	2	7	112	2	DE
	GR	27	0	1	0	0	27	501	2	1	4	0	0	0	5	0	6	671	16	0	0	51	0	0	0	0	0	0	GR
	HU	2	0	12	1	2	84	32	30	0	46	0	0	0	11	0	53	5	607	0	0	58	0	0	1	0	1	0	HU
	IS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	24	1	0	0	0	0	0	0	0	IS
	IE	0	0	0	0	2	0	0	0	0	1	0	0	0	6	0	5	0	0	0	315	1	0	0	0	0	1	0	IE
	IT	10	0	9	1	4	81	30	35	0	20	1	0	0	95	0	38	17	47	0	0	1229	0	0	1	0	1	0	IT
R	LV	0	0	1	19	2	4	6	1	0	16	5	12	3	5	0	42	1	10	0	1	3	0	45	46	0	1	0	LV
E	LT	0	0	1	19	3	5	10	1	0	25	5	4	2	8	0	69	1	15	0	1	4	0	11	107	0	2	0	LT
C	LU	0	0	0	0	6	0	0	0	0	0	0	0	0	11	0	3	0	0	0	0	0	0	0	0	1	1	0	LU
E	MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	MT
P	NL	0	0	0	0	97	0	0	0	0	4	1	0	0	58	0	42	0	1	0	2	2	0	0	0	0	140	0	NL
T	NO	0	0	1	2	11	3	2	1	0	18	16	3	4	23	0	78	0	9	0	6	5	0	1	3	0	5	52	NO
O	PL	2	0	13	20	32	52	54	14	0	392	19	3	2	61	0	1094	4	201	0	3	47	0	4	22	1	14	1	PL
R	PT	0	0	0	0	0	0	0	0	0	1	0	0	0	4	0	2	0	0	0	0	2	0	0	0	0	0	0	PT
S	MD	1	0	0	2	0	8	30	1	0	4	0	0	0	1	0	6	3	14	0	0	5	1	0	0	0	0	0	MD
	RO	12	0	6	6	2	147	399	13	0	43	1	0	0	12	1	61	41	233	0	0	81	2	0	2	0	1	0	RO
	RU	12	3	10	353	18	99	440	14	6	151	19	254	74	51	54	343	64	214	0	3	103	182	53	97	0	10	4	RU
	SK	1	0	8	1	2	28	17	9	0	56	1	0	0	7	0	57	2	224	0	0	24	0	0	1	0	1	0	SK
	SI	0	0	4	0	0	7	2	20	0	5	0	0	0	5	0	8	1	17	0	0	47	0	0	0	0	0	0	SI
	ES	0	0	1	0	4	7	4	2	0	7	0	0	0	64	0	15	1	4	0	4	35	0	0	0	0	2	0	ES
	SE	0	0	2	9	14	10	7	2	0	39	48	20	37	27	0	150	1	25	0	4	9	1	6	13	0	7	20	SE
	CH	0	0	1	0	5	1	0	1	0	2	0	0	0	55	0	18	0	1	0	0	59	0	0	0	0	2	0	CH
	MK	19	0	0	0	0	13	63	1	0	2	0	0	0	2	0	2	25	7	0	0	14	0	0	0	0	0	0	MK
	TR	10	2	1	3	1	35	443	3	35	9	0	0	0	6	9	15	124	27	0	0	61	4	0	1	0	0	0	TR
	UA	7	0	9	89	7	112	288	17	1	104	4	5	1	23	6	187	40	321	0	1	80	10	3	14	0	3	0	UA
	GB	0	0	0	0	21	1	0	1	0	10	5	0	0	72	0	52	0	2	0	90	4	0	0	1	0	11	1	GB
	YU	19	0	3	1	1	258	105	14	0	19	0	0	0	9	0	23	23	98	0	0	69	0	0	0	0	0	0	YU
	EU	38	0	91	25	665	168	561	63	1	397	141	83	242	2588	0	2674	697	192	1	447	1585	2	15	33	12	352	27	EU
	BAS	0	0	3	23	26	14	15	3	0	79	90	87	83	43	0	350	2	38	0	5	12	1	31	56	0	14	6	BAS
	BLS	8	0	3	9	1	66	486	6	4	23	1	1	0	6	13	38	58	74	0	0	44	6	1	2	0	0	0	BLS
	MED	110	0	16	4	11	340	1077	89	84	64	1	1	0	408	1	104	988	173	0	2	1753	1	1	2	0	4	0	MED
	NOS	1	0	3	2	122	5	5	2	0	59	51	2	1	340	0	294	1	17	1	54	17	0	2	5	1	117	23	NOS
	ATL	1	0	3	7	61	8	8	3	0	57	19	14	18	289	0	240	1	25	103	341	39	3	4	8	1	23	36	ATL
	REM	12	4	3	6	4	62	205	8	36	18	1	1	0	47	57	34	140	35	0	1	275	243	0	2	0	1	0	REM
	SUM	326	14	221	923	996	2252	5647	428	184	2147	381	534	440	4072	144	6319	2307	2848	129	868	4627	459	194	463	15	559	149	SUM
		AL	AM	AT	BY	BE	BA	BG	HR	CY	CZ	DK	EE	FI	FR	GE	DE	GR	HU	IS	IE	IT	KZ	LV	LT	LU	NL	NO	

Table 8 (cont.): The 1998 country-to-country blame matrices computed with the EMEP Eulerian Acid Deposition model for sulphur.

EMITTERS

RECEPTORS

	PL	PT	MD	RO	RU	SK	SI	ES	SE	CH	MK	TR	UA	GB	YU	EU	BAS	BLS	MED	NOS	ATL	BIC	NAT	ASI	REM	VOL	SUM	
AL	4	0	0	9	0	1	1	10	0	0	4	2	2	0	37	63	0	0	20	0	0	16	1	0	3	84	352	AL
AM	0	0	0	1	1	0	0	0	0	0	0	58	1	0	0	1	0	0	1	0	0	61	0	24	0	1	161	AM
AT	48	1	0	6	0	17	85	17	0	7	0	1	3	13	12	305	1	0	9	4	1	33	1	0	2	40	693	AT
BY	573	0	4	64	65	30	9	14	2	1	0	5	157	26	27	242	13	1	4	6	1	54	2	1	1	35	1909	BY
BE	6	1	0	0	0	0	0	17	0	0	0	0	0	74	0	468	0	0	1	43	3	15	2	0	0	1	543	BE
BA	27	1	0	22	1	8	9	20	0	0	1	1	4	2	97	122	0	0	23	1	1	26	1	0	5	114	1064	BA
BG	23	0	3	287	10	7	4	9	0	0	8	19	51	1	108	110	0	6	20	0	0	36	2	1	5	95	2182	BG
HR	30	1	0	22	0	8	25	20	0	0	0	1	4	2	54	131	0	0	26	1	1	19	1	0	4	72	685	HR
CY	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	2	0	0	5	0	0	7	1	2	0	2	48	CY
CZ	289	0	0	11	0	33	17	17	0	3	0	1	4	20	17	437	2	0	4	7	1	24	1	0	1	23	1432	CZ
DK	28	0	0	1	4	1	1	8	3	0	0	0	1	81	1	237	39	0	0	37	2	370	9	0	0	4	753	DK
EE	45	0	0	4	19	2	1	4	2	0	0	0	8	10	2	54	21	0	0	3	0	11	2	0	0	2	274	EE
FI	110	0	1	9	348	5	1	9	15	0	0	1	29	39	5	361	74	0	1	9	2	101	6	0	1	4	1209	FI
FR	43	20	0	4	0	4	8	716	0	13	0	0	3	350	5	3070	2	0	65	169	87	265	35	0	14	56	3895	FR
DE	277	4	0	10	1	13	14	141	2	29	0	1	7	398	14	3452	42	0	12	153	13	150	13	0	4	48	4524	DE
GR	13	1	1	56	3	4	2	13	0	0	8	24	20	1	46	749	0	2	82	0	1	41	5	2	8	181	1826	GR
HU	103	1	1	91	1	79	25	14	0	1	0	3	15	5	98	162	1	0	13	1	1	18	1	0	3	77	1497	HU
IS	1	0	0	0	0	0	0	1	0	0	0	0	0	13	0	17	0	0	0	1	2	51	14	0	0	0	110	IS
IE	1	1	0	0	0	0	0	17	0	0	0	0	0	79	0	427	0	0	1	5	18	51	16	0	0	0	520	IE
IT	40	6	0	20	1	10	51	127	0	8	1	2	6	12	46	1539	1	0	223	3	5	130	12	0	27	1280	3630	IT
LV	110	0	0	8	16	5	2	7	2	0	0	0	15	17	4	90	20	0	1	4	1	16	2	0	0	4	457	LV
LT	212	0	1	10	17	7	2	7	2	0	0	0	17	20	5	125	17	0	1	5	1	16	2	0	0	7	642	LT
LU	1	0	0	0	0	0	0	2	0	0	0	0	0	4	0	28	0	0	0	1	0	1	0	0	0	0	31	LU
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	5	8	MT
NL	11	1	0	1	0	1	0	14	0	0	0	0	0	117	1	474	1	0	1	80	3	15	4	0	0	1	598	NL
NO	67	1	0	5	185	4	2	25	11	0	0	0	6	140	3	326	21	0	2	48	15	191	24	0	2	6	1001	NO
PL	3636	1	2	60	21	99	26	46	5	3	0	2	86	106	54	1448	57	0	10	30	3	68	6	1	3	71	6451	PL
PT	1	321	0	0	0	0	0	140	0	0	0	0	0	4	0	473	0	0	5	1	48	44	9	0	2	1	585	PT
MD	25	0	17	88	6	4	1	1	0	0	0	5	60	1	9	17	0	1	2	0	0	10	0	1	1	11	319	MD
RO	157	1	14	1792	19	54	15	24	0	1	4	25	151	7	256	237	2	9	26	2	1	72	3	2	7	187	3894	RO
RU	939	2	22	321	6887	75	31	83	14	2	4	389	1680	108	106	902	75	20	40	24	10	2774	26	133	15	208	16619	RU
SK	177	0	0	25	1	149	12	7	0	1	0	1	10	4	27	113	1	0	5	1	0	12	0	0	1	33	906	SK
SI	7	0	0	4	0	2	77	9	0	0	0	0	1	1	6	75	0	0	8	0	0	8	0	0	2	21	262	SI
ES	9	133	0	4	0	1	3	2289	0	1	0	0	3	33	5	2581	0	0	104	9	102	256	24	0	26	41	3193	ES
SE	196	1	1	17	97	10	4	27	101	1	0	1	24	143	10	571	147	0	2	48	6	119	14	1	1	13	1435	SE
CH	3	1	0	0	0	0	1	27	0	44	0	0	0	14	1	182	0	0	6	4	1	30	1	0	2	18	298	CH
MK	4	0	0	13	0	1	1	5	0	0	14	3	3	0	35	48	0	0	8	0	0	11	0	0	2	41	289	MK
TR	33	1	5	133	39	7	5	22	0	0	3	2976	117	3	51	234	1	33	149	1	1	1000	16	244	29	212	5870	TR
UA	804	1	48	411	178	108	25	31	1	1	3	95	2102	30	127	418	9	18	26	6	2	195	8	14	8	160	5743	UA
GB	19	3	0	1	0	1	1	72	1	0	0	0	0	2486	1	2817	5	0	3	162	69	139	43	0	2	2	3281	GB
YU	41	1	1	110	1	15	9	21	0	0	7	4	13	3	755	153	0	0	25	1	1	35	2	0	6	152	1845	YU
EU	803	493	3	129	454	67	170	3609	122	59	9	30	96	3834	146	17552	312	2	509	724	360	1730	193	3	87	1672	47860	EU
BAS	546	1	1	21	86	17	5	38	59	1	0	1	35	167	14	893	502	0	3	58	5	72	26	1	1	18	2659	BAS
BLS	101	0	19	365	103	18	10	16	0	0	2	361	420	7	91	174	2	154	38	1	0	132	32	28	7	106	2863	BLS
MED	157	33	5	242	16	35	84	819	1	7	13	579	80	44	263	4184	3	18	3846	12	52	787	284	150	361	3765	16890	MED
NOS	142	5	0	6	5	8	5	137	10	2	0	0	5	2101	6	3254	46	0	7	1125	87	250	198	0	4	15	5289	NOS
ATL	158	657	1	13	935	11	8	1220	10	3	0	4	22	1268	7	4190	26	0	39	179	2439	8691	2804	2	19	30	19858	ATL
REM	62	22	4	80	314	9	11	217	0	2	3	829	181	14	53	759	1	7	506	3	25	3085	51	2509	772	972	10927	REM
SUM	9279	1223	151	4347	9380	863	593	6480	241	131	75	5406	5346	7968	2459	36717	1132	269	5374	2248	3011	19508	3704	3116	1351	8219	139520	SUM
	PL	PT	MD	RO	RU	SK	SI	ES	SE	CH	MK	TR	UA	GB	YU	EU	BAS	BLS	MED	NOS	ATL	BIC	NAT	ASI	REM	VOL		

Table 9: The 1998 country-to-country blame matrices computed with the EMEP Eulerian Acid Deposition model for oxidized nitrogen.

EMITTERS

		AL	AM	AT	BY	BE	BA	BG	HR	CY	CZ	DK	EE	FI	FR	GE	DE	GR	HU	IS	IE	IT	KZ	LV	LT	LU	NL	NO	
	AL	4	0	1	0	0	3	3	1	0	1	0	0	0	4	0	2	17	1	0	0	37	0	0	0	0	0	0	AL
	AM	0	6	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	AM
	AT	0	0	75	0	5	2	0	6	0	28	1	0	0	26	0	105	1	8	0	0	93	0	0	0	1	6	0	AT
	BY	0	0	8	78	5	1	3	2	0	30	9	2	5	17	0	70	1	13	0	1	17	0	5	17	0	9	2	BY
	BE	0	0	0	0	93	0	0	0	0	2	1	0	0	91	0	33	0	0	0	2	2	0	0	0	1	36	1	BE
	BA	1	0	7	0	1	30	2	12	0	8	0	0	0	11	0	14	3	12	0	0	83	0	0	0	0	1	0	BA
	BG	3	0	3	1	1	5	178	2	0	5	1	0	0	5	0	10	32	9	0	0	26	0	0	0	0	1	0	BG
	HR	1	0	12	0	1	17	1	25	0	10	0	0	0	16	0	19	1	15	0	0	107	0	0	0	0	2	0	HR
	CY	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	CY
	CZ	0	0	30	0	11	2	1	4	0	155	3	0	0	36	0	184	1	14	0	1	30	0	0	0	1	13	1	CZ
	DK	0	0	1	1	7	0	0	0	0	4	27	0	1	15	0	40	0	0	1	2	2	0	0	0	0	16	5	DK
	EE	0	0	0	4	1	0	0	0	0	3	5	6	10	3	0	13	0	1	0	0	1	0	5	4	0	3	2	EE
	FI	0	0	1	7	4	0	0	0	0	5	15	15	191	9	0	36	0	1	0	1	3	0	6	6	0	8	11	FI
	FR	0	0	7	1	86	1	0	2	0	15	5	0	2	1725	0	173	1	2	1	14	143	0	0	0	7	56	4	FR
	DE	0	0	38	2	200	1	0	2	0	107	24	0	2	387	0	1568	0	7	0	8	87	0	0	1	14	251	8	DE
	GR	7	0	2	1	1	4	49	2	0	3	1	0	0	9	0	7	229	3	0	0	53	0	0	0	0	1	0	GR
	HU	0	0	30	1	3	13	5	19	0	40	1	0	0	16	0	48	2	166	0	0	69	0	0	0	0	3	1	HU
	IS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	8	1	0	0	0	0	0	0	1	IS
	IE	0	0	0	0	2	0	0	0	0	0	1	0	0	9	0	5	0	0	0	39	1	0	0	0	0	4	1	IE
	IT	2	0	22	1	5	17	4	20	0	12	2	0	1	144	0	55	9	10	0	1	1369	0	0	0	0	7	2	IT
R	LV	0	0	2	9	3	0	0	0	0	8	10	3	6	7	0	28	0	2	0	1	3	0	13	13	0	6	2	LV
E	LT	0	0	3	8	4	0	0	0	0	14	12	1	3	10	0	43	0	3	0	1	4	0	5	16	0	7	2	LT
C	LU	0	0	0	0	4	0	0	0	0	0	0	0	0	10	0	4	0	0	0	0	0	0	0	0	2	1	0	LU
E	MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	MT
P	NL	0	0	0	0	46	0	0	0	0	2	2	0	0	47	0	57	0	0	0	2	2	0	0	0	1	142	1	NL
T	NO	0	0	1	1	8	0	0	0	0	5	25	1	6	21	0	42	0	1	0	3	3	0	1	1	0	13	83	NO
O	PL	0	0	30	11	32	4	3	7	0	220	34	1	5	79	0	502	1	40	0	3	47	0	3	8	2	51	7	PL
R	PT	0	0	0	0	1	0	0	0	0	0	0	0	0	8	0	2	0	0	0	0	2	0	0	0	0	1	0	PT
S	MD	0	0	1	1	0	1	4	0	0	2	0	0	0	1	0	3	1	2	0	0	3	0	0	0	0	0	0	MD
	RO	3	0	14	3	3	16	58	9	0	30	2	0	1	16	1	43	14	56	0	0	72	1	0	1	0	4	1	RO
	RU	2	3	18	166	18	5	26	5	1	63	40	50	111	65	39	185	16	28	1	4	75	45	26	36	1	34	26	RU
	SK	0	0	17	0	2	4	2	6	0	42	1	0	0	10	0	38	1	48	0	0	26	0	0	0	0	3	0	SK
	SI	0	0	10	0	0	2	0	9	0	3	0	0	0	7	0	9	0	4	0	0	64	0	0	0	0	1	0	SI
	ES	0	0	2	0	4	1	1	1	0	4	1	0	1	104	0	18	1	1	0	3	46	0	0	0	0	4	1	ES
	SE	0	0	3	5	13	0	0	1	0	14	72	4	41	30	0	93	0	3	0	4	6	0	4	4	1	28	42	SE
	CH	0	0	2	0	4	0	0	0	0	1	0	0	0	50	0	27	0	0	0	0	68	0	0	0	0	3	0	CH
	MK	3	0	1	0	0	1	8	1	0	1	0	0	0	2	0	1	24	1	0	0	13	0	0	0	0	0	0	MK
	TR	3	3	3	2	2	3	44	2	8	6	2	0	1	15	9	17	66	5	0	1	42	1	0	1	0	3	2	TR
	UA	2	0	18	40	7	9	31	9	0	61	9	1	4	32	4	107	14	56	0	1	69	3	2	5	1	12	3	UA
	GB	0	0	1	1	21	0	0	0	0	4	11	0	1	85	0	51	0	0	1	37	4	0	0	0	1	38	6	GB
	YU	5	0	9	1	1	22	15	10	0	14	1	0	0	12	0	22	12	28	0	0	73	0	0	0	0	2	0	YU
	EU	9	0	152	19	492	26	54	34	0	200	163	19	240	2699	0	2247	241	35	3	113	1813	0	10	11	28	599	82	EU
	BAS	0	0	6	11	22	1	1	1	0	34	75	12	59	51	0	196	0	5	0	4	11	0	11	12	1	43	15	BAS
	BLS	2	1	6	5	2	6	56	3	1	14	3	0	2	12	10	28	24	13	0	1	38	2	1	1	0	3	2	BLS
	MED	22	0	40	7	20	47	105	37	23	47	13	1	9	434	2	169	448	37	1	5	1331	2	2	3	2	30	10	MED
	NOS	0	0	5	2	91	0	0	1	0	24	69	1	5	274	0	253	0	2	1	32	15	0	2	2	3	188	77	NOS
	ATL	0	0	6	7	55	0	0	1	0	20	45	4	42	376	0	188	1	3	35	128	41	1	4	4	3	76	137	ATL
	REM	3	8	10	8	8	7	18	6	12	17	8	1	7	98	45	63	68	7	1	2	247	75	1	2	1	13	6	REM
	SUM	63	21	445	385	797	225	618	206	51	1078	531	103	516	4380	113	4572	989	607	50	302	4430	130	91	137	43	1123	462	SUM
		AL	AM	AT	BY	BE	BA	BG	HR	CY	CZ	DK	EE	FI	FR	GE	DE	GR	HU	IS	IE	IT	KZ	LV	LT	LU	NL	NO	

Table 9 (cont.): The 1998 country-to-country blame matrices computed with the EMEP Eulerian Acid Deposition model for oxidized nitrogen

EMITTERS

		PL	PT	MD	RO	RU	SK	SI	ES	SE	CH	MK	TR	UA	GB	YU	EU	BAS	BLS	MED	NOS	ATL	BIC	NAT	ASI	REM	VOL	SUM	
	AL	1	0	0	2	1	0	0	5	0	0	1	1	1	1	3	67	0	0	25	0	1	35	0	0	0	2	153	AL
	AM	0	0	0	0	2	0	0	0	0	0	0	12	0	0	0	0	0	0	1	0	0	41	0	3	0	0	68	AM
	AT	14	0	0	1	1	5	22	4	0	16	0	0	1	7	1	324	1	0	6	4	1	64	0	0	0	0	505	AT
	BY	169	0	2	11	54	12	2	4	7	3	0	1	45	20	1	173	13	1	2	8	3	80	0	0	0	0	733	BY
	BE	2	1	0	0	0	0	0	6	0	1	0	0	0	55	0	321	1	0	1	32	5	24	0	0	0	0	390	BE
	BA	9	1	0	4	1	4	3	8	0	2	0	0	1	3	9	132	0	0	23	1	1	57	0	0	0	1	313	BA
	BG	9	0	1	63	12	3	1	3	1	1	1	9	16	3	11	86	1	7	17	1	1	68	0	0	0	0	511	BG
	HR	11	1	0	4	1	5	8	9	0	2	0	0	1	3	5	171	0	0	29	1	2	41	0	0	0	1	351	HR
	CY	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	2	0	0	7	0	0	6	0	0	0	0	29	CY
	CZ	56	0	0	2	1	12	6	5	1	7	0	0	1	16	1	332	2	0	3	8	2	43	0	0	0	0	653	CZ
	DK	9	0	0	0	2	0	0	3	7	0	0	0	0	46	0	167	22	0	0	30	5	320	0	0	0	0	566	DK
	EE	13	0	0	0	13	1	0	1	8	0	0	0	2	8	0	53	18	0	0	4	1	14	0	0	0	0	144	EE
	FI	28	0	0	1	61	1	0	2	40	1	0	0	6	23	0	333	63	0	1	11	4	95	0	0	0	0	656	FI
	FR	16	19	0	1	6	2	3	282	3	33	0	1	1	287	0	2810	4	0	67	154	112	453	0	0	1	0	3690	FR
	DE	80	4	0	2	8	5	5	43	8	67	0	0	2	275	0	2909	31	0	8	142	23	243	0	0	0	0	3653	DE
	GR	5	0	0	12	7	1	1	7	1	1	1	13	7	4	5	315	1	3	91	1	2	82	0	0	1	2	620	GR
	HU	40	0	0	17	3	40	11	4	1	4	0	1	4	6	11	183	1	0	11	3	2	40	0	0	0	0	616	HU
	IS	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	9	0	0	0	1	2	50	0	0	0	0	71	IS
	IE	0	1	0	0	0	0	0	5	1	0	0	0	0	59	0	127	1	0	1	7	19	65	0	0	0	0	221	IE
	IT	14	5	0	6	7	4	22	71	1	26	0	1	3	15	5	1707	2	0	268	6	11	272	0	0	3	11	2436	IT
R	LV	38	0	0	1	13	2	0	3	10	1	0	0	4	13	0	92	22	0	0	7	1	26	0	0	0	0	257	LV
E	LT	70	0	0	2	14	3	1	3	8	1	0	0	5	15	0	113	18	0	1	7	2	29	0	0	0	0	315	LT
C	LU	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	25	0	0	0	1	0	2	0	0	0	0	28	LU
E	MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	2	MT
P	NL	4	1	0	0	1	0	0	5	0	1	0	0	0	77	0	382	1	0	0	56	5	23	0	0	0	0	476	NL
T	NO	15	1	0	1	9	1	0	7	25	1	0	0	1	66	0	221	17	0	1	34	12	158	0	0	0	0	564	NO
O	PL	839	1	1	12	22	43	9	17	18	10	0	1	19	83	4	905	53	0	6	39	8	123	0	0	0	0	2398	PL
R	PT	0	239	0	0	0	0	0	99	0	0	0	0	0	4	0	356	0	0	8	1	61	73	0	0	0	0	499	PT
S	MD	8	0	5	19	6	2	0	0	0	0	0	2	15	1	1	10	0	1	1	0	0	15	0	0	0	0	95	MD
	RO	50	1	5	307	23	25	5	7	2	4	1	11	39	8	25	187	3	9	18	3	2	132	0	0	0	0	1028	RO
	RU	264	2	7	58	3520	25	6	20	53	8	0	116	382	98	5	740	82	20	25	41	22	1800	0	17	1	0	7661	RU
	SK	57	0	0	6	1	48	5	2	0	3	0	0	3	4	4	104	1	0	4	2	1	24	0	0	0	0	365	SK
	SI	3	0	0	1	0	1	16	3	0	1	0	0	0	1	1	95	0	0	8	1	1	16	0	0	0	0	162	SI
	ES	4	121	0	1	2	1	1	1267	1	3	0	1	1	32	0	1605	1	0	121	12	112	436	0	0	3	0	2313	ES
	SE	53	1	0	2	27	3	1	9	181	1	0	1	5	89	0	571	112	0	1	53	11	154	0	0	0	0	1072	SE
	CH	1	0	0	0	0	0	0	6	0	59	0	0	0	6	0	166	0	0	4	2	1	57	0	0	0	0	291	CH
	MK	1	0	0	2	1	0	0	2	0	0	1	1	1	1	3	44	0	0	6	0	0	25	0	0	0	0	100	MK
	TR	15	1	2	31	64	3	1	9	2	2	1	1001	33	11	4	175	3	35	136	4	4	907	0	27	3	0	2540	TR
	UA	253	1	17	100	200	46	7	9	7	6	1	42	329	26	10	317	12	21	20	11	6	263	0	2	0	0	1889	UA
	GB	6	3	0	0	3	0	0	25	5	1	0	0	0	1009	0	1292	8	0	2	124	66	185	0	0	0	0	1699	GB
	YU	14	0	0	20	3	8	3	7	0	2	2	2	4	5	43	144	1	0	22	2	2	76	0	0	0	1	444	YU
	EU	235	395	0	26	125	22	55	1829	248	151	1	17	26	1985	11	13244	248	3	575	634	437	2491	0	0	8	13	34662	EU
	BAS	135	1	0	3	40	5	1	14	94	3	0	0	8	103	0	680	219	0	2	53	10	103	0	0	0	0	1365	BAS
	BLS	39	0	6	81	144	7	2	5	3	2	1	154	101	11	9	138	4	88	34	4	3	140	0	3	0	0	1077	BLS
	MED	77	32	3	64	71	16	27	475	11	28	4	272	37	90	27	3109	16	21	2528	37	81	1227	0	20	41	46	8098	MED
	NOS	43	6	0	1	10	2	1	47	29	5	0	0	1	981	0	1998	45	0	6	513	94	323	0	0	0	0	3154	NOS
	ATL	43	284	0	3	117	3	1	379	42	8	0	3	6	800	0	2466	41	0	42	201	1433	5322	0	0	2	0	9907	ATL
	REM	37	19	2	21	331	5	4	140	8	8	1	322	54	39	3	731	10	11	622	16	44	2308	0	366	117	0	5230	REM
	SUM	2545	746	51	862	4802	344	175	3023	578	322	15	1976	1139	4413	191	26888	830	217	4180	1638	2179	16040	0	438	172	64	69408	SUM
		PL	PT	MD	RO	RU	SK	SI	ES	SE	CH	MK	TR	UA	GB	YU	EU	BAS	BLS	MED	NOS	ATL	BIC	NAT	ASI	REM	VOL		

Table 10: The 1998 country-to-country blame matrices computed with the EMEP Eulerian Acid Deposition model for reduced nitrogen.

EMITTERS

RECEPTORS

	AL	AM	AT	BY	BE	BA	BG	HR	CY	CZ	DK	EE	FI	FR	GE	DE	GR	HU	IS	IE	IT	KZ	LV	LT	LU	NL	NO	
AL	80	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	10	1	0	0	14	0	0	0	0	0	0	AL
AM	0	74	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	268	0	3	1	0	4	0	25	0	0	0	14	0	188	0	14	0	0	76	0	0	0	0	3	0	AT
BY	0	0	4	1090	1	1	3	1	0	10	3	2	0	5	1	26	1	9	0	0	6	0	7	27	0	2	0	BY
BE	0	0	0	0	254	0	0	0	0	0	0	0	0	115	0	26	0	0	0	1	1	0	0	0	7	44	0	BE
BA	2	0	5	0	0	83	2	16	0	4	0	0	0	4	0	4	1	12	0	0	42	0	0	0	0	0	0	BA
BG	7	0	2	1	0	2	245	1	0	1	0	0	0	2	0	3	31	5	0	0	10	0	0	0	0	0	0	BG
HR	1	0	12	0	0	33	1	65	0	4	0	0	0	5	0	6	1	22	0	0	67	0	0	0	0	0	0	HR
CY	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CY
CZ	0	0	63	0	4	1	0	2	0	285	2	0	0	15	0	223	0	9	0	0	13	0	0	0	0	6	0	CZ
DK	0	0	1	1	4	0	0	0	0	2	263	0	0	8	0	73	0	0	0	1	1	0	0	0	0	11	1	DK
EE	0	0	0	7	1	0	0	0	0	1	3	84	3	2	0	7	0	0	0	0	1	0	10	4	0	1	0	EE
FI	0	0	1	12	1	0	0	0	0	2	8	23	194	4	0	19	0	1	0	1	1	0	3	5	0	3	4	FI
FR	0	0	3	0	79	0	0	1	0	2	1	0	0	4536	0	82	0	1	0	13	94	0	0	0	8	24	0	FR
DE	0	0	59	1	142	2	0	1	0	50	33	0	0	270	0	3038	0	4	0	5	35	0	0	0	24	410	1	DE
GR	27	0	0	0	0	2	22	1	0	0	0	0	0	2	0	1	237	1	0	0	17	0	0	0	0	0	0	GR
HU	1	0	36	1	0	9	3	25	0	15	0	0	0	5	0	19	1	248	0	0	36	0	0	0	0	1	0	HU
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	9	1	0	0	0	0	0	0	0	IS
IE	0	0	0	0	1	0	0	0	0	0	0	0	0	10	0	2	0	0	0	549	1	0	0	0	0	1	0	IE
IT	5	0	13	0	1	8	1	10	0	2	0	0	0	54	0	15	3	5	0	0	2100	0	0	0	0	0	0	IT
LV	0	0	1	37	1	0	0	0	0	3	5	15	1	3	0	15	0	2	0	0	1	0	37	36	0	2	0	LV
LT	0	0	2	74	1	0	0	0	0	6	6	3	0	5	0	24	0	2	0	0	2	0	7	138	0	3	0	LT
LU	0	0	0	0	8	0	0	0	0	0	0	0	0	14	0	6	0	0	0	0	0	0	0	0	9	1	0	LU
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	MT
NL	0	0	0	0	143	0	0	0	0	0	1	0	0	32	0	115	0	0	0	2	1	0	0	0	1	582	0	NL
NO	0	0	0	1	4	0	0	0	0	2	25	1	1	15	0	27	0	1	0	2	1	0	0	1	0	7	118	NO
PL	1	0	24	63	12	4	3	4	0	115	25	2	0	32	0	300	1	22	0	1	18	0	1	11	1	25	1	PL
PT	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1	0	0	0	0	1	0	0	0	0	0	0	PT
MD	0	0	0	2	0	0	2	0	0	0	0	0	0	0	1	0	1	1	0	0	1	0	0	0	0	0	0	MD
RO	7	0	10	4	1	9	57	5	0	11	0	0	0	6	1	16	11	68	0	0	34	0	0	0	0	0	0	RO
RU	3	13	5	308	4	4	17	2	0	18	13	42	37	16	207	64	9	17	0	0	21	29	20	34	0	5	3	RU
SK	0	0	21	1	1	3	2	4	0	30	0	0	0	3	0	21	1	53	0	0	14	0	0	0	0	1	0	SK
SI	0	0	14	0	0	1	0	9	0	1	0	0	0	2	0	4	0	5	0	0	51	0	0	0	0	0	0	SI
ES	0	0	1	0	1	1	0	0	0	1	0	0	0	119	0	6	0	1	0	2	18	0	0	0	0	1	0	ES
SE	0	0	2	7	6	0	0	1	0	6	84	6	21	17	0	66	0	4	0	2	3	0	2	4	0	14	24	SE
CH	0	0	2	0	3	0	0	0	0	0	0	0	0	66	0	37	0	0	0	0	62	0	0	0	0	2	0	CH
MK	23	0	0	0	0	1	5	0	0	0	0	0	0	1	0	0	16	1	0	0	5	0	0	0	0	0	0	MK
TR	4	21	1	1	0	1	21	0	5	1	0	0	0	1	32	2	24	1	0	0	12	1	0	0	0	0	0	TR
UA	3	1	10	159	1	7	19	5	0	17	2	0	0	8	11	31	8	39	0	0	30	2	0	3	0	2	0	UA
GB	0	0	1	0	14	0	0	0	0	1	7	0	0	110	0	29	0	0	0	115	2	0	0	0	1	21	0	GB
YU	19	0	6	0	0	29	14	9	0	5	0	0	0	4	0	7	7	30	0	0	34	0	0	0	0	0	0	YU
EU	32	0	349	21	657	14	23	18	0	91	397	29	215	5310	0	3667	240	31	0	691	2351	0	5	9	50	1115	30	EU
BAS	0	0	4	22	10	1	1	1	0	14	201	57	47	27	0	269	0	5	0	2	4	0	15	20	1	27	5	BAS
BLS	2	2	2	3	0	4	43	1	0	2	0	0	0	2	42	6	13	5	0	0	16	1	0	0	0	0	0	BLS
MED	52	0	12	1	2	29	37	18	16	4	0	0	0	168	1	10	166	9	0	0	830	0	0	0	0	0	0	MED
NOS	0	0	3	1	112	0	0	0	0	8	153	1	0	473	0	276	0	2	0	31	5	0	1	1	2	208	22	NOS
ATL	0	0	2	2	21	1	0	1	0	5	18	2	6	541	0	71	0	2	15	313	14	0	0	1	1	22	42	ATL
REM	5	84	1	2	2	4	7	1	3	2	0	0	0	25	448	3	14	2	0	0	71	76	0	0	0	0	0	REM
SUM	242	195	591	1801	838	242	506	188	28	655	853	238	310	6748	774	5138	556	604	24	1041	3766	109	103	285	55	1429	221	SUM
	AL	AM	AT	BY	BE	BA	BG	HR	CY	CZ	DK	EE	FI	FR	GE	DE	GR	HU	IS	IE	IT	KZ	LV	LT	LU	NL	NO	

Table 10 (cont.): The 1998 country-to-country blame matrices computed with the EMEP Eulerian Acid Deposition model for reduced nitrogen.

EMITTERS (columns) / ***RECEPTORS*** (rows)

	PL	PT	MD	RO	RU	SK	SI	ES	SE	CH	MK	TR	UA	GB	YU	EU	BAS	BLS	MED	NOS	ATL	BIC	NAT	ASI	REM	VOL	SUM	
AL	0	0	0	1	0	0	0	4	0	0	7	0	1	0	14	29	0	0	0	0	0	0	0	0	2	0	137	AL
AM	0	0	0	0	1	0	0	0	0	0	0	44	0	0	0	0	0	0	0	0	0	0	0	44	0	0	193	AM
AT	8	0	0	2	0	7	19	4	0	25	0	0	1	3	2	559	0	0	0	0	0	0	0	0	1	0	668	AT
BY	161	0	3	19	45	7	1	2	2	1	0	1	268	4	3	56	0	0	0	0	0	0	0	0	0	0	1716	BY
BE	1	0	0	0	0	0	0	3	0	1	0	0	0	12	0	463	0	0	0	0	0	0	0	0	0	0	465	BE
BA	5	0	0	5	0	3	2	7	0	1	1	0	2	0	32	63	0	0	0	0	0	0	0	0	3	0	236	BA
BG	2	0	3	103	5	1	1	2	0	0	13	4	32	0	48	50	0	0	0	0	0	0	0	0	2	0	526	BG
HR	4	0	0	5	0	3	15	7	0	1	0	0	2	0	13	98	0	0	0	0	0	0	0	0	3	0	270	HR
CY	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	1	0	0	12	CY
CZ	43	0	0	2	0	18	3	4	0	7	0	0	2	4	2	334	0	0	0	0	0	0	0	0	0	0	708	CZ
DK	6	0	0	0	0	0	0	2	6	0	0	0	1	7	0	377	0	0	0	0	0	0	0	0	0	0	388	DK
EE	10	0	0	1	6	0	0	1	4	0	0	0	5	2	0	25	0	0	0	0	0	0	0	0	0	0	153	EE
FI	23	0	0	1	20	1	0	2	19	0	0	0	14	6	1	259	0	0	0	0	0	0	0	0	0	0	369	FI
FR	4	9	0	1	0	0	1	302	0	57	0	0	1	72	0	5223	0	0	0	0	0	0	0	0	11	0	5302	FR
DE	68	1	0	1	0	3	2	29	3	125	0	0	2	58	2	4107	0	0	0	0	0	0	0	0	1	0	4370	DE
GR	1	0	1	10	1	0	0	4	0	0	21	11	11	0	11	261	0	0	0	0	0	0	0	0	5	0	386	GR
HU	12	0	0	55	1	33	13	3	0	2	1	0	15	1	34	102	0	0	0	0	0	0	0	0	1	0	571	HU
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	5	0	0	0	0	0	0	0	0	0	0	14	IS
IE	0	1	0	0	0	0	0	3	0	0	0	0	0	49	0	617	0	0	0	0	0	0	0	0	0	0	617	IE
IT	3	2	0	3	0	1	11	47	0	18	1	0	2	1	7	2236	0	0	0	0	0	0	0	0	17	0	2330	IT
LV	31	0	0	2	7	1	0	2	6	0	0	0	11	4	0	41	0	0	0	0	0	0	0	0	0	0	223	LV
LT	80	0	0	3	14	2	0	2	4	1	0	0	17	4	1	53	0	0	0	0	0	0	0	0	0	0	401	LT
LU	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	40	0	0	0	0	0	0	0	0	0	0	40	LU
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	MT
NL	1	0	0	0	0	0	0	2	0	1	0	0	0	11	0	890	0	0	0	0	0	0	0	0	0	0	892	NL
NO	12	0	0	1	1	1	0	6	17	1	0	0	2	19	0	124	0	0	0	0	0	0	0	0	0	0	266	NO
PL	1863	1	1	16	12	40	5	11	10	6	0	0	104	20	8	481	0	0	0	0	0	0	0	0	1	0	2764	PL
PT	0	318	0	0	0	0	0	127	0	0	0	0	0	1	0	453	0	0	0	0	0	0	0	0	1	0	454	PT
MD	2	0	59	59	4	0	0	0	0	0	0	1	109	0	1	2	0	0	0	0	0	0	0	0	0	0	243	MD
RO	17	0	27	995	11	13	3	6	0	2	6	6	164	1	68	85	0	0	0	0	0	0	0	1	3	0	1563	RO
RU	175	0	10	63	4577	11	2	10	14	1	2	81	747	16	10	214	0	0	0	0	0	0	0	56	6	0	6672	RU
SK	40	0	0	10	0	95	4	2	0	2	0	0	16	1	7	65	0	0	0	0	0	0	0	0	0	0	332	SK
SI	1	0	0	1	0	1	47	3	0	1	0	0	0	0	1	74	0	0	0	0	0	0	0	0	1	0	143	SI
ES	2	98	0	1	0	0	0	2499	0	2	0	0	1	8	1	2753	0	0	0	0	0	0	0	0	19	0	2782	ES
SE	46	0	0	3	8	2	1	6	260	1	0	0	11	21	1	502	0	0	0	0	0	0	0	0	0	0	629	SE
CH	0	0	0	0	0	0	0	6	0	301	0	0	0	3	0	181	0	0	0	0	0	0	0	0	1	0	483	CH
MK	0	0	0	3	0	0	0	1	0	0	44	0	2	0	20	23	0	0	0	0	0	0	0	0	1	0	123	MK
TR	3	1	2	24	24	0	0	6	0	0	3	1566	55	0	7	47	0	0	0	0	0	0	0	171	15	0	2005	TR
UA	174	0	78	210	153	24	4	6	1	2	2	23	3831	4	19	103	0	0	0	0	0	0	0	6	4	0	4899	UA
GB	4	2	0	0	0	0	0	18	1	1	0	0	0	1401	0	1722	0	0	0	0	0	0	0	0	1	0	1729	GB
YU	5	0	0	41	1	4	2	6	0	1	17	1	8	1	351	65	0	0	0	0	0	0	0	0	3	0	605	YU
EU	167	431	1	22	29	14	34	3049	289	231	22	11	44	1651	25	20462	0	0	0	0	0	0	0	0	56	0	45684	EU
BAS	170	1	0	4	19	3	1	9	113	2	0	0	18	26	2	741	0	0	0	0	0	0	0	0	0	0	1101	BAS
BLS	11	0	13	111	89	2	1	3	0	1	2	119	410	1	13	43	0	0	0	0	0	0	0	9	2	0	931	BLS
MED	8	11	1	29	6	2	12	397	0	7	11	308	28	4	35	1600	0	0	0	0	0	0	0	70	181	0	2465	MED
NOS	31	3	0	1	2	2	1	32	18	4	0	0	2	623	1	1939	0	0	0	0	0	0	0	0	1	0	2020	NOS
ATL	17	187	0	2	22	1	1	300	7	5	0	0	5	486	1	1989	0	0	0	0	0	0	0	0	8	0	2122	ATL
REM	5	8	1	10	177	1	1	81	0	1	2	221	42	1	7	206	0	0	0	0	0	0	0	1683	1038	0	4029	REM
SUM	3049	643	199	1798	5206	282	153	3968	485	581	133	2393	5942	2879	723	29300	0	0	0	0	0	0	0	2041	1332	0	59347	SUM
	PL	PT	MD	RO	RU	SK	SI	ES	SE	CH	MK	TR	UA	GB	YU	EU	BAS	BLS	MED	NOS	ATL	BIC	NAT	ASI	REM	VOL		

Appendix C: Import-Export Budgets for 1998 Computed with the EMEP Eulerian Acid Deposition Model

Receptors	Oxidized sulphur						Oxidized Nitrogen						Reduced Nitrogen					
	Export		Import		Sea	EMEP	Export		Import		Sea	EMEP	Export		Import		Sea	EMEP
	Mass	%	Mass	%	%	%	Mass	%	Mass	%	%	%	Mass	%	Mass	%	%	%
AL	307	85	299	85	33	91	69	94	149	97	33	86	175	69	57	42	21	95
AM	12	73	156	97	0	85	27	81	62	91	3	63	132	64	119	62	1	95
AT	175	76	638	92	12	96	442	85	430	85	12	86	325	55	400	60	4	100
BY	628	66	1587	83	5	97	421	84	655	89	6	77	714	40	626	36	2	100
BE	832	82	360	66	22	98	823	90	297	76	21	87	561	69	211	45	18	103
BA	1897	79	561	53	18	94	213	87	283	90	22	92	172	67	153	65	14	95
BG	4974	80	901	41	25	90	501	74	333	65	24	91	299	55	281	53	15	93
HR	367	82	605	88	23	96	206	89	326	93	19	89	127	66	205	76	11	98
CY	229	93	32	67	36	75	61	91	23	79	36	76	29	88	8	67	49	85
CZ	1762	80	979	68	13	97	1102	88	498	76	11	86	374	57	423	60	5	99
DK	326	85	694	92	42	99	676	96	539	95	29	76	593	69	125	32	43	100
EE	496	90	220	80	19	97	134	96	138	96	13	74	155	65	69	45	25	100
FI	245	54	1004	83	23	98	576	75	465	71	15	67	117	38	175	47	17	100
FR	2537	61	2247	58	26	97	3303	66	1965	53	23	87	2275	33	766	14	18	99
DE	4448	69	2512	56	16	98	3849	71	2085	57	15	84	2109	41	1332	30	12	100
GR	2029	75	1155	63	39	85	934	80	391	63	41	85	372	61	149	39	29	91
HU	2348	79	890	59	11	96	494	75	450	73	9	92	361	59	323	57	4	99
IS	110	82	86	78	78	96	76	90	63	89	44	59	16	65	5	36	61	97
IE	565	64	205	39	46	99	332	89	182	82	46	81	497	48	68	11	33	100
IT	3876	76	2401	66	37	91	3759	73	1067	44	28	86	1746	45	230	10	23	98
LV	155	77	412	90	19	97	115	90	244	95	16	71	70	65	186	83	15	96
LT	363	77	535	83	16	99	167	91	299	95	12	75	150	52	263	66	8	99
LU	19	95	30	97	10	75	50	97	26	93	17	83	49	85	31	78	7	95
NL	425	75	458	77	28	99	1200	89	334	70	25	84	876	60	310	35	18	98
NO	98	65	949	95	43	99	599	88	481	85	35	68	104	47	148	56	31	99
PL	5849	62	2815	44	12	98	2177	72	1559	65	11	84	1192	39	901	33	8	100
PT	1349	81	264	45	42	73	899	79	260	52	28	66	481	60	136	30	25	80
MD	143	89	302	95	16	94	61	92	90	95	14	77	147	71	184	76	7	97
RO	2768	61	2102	54	14	95	661	68	721	70	16	89	825	45	568	36	8	99
RU	4148	38	9732	59	10	85	4052	54	4141	54	5	63	981	18	2095	31	2	94
SK	746	83	757	84	10	96	348	88	317	87	8	87	191	67	237	71	3	99
SI	538	87	185	71	18	96	179	92	146	90	16	90	109	70	96	67	10	98
ES	5201	69	904	28	30	87	2367	65	1046	45	25	83	1759	41	283	10	17	93
SE	144	59	1334	93	33	98	601	77	891	83	23	74	226	47	369	59	28	100
CH	94	68	254	85	9	95	317	84	232	80	12	86	280	48	182	38	3	100
MK	71	84	275	95	18	88	17	93	99	99	27	82	96	69	79	64	9	95
TR	3465	54	2894	49	15	84	1587	61	1539	61	17	76	1078	41	439	22	16	91
UA	3560	63	3641	63	10	94	1056	76	1560	83	11	82	2173	36	1068	22	8	99
GB	5591	69	795	24	44	99	4328	81	690	41	37	83	1485	51	328	19	40	100
YU	1850	71	1090	59	15	94	158	79	401	90	18	95	390	53	254	42	7	98
EU	21925	56	30308	63	32	93	19051	59	21418	62	26	83	9516	32	25222	55	21	98
BAS	640	56	2157	81	51	99	853	80	1146	84	30	77	0	0	1101	100	0	
BLS	130	46	2709	95	61	95	173	66	989	92	42	83	0	0	931	100	0	
MED	2098	35	13044	77	66	90	2460	49	5570	69	52	84	0	0	2465	100	0	
NOS	1143	50	4164	79	61	99	1458	74	2641	84	41	83	0	0	2020	100	0	
ATL	2065	46	17419	88	57	67	2419	63	8474	86	42	57	0	0	2122	100	0	

Export in 100 tonnes (mass of S or N) and as a percentage of the country (region) emission.
Import in 100 tonnes (mass of S or N) and as a percentage of the total deposition to the country (region).
Sea is the percent of the country (region) emission deposited to the sea surface.
EMEP is the percent of the country (region) emission deposited to the EMEP domain.