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**TRANSBOUNDARY  
ACIDIFICATION AND EUTROPHICATION  
IN EUROPE**

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# Transboundary Acidification and Eutrophication in Europe

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EMEP recognises the need for further co-operation and harmonisation in the compilation of relevant air quality data and appreciates to that term the positive working dialogue with the European Environmental Agency, in particular with Roel van Aalst and André Jol.

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The calculations presented in this report are based on meteorological data obtained from the Numerical Weather Prediction (NWP) model run at the Norwegian Meteorological Institute. We would specially like to thank Jan Erik Haugen and Dag Bjørge for their efforts updating the meteorological model HIRLAM-PS for use in MSC-W dispersion pollution models.

The calculations were facilitated by access to a CRAY T3E supercomputer at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. The invaluable assistance from the staff at NTNU is greatly acknowledged here.

***Leonor Tarrasón and Jan Schaog (editors)***



## *Preface*

The main task of the Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air pollutants in Europe (EMEP) is to provide the ECE Governments and the Convention on Long-range Transboundary Air Pollution with qualified scientific information to support the review and further extension of the international co-operation to solve transboundary air pollution problems.

This report focuses on the first of the five thematic areas in EMEP: “Acid deposition and eutrophication”. The report has been prepared for presentation and consideration at the twenty-fourth session of the Steering Body to EMEP. It summarises the 1998 European situation with respect to acidifying and eutrophying pollution transport across national boundaries. While the 1999 EMEP Summary Report evaluated the status and qualified the limitations of the EMEP programme with respect to emission collection, monitoring data and model development, the main focus in this year report is the ability of the EMEP programme to determine air quality trends.

In the first chapter, changes in emissions, transboundary depositions and exceedances to critical loads are analysed. We have enhanced differences from previous reports and tried to explain the origin of significant changes. In the second chapter, we present an example evaluation of trends combining information both from monitoring and modelled data. The approach has recognised limitations and it is primarily intended to encourage further evaluation and discussions under the forthcoming meeting of the Task Force on Measurements and Modelling.

As in the past year, we have organised the information in the Appendix with dedicated data for each individual country. We trust that this form of presenting the information available under EMEP is useful for the Parties to the LRTAP Convention, its Executive Body and subsidiary bodies.

The present report, and the technical notes that support it, are intended to stimulate communication between the participants and users of EMEP. Their purpose is to facilitate the exchange of information by:

- a) documenting the availability of the data,
- b) sharing methodologies and research developments
- c) clarifying the operational objectives and needs of the programme
- d) providing a common basis for discussion

All data included in this report will be available via Internet after it is approved by the Steering Body of EMEP. Countries are encouraged to analyse the data and provide their own conclusions. Reactions and comments are both welcome and encouraged.

<http://www.emep.int>

Overview of EMEP technical notes supporting the results presented in this report

	Reference	Title	Author
D O C U M E N T A T I O N & D A T A	EMEP/MSC-W Note 1/2000	EMEP Emission Data. Status report 2000”	V.Vestreng and E. Støren
	EMEP/MSC-W Note 2/2000	Meteorological input data for EMEP/MSC- W air pollution models	H. S. Lenschow and S. Tsyro
	EMEP/MSC-W Note 3/2000	EMEP Eulerian Acid Deposition Model. Model performance for 1998.	K. Olendrzynski
	EMEP/MSC-W Note 4/2000	“Non-linear effects in the source receptor matrices computed with the EMEP Euleri- an Acid Deposition Model”	J. Bartnicki
	EMEP/CCC Report 3/2000	Data Report 1998 Part 1: annual summaries	A-G. Hjellbrekke
	EMEP/CCC Report 4/2000	Data Report 1998 Part 2: monthly and seasonal summaries	A-G. Hjellbrekke
	EMEP/CCC Report 6/2000	Data quality 1998, quality assurance and fields comparisons	W.Aas, A-G. Hjellbrekke and J. Schaug
R E S E A R C H	EMEP/MSC-W Note 5/2000	Effects of international shipping on Euro- pean pollution levels”	J. E. Jonson, L. Tarrason and J. Bartnicki
	EMEP/MSC-W Note 6/2000 -	Towards a model of ozone deposition and stomatal uptake over Europe	L.D.Emberson, D.Simpson, J.-P. Tuovinen,M.R. Ash- more and H.M. Cambridge
	EMEP/MSC-W Note 7/2000	Parametrisation of aerosol deposition pro- cesses in EMEP MSC-E and MSC-W trans- port models	S. Tsyro and L. Erdman
D I S C U S S I O N	EMEP/MSC-W and CIAM Note8/2000	The need of nationally reported activity and emission data for UN/ECE-EMEP	M. Amann, J. Cofala, Z. Kli- mont, and L.Tarrason

*Transboundary acidification and  
eutrophication in the EMEP area  
in 1998*

Leonor Tarrasón, Krzysztof Olendrzynski, Max Posch  
Egil Støren, Jerzy Bartnicki and Vigdis Vestreng



## ***1. Transboundary acidification and eutrophication the EMEP area***

Reductions of sulphur emissions in Europe have positively contributed to limit exposure to acidification. However, eutrophication remains to be an unsolved problem. In 1998, in central Europe more than 90% of ecosystem areas were exposed to exceedances of the critical load for eutrophication. This situation is generally widespread: in 70% of the EMEP area countries more than half of the ecosystem areas are affected by eutrophication. The situation shows little improvement since 1990. The percentage of ecosystem areas exposed to eutrophication has increased since 1990 in about half of the countries in the EMEP area.

Austria, Belgium and Poland are the countries that have more largely benefited from the sulphur emission reductions in Europe since 1990. The reduction of exposed ecosystem areas in these countries is directly related to reductions of emissions in neighbouring countries and not to emission reductions in the countries themselves. While central European countries have benefited from the reductions of sulphur emissions, northern European countries like Norway, Estonia and Latvia, have experienced the largest reductions in transboundary nitrogen deposition.

Relevant differences with respect to previous years modelled estimates of the status and trends of eutrophying and acidifying air pollution in Europe are the analysis of the influence of international ship traffic in the Mediterranean and Black Seas and the inclusion of boundary conditions to represent intercontinental sources outside the model domain. The meteorological input and the parametrisation of dry deposition in the Eulerian Acid deposition model have been revised and improved. Differences in the calculations are interpreted in terms of reported re-calculations in national emissions and the four independent factors identified above.

### ***1.1. Transboundary depositions in 1998***

Acidification and eutrophication are caused by deposition of atmospheric sulphur and nitrogen oxides and reduced nitrogen in areas with sensible ecosystems. In 1998, about 9,1 Mtonnes (S) (=  $9,1 \cdot 10^{12}$  g (S)) were reported to be emitted to the atmosphere from countries in the EMEP area and 8,0 Mtonnes (S) were deposited in the same area. About 58% of the sulphur deposition in EMEP countries originates from the transboundary exchange of pollution among these countries and neighbouring areas. In 1998, 4,7 Mtonnes (S) deposited in EMEP countries were caused by transboundary exchange.

For nitrogen, both oxidised and reduced, 9,8 Mtonnes (N) (=  $9,8 \cdot 10^{12}$  g (N)) were reported to be emitted to the atmosphere from countries in the EMEP area in 1998. Of these, 8,6 Mtonnes (N) were deposited in the EMEP area where 3,9 Mtonnes (N) have been estimated to be caused by transboundary exchange. The transboundary deposition accounts for ~45% of total nitrogen deposition. This contribution is somewhat smaller than in the case of sulphur because reduced nitrogen has also been considered in these calculations.

There are significant differences in the influence of transboundary deposition in European

areas. These differences are documented in the 1998 source-receptor matrices computed with the EMEP Eulerian Acid Deposition model as presented in Tables A1 to A4 at the end of this chapter. Deposition in each country originating from transboundary sources is indicated in Table A4, at the end of this chapter, under the heading “Import” while “Export” denotes the mass of pollutant deposited outside the emission area. The accuracy of the source-receptor matrices calculated by the Eulerian model is discussed in detail in Bartnicki (2000).

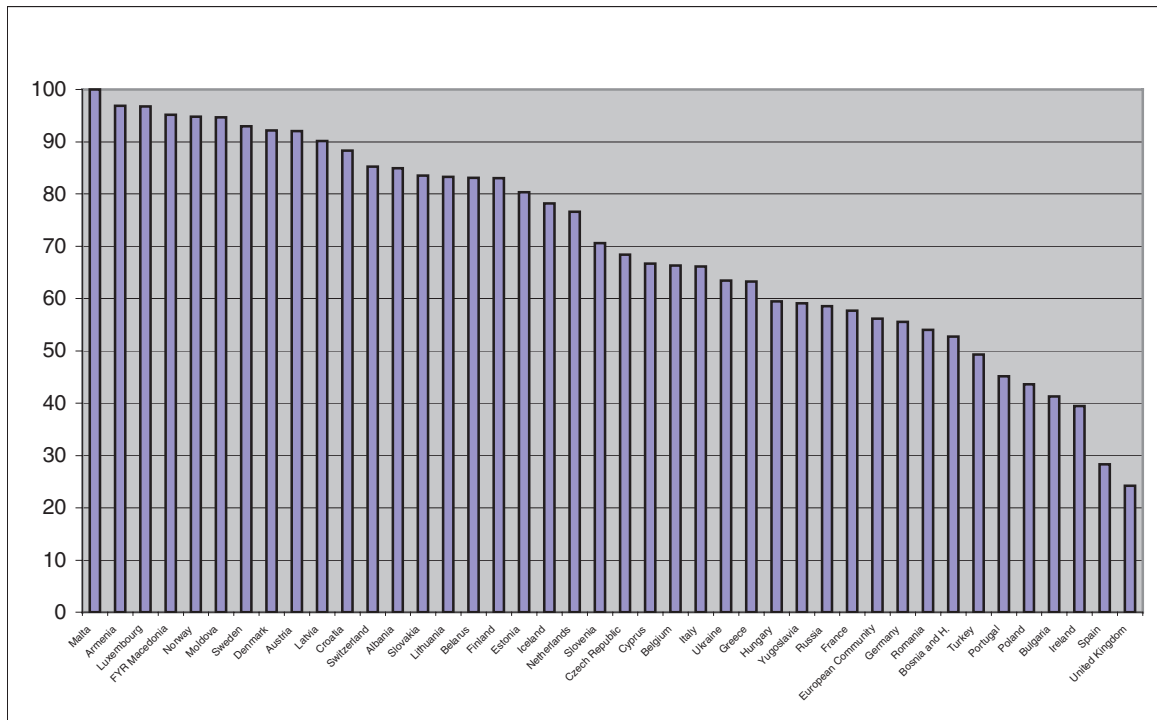
Figures 1.1. and 1.2. in the next page show the relative contribution of transboundary deposition in each country in the EMEP area, respectively for sulphur and nitrogen deposition. The relative contribution of transboundary deposition in 1998 is calculated as the percentage of the total deposition in the countries which is caused by emissions originating outside of the national country borders. For nitrogen, the sum of the oxidised and reduced deposition is considered as this is of relevance for the calculation of exceedances to critical loads of acidification and eutrophication. The inclusion of reduced nitrogen in Figure 1.2. explains why the contribution of transboundary nitrogen deposition (measured as Mtonnes (N)/year) is in general smaller than for sulphur deposition.

Only in 7 countries the contribution of transboundary sulphur deposition is below half of the total deposition. In most of these countries, transboundary sulphur deposition is dependant on pollution supply from areas outside the EMEP domain and is only considered in the calculations as boundary conditions. This is specially the case for Turkey, Portugal, Ireland and Spain. On the other hand, the low relative contribution of transboundary deposition in Poland and United Kingdom, is a consequence of the large indigenous deposition in these countries. As presented in Tables A5-A7 (adapted from Vestreng and Støren, 2000), national emissions from Poland and United Kingdom are among the largest in Europe. Transboundary air pollution calculations have identified these countries as “emitter” areas.

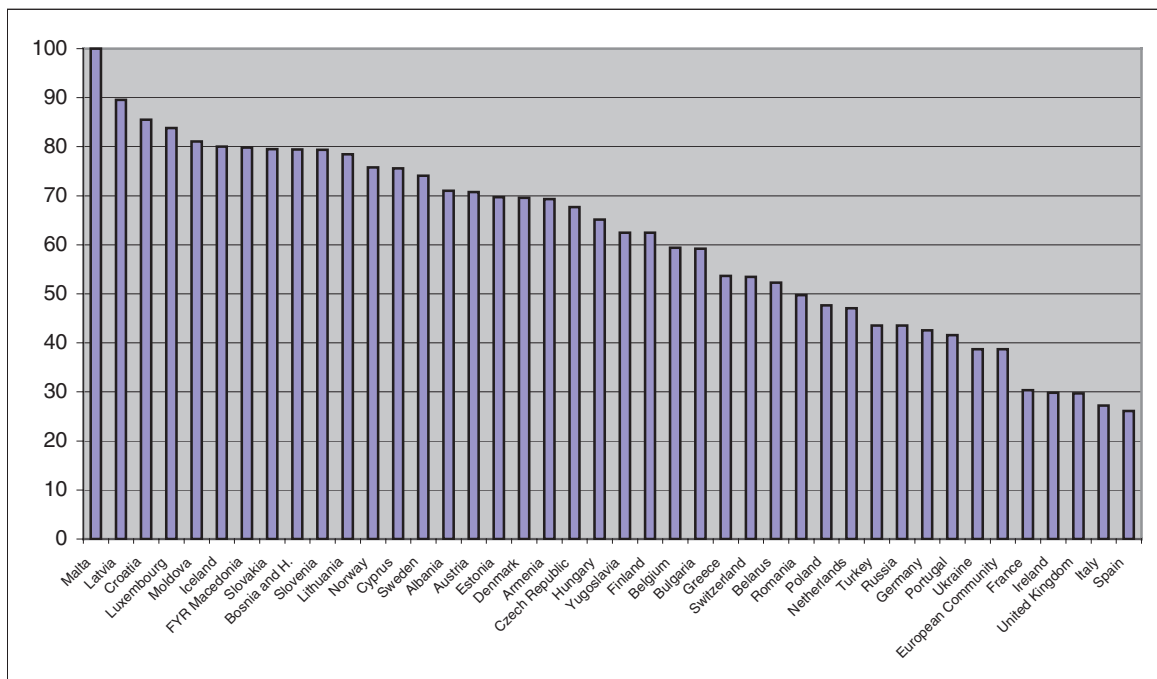
Transboundary nitrogen deposition contributes below 50% of total deposition in 13 countries/ areas. Again, these areas are either those with large indigenous contributions: United Kingdom, Russian Federation, Germany, Netherlands, Poland or areas close to the borders of the EMEP domain: Spain, Ireland, Turkey.

Malta has been introduced for the first time as receptor country in EMEP calculations. This means that there are no calculations of indigenous deposition over Malta and thus all deposition has a transboundary origin. The estimated emissions from Malta are below the accuracy limits of the source-receptor calculations and do not justify a separate study of Malta as emitter country.

Two different approaches have been used to determine the relative contribution of transboundary fluxes in the European Community. In Tables A1-A4, the European Community is considered as a single emitter region and transboundary exchange is considered only from and to areas outside the European Community. The second approach considers transboundary exchange among EU member countries as a part of the European Community transboundary exchange. This second approach has adopted in Figures 1.1. and 1.2 and in the timeseries presented in page 121 in Appendix II. According to this, transboundary deposition in 1998 represents 56% of the total sulphur deposition in the European Community as a whole. For nitrogen, the contribution from transboundary deposition is estimated to be 39%.

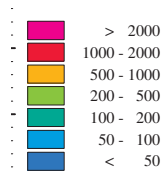
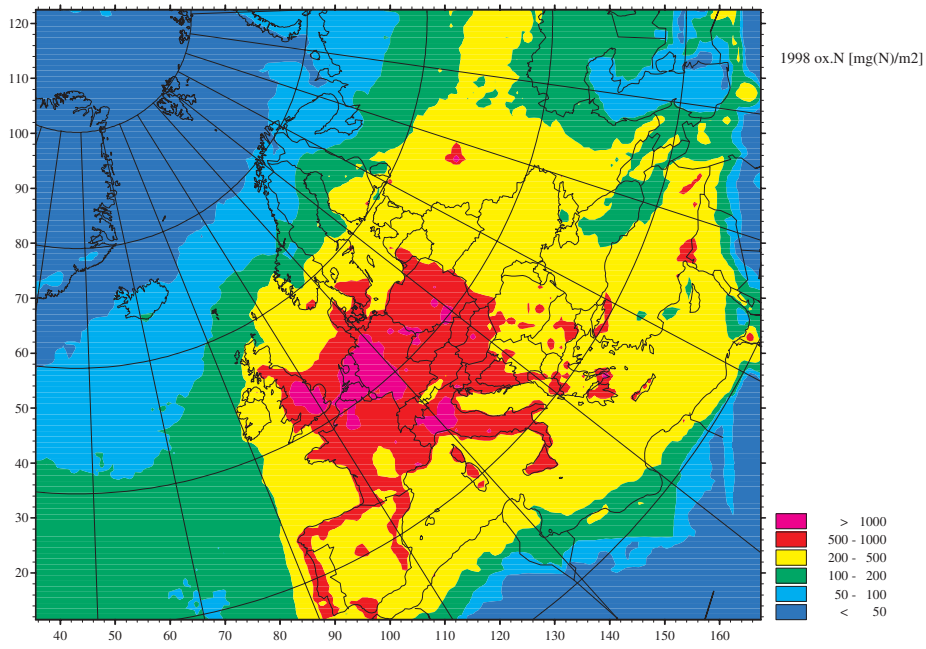


**Figure 1.1.** Relative contribution of transboundary deposition of sulphur in 1998, calculated as percentage of the total deposition per country.

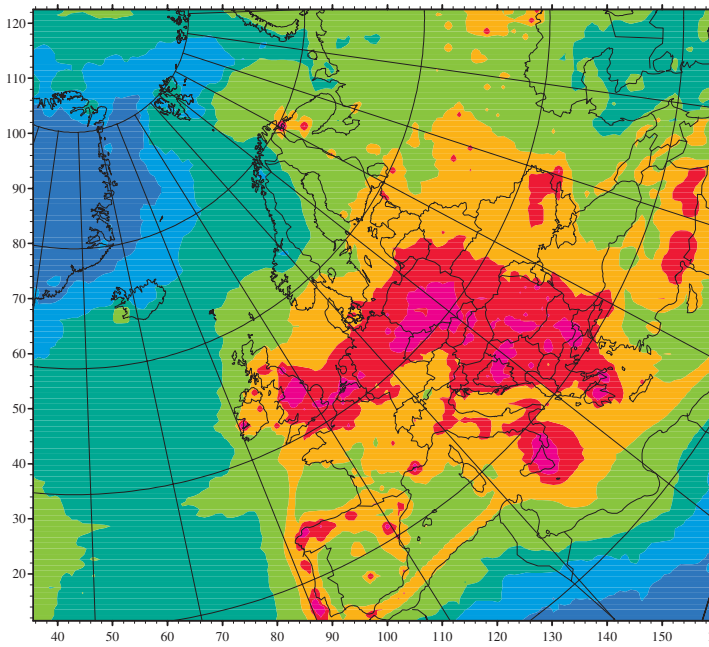


**Figure 1.2.** Relative contribution of transboundary deposition of nitrogen compounds in 1998, calculated as percentage of the total deposition of oxidized and reduced nitrogen per country.

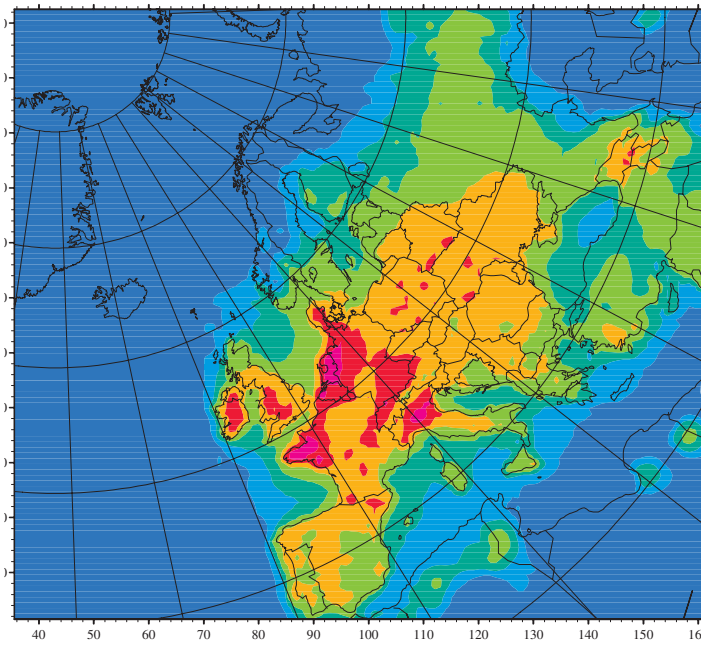
a)



b)



c)



**Figure 1.3.** a) 1998 total deposition of oxidised nitrogen ( $\text{mg(N)/m}^2/\text{a}$ )  
b) 1998 total deposition of oxidised sulphur ( $\text{mg(S)/m}^2/\text{a}$ )  
c) 1998 total deposition of reduced nitrogen ( $\text{mg(N)/m}^2/\text{a}$ )  
\* Colour scale for b) and c) is given in the centre of the page

## *The geographical distribution of acidifying and eutrophying depositions*

The transboundary exchange calculations presented above are based on the latest update of the EMEP Eulerian Acid Deposition model runs. The 1998 model update is extensively described in Olendrzynski (2000) where the performance of the model is also analysed. Here we are primarily interested in commenting the main differences with respect to previous calculations of transboundary exchange. We have identified four significant differences from the 1997 calculations, namely:

- a) revision and update of input precipitation fields (Lenschow and Tsyro, 2000)
- b) revision of dry deposition model routines (Olendrzynski, 2000)
- c) introduction of boundary and initial conditions (Bartnicki, 2000)
- d) new emission estimates from ship traffic in the Mediterranean and Black Seas (Jonson et al., 2000)

Figure 1.3 shows the geographical distribution of the 1998 yearly accumulated deposition of oxidised nitrogen, oxidised sulphur and reduced nitrogen as derived by the EMEP Eulerian Acid Deposition model. The visible differences with respect to last year's calculations can not only be explained in terms of meteorological variability.

For oxidised sulphur, major differences with respect to previous estimates are visible over Mediterranean areas, Turkey and Ukraine. Turkey has reported a considerable increase in national sulphur emissions with respect to previous years reports, as now the whole of the country is included in the EMEP calculations. The increase of Turkish emission by a factor of 6 and the inclusion of international ship traffic emissions in the Mediterranean and the Black seas compensates for reported sulphur emission reductions in other European regions so that the total sulphur emissions in the EMEP area for 1998 are very similar to the values reported last year for 1997. The increased deposition of sulphur in southern Europe in 1998 calculations is the combined result of increased emissions in Turkey and southern sea areas, the inclusion of boundary conditions and the increased wet deposition of particulate sulphate. As discussed in Lenschow and Tsyro (2000), the underestimation of convective precipitation in 1997 calculations affected primarily wet deposition calculations over sea areas in southern Europe. For the 1998 input meteorological fields have been checked for consistency in the vertical and total precipitation amounts agree better with observations. As a consequence and despite the recognised limitations of the present parametrisation of wet scavenging, wet deposition estimates have improved over the EMEP area (Olendrzynski, 2000).

For oxidised nitrogen, major differences are visible over all sea areas. This is mainly the result of the reformulation of the dry deposition where surface resistances over sea areas have now been decreased in accordance to documented values in the scientific literature. Consequently, there is an increase in the deposition of oxidised nitrogen over sea areas. In general, emissions of nitrogen dioxide in EMEP area are reported to be ~10% higher in 1998 than in 1997. The main increase in emission occurs again in Turkey and for the Mediterranean and the Black Seas. Figure 1.3.a) shows also significant differences in the eastern boundary of the EMEP domain as a consequence of the introduction of new boundary conditions.

Emissions of ammonia in the EMEP area have been reported to be about 7% larger in 1998 than in last year's calculations. The main increases of ammonia emissions have been reported after an exhaustive re-calculation of  $\text{NH}_3$  emissions carried out in France and Spain. The corresponding increase in reduced nitrogen deposition over France and Spain is depicted in

Figure 1.3.c). Other differences with respect to last year's calculations are explained by the decrease in the surface resistance of  $\text{NH}_3$  over sea areas.

### ***The influence of boundary and initial conditions in the calculations***

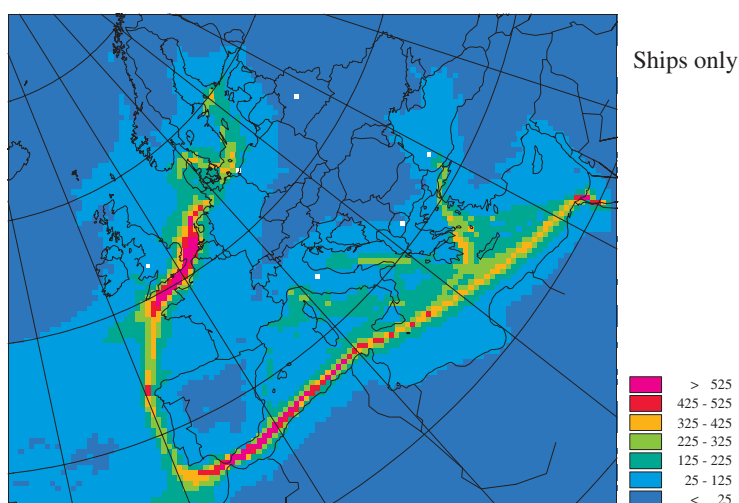
Bartnicki (2000) presents an overview of the contribution of boundary and initial conditions in the source-receptor calculations. In the 1998 calculations, boundary and initial concentrations of oxidised sulphur and nitrogen are taken into account as additional sources. These represent the influence of sources outside the EMEP domain (North American sources, Asian sources).

The largest contribution from boundary and initial conditions is estimated for countries affected by pollution inflow from areas outside the EMEP domain like Denmark, mainly because of Greenland, Norway, Sweden, Ireland, Spain and Turkey. The contribution of boundary conditions to depositions over the entire EMEP area are 14% and 23% for sulphur and nitrogen oxides, respectively.

The second page included in Appendix II includes an overview of the five largest contributors to import and export of oxidised sulphur, oxidised nitrogen and reduced nitrogen for each country/area. Values from the Lagrangian Acid Deposition model calculations for 1985, averaged (1985-1996) and 1996 are compared to the calculations by the Eulerian Acid Deposition model for 1997 and 1998. In most areas, it is possible to draw conclusions on the comparability of the source-receptor calculations by the two models. It is interesting to note that, in many cases, the "indeterminate origin" in the Lagrangian calculations can now be explained to a certain degree by the contribution by "boundary and initial conditions".

### ***International ship traffic in the Mediterranean and the Black Sea***

As a result of close co-operation with different international organisations (HELCOM, Directorate General for Environment in the European Commission, the Swedish Environmental Protection Agency) emission estimates of European ship traffic quantified by Lloyd's Register with comparable methods are now available for all the sea areas in the EMEP domain.



**Figure 1.4.** The contribution from international shipping to oxidised sulphur deposition in 1998. Units:  $\text{mg(S)} \text{ m}^{-2}$  (from Jonson et al. (2000))

An analysis of the effects of international ship traffic on acidification, eutrophication and ground level ozone is given in Jonson et al. 2000 (EMEP/MSC-W Note 5/2000). It is interesting to note that ship traffic emissions is among the five largest single contributors to sulphur deposition values in Belgium, Cyprus, Denmark, Estonia, Finland, France, Greece, Iceland, Ireland, Italy, Malta, Netherlands, Portugal, Spain, Sweden, Turkey and United Kingdom. For several countries bordering the Baltic Sea and the Mediterranean Sea, emissions from ship traffic are the largest identified transboundary contributor to oxidised nitrogen deposition. The effects in depositions are reflected also in significant contributions to exceedance of critical loads of acidification and eutrophication.

The relative contribution of ship emissions to exceedance of critical loads is likely to increase in time if no emission reductions are implemented that follow in parallel land based emission reduction plans.

## ***1.2. Accumulated exceedance of critical loads in 1998***

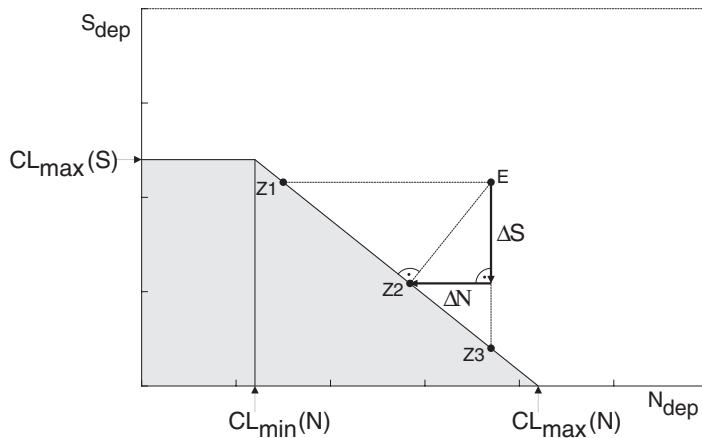
In the negotiations of the 1999 Protocol to “Abate Acidification, Eutrophication and Ground-level Ozone” two different critical loads have been used: the critical load of nutrient nitrogen, the maximum acceptable deposition of nitrogen not causing eutrophication of ecosystems, and critical loads of acidity, the maximum deposition of sulphur and nitrogen not causing detrimental leaching of acidity.

To harmonise with the work under the Working Group of Effects and in co-ordination with the Coordinating Centre for Effects (CCE) the calculations presented in this report have adopted for the first time the definition of accumulated exceedances of critical loads. Previous EMEP reports had only considered the definition of conditional critical loads.

**The critical load of nutrient nitrogen** for an ecosystem,  $CL_{nut}(N)$ , is a single number, and thus its exceedance is simply defined as  $Ex = \max\{N_{dep} - CL_{nut}(N), 0\}$ . The accumulated exceedance (AE) for a grid cell is obtained by multiplying the exceedance of each ecosystem with its area and summing over all “n” ecosystems in the gridcell:  $AE_{nut} = A_1 \times Ex_1 + A_2 \times Ex_2 + \dots + A_n \times Ex_n$ , where  $A_i$  is the area of the i-th ecosystem;  $AE_{nut}$  is the total amount of excess nitrogen (per year) in the gridcell.

**The critical loads of acidity** are not single numbers, but every ecosystem is characterized by a trapezoidal critical load function, defined by three numbers,  $CL_{max}(S)$ ,  $CL_{min}(N)$  and  $CL_{max}(N)$  as depicted in Figure 1.5. Every pair of depositions ( $N_{dep}, S_{dep}$ ) lying on or below the critical load function avoids excess leaching of acidity. Since, in general,  $CL_{max}(N) - CL_{min}(N) > CL_{max}(S)$ , no unique excess deposition exists. However, for the purpose of integrated assessment modelling an exceedance has been defined as the sum of emission reductions,  $Ex_{aci} = \max\{DN + DS, 0\}$ , needed to reach the closest point on the critical load function. Note that DN and DS have to be expressed in equivalents (moles of charge) before they can be added. The accumulated exceedance, i.e. the total annual amount of excess acidifying S and N deposition in a grid cell (expressed in equivalents) is again defined by multiplying the exceedance of every ecosystem with its area and summing up over all ecosystems in the grid cell.

More information on European critical loads and exceedance calculations can be found in Posch *et al.* (1999).



**Figure 1.5.:** Example of a critical load function for S and acidifying N defined by the  $CL_{max}(S)$ ,  $CL_{min}(N)$  and  $CL_{max}(N)$ . It shows that no unique exceedance can be defined: Let the point E denote the current deposition of N and S. Reducing  $N_{dep}$  substantially one reaches point Z1 and thus non-exceedance without reducing  $S_{dep}$ ; on the other hand one can reach non exceedance by reducing  $S_{dep}$  only (by a smaller amount) until reaching Z3. For the purpose of the protocol negotiations, an exceedance has been *defined* as the sum of  $N_{dep}$  and  $S_{dep}$  reductions ( $N+S$ ) which are needed to reach the critical load function on the shortest path (point Z2).

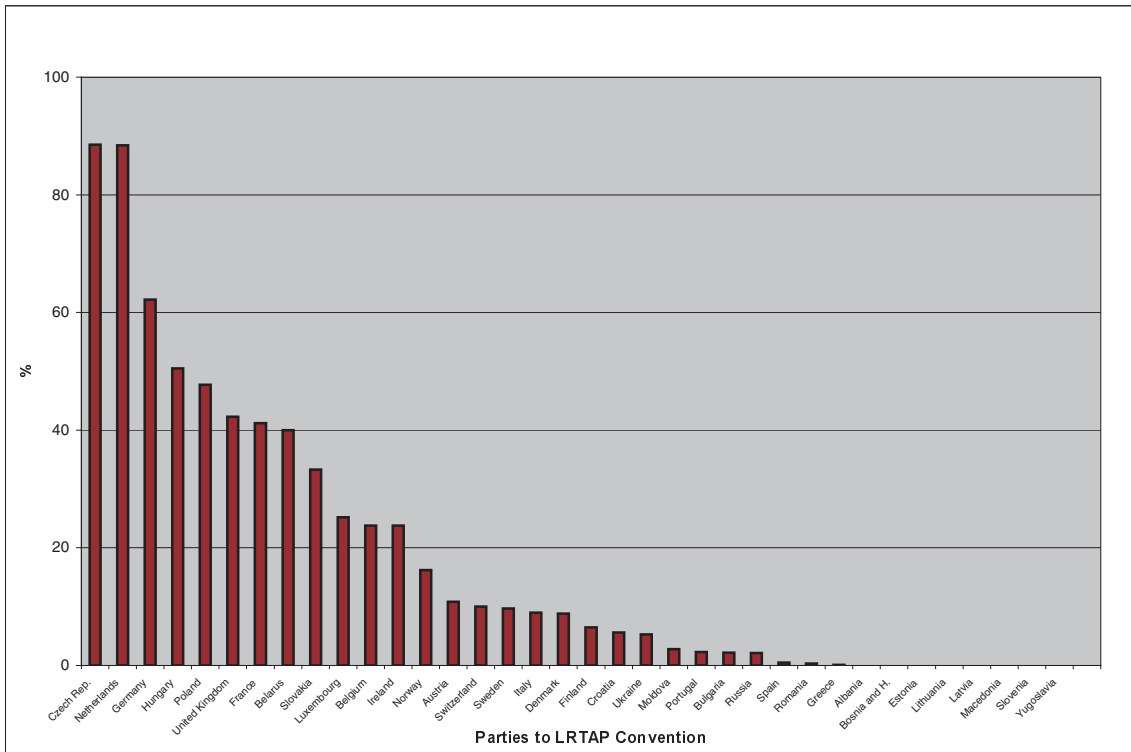
The resulting exceedances of critical loads are presented by country in Appendix II. From these calculations, the percentage area of ecosystems exposed to exceedances of critical loads can be estimated. Figures 1.6. and 1.7 provide an overview of the percentage ecosystem area affected by acidification and eutrophication in 1998.

In central Europe more than 90% of ecosystem areas are exposed to exceedances of the critical load for eutrophication. This situation is generally widespread: in 70% of the EMEP area countries more than half of the ecosystem areas are affected by eutrophication.

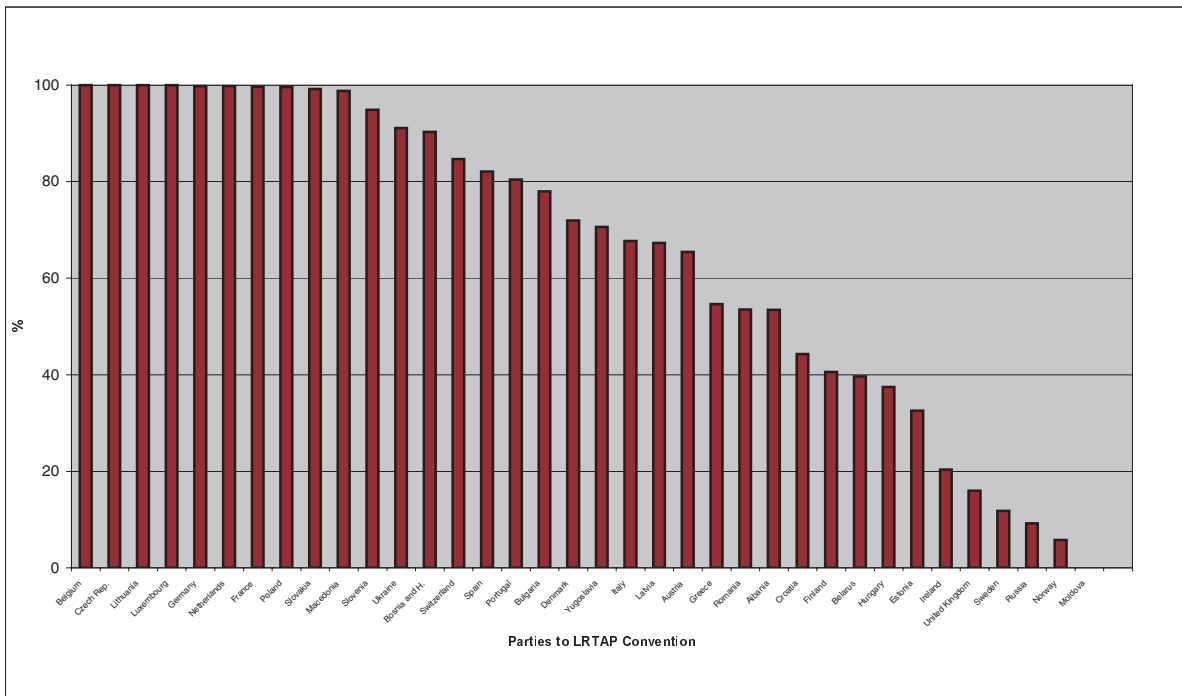
Acidification remains to be a problem in central Europe. In 1998, over 40% of ecosystem areas in most central European countries were affected by exceedances to critical loads of acidification. For Mediterranean countries, acidification affects generally below 10% of the registered sensitive ecosystem areas.

### ***1.3. Trends of emissions, depositions and critical load exceedances***

The evolution of emissions of sulphur dioxide, nitrogen oxides and ammonia as used by EMEP/MS-CW models is documented in tables A5-A7 at the end of this chapter. Officially reported data to UNECE/EMEP is given inside grey boxes. There is an overall marked progress in the official reporting of emissions for the main components. Differences with respect to last year's reporting are enhanced in bold letters to facilitate comparison. About 30% of the Parties to the Convention have reported recalculation of emissions values for years previous to 1998. Such recalculation have an influence in the overall trends of the region and



**Figure 1.6.** Ecosystem area exposed to exceedance of critical load of acidification in 1998, as percentage of total ecosystem area. Critical load data and accumulated exceedances are processed by CCE.



**Figure 1.7.** Ecosystem area exposed to exceedance of critical load of eutrophication in 1998, as percentage of total ecosystem area. Critical load data and accumulated exceedances processed by CCE.

in the determination of the progress towards the implementation of the different Protocols. In most cases, the recalculation of emissions reported by the Parties does not imply changes larger than 10-15% of the originally reported emissions. Significant exceptions have been the recalculations of sulphur and nitrogen oxides emissions in Turkey and the recalculation of ammonia emissions by France and Spain.

Trends on emissions, depositions, transboundary depositions, and exceedances to critical loads have been estimated for each Party to the Convention on Long Range Transboundary Air Pollution. The analysis has been performed separately for sulphur and nitrogen compounds, using accumulated exceedances of critical loads as calculated by the Coordination Centre for Effects (CCE). In addition, the ecosystem area in each country exposed to exceedances of critical loads has been calculated and it is presented as percentage of the total area of the country. This information is given in the Appendix, using three different figures for each country.

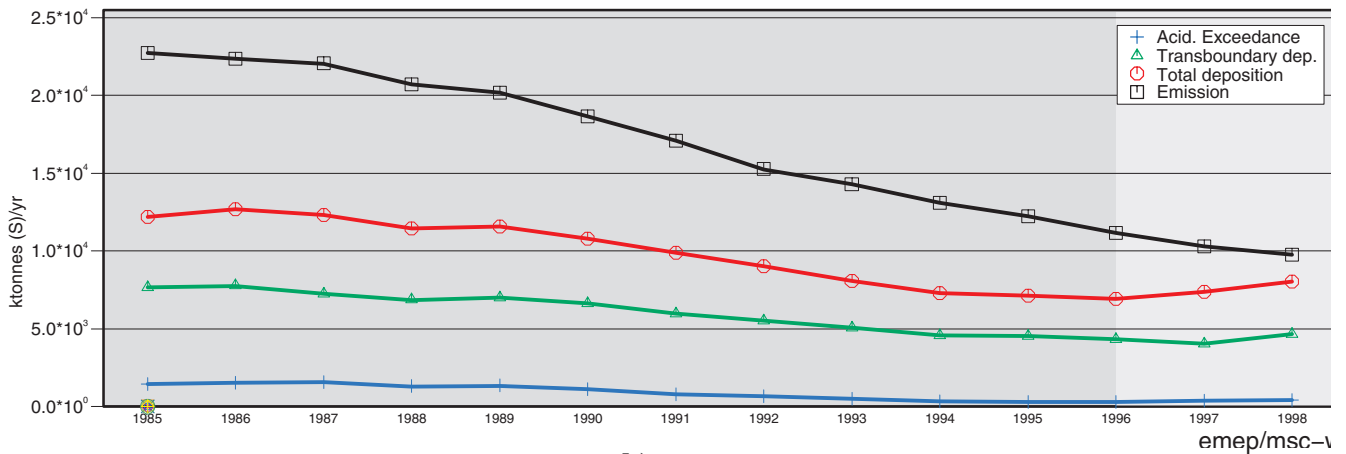
Figure 1.8 shows the calculated time evolution of emissions, depositions, transboundary depositions and exceedances for all countries in the EMEP area where there exists estimations of critical loads. Different models have been used to determine these timeseries: from 1985 to 1996 model results from the Lagrangian Acid Deposition model have been updated according to the 1998 reported emission recalculations. For 1997 and 1998, calculations are made with the Eulerian Acid Deposition model. These differences are shown in the figures by using two different grey tones in the background. No recalculations have been made for 1997. Thus we can expect inconsistencies for this year, in particular over southern European areas and in areas largely affected by boundary conditions.

As explained in previous reports, the first figure, for acidifying sulphur, shows the total sulphur mass emitted from the country each year, the total mass of sulphur deposited over the country and the total mass in exceedance of the critical load of acidification. In general, trends in the exceedances follow the trends in sulphur and nitrogen deposition. The acidifying sulphur figure includes also a curve depicting the changes of deposition of transboundary origin to the specific country. Differences between total deposition and transboundary deposition give a good measure of the importance of indigenous deposition in the country. In many cases, specially over central European countries, it can be seen how the relative contribution of transboundary deposition has increased after the emissions from the countries themselves have decreased. Direct comparison between the emissions and depositions values allows a first analysis of the country balance of imported vs exported deposition.

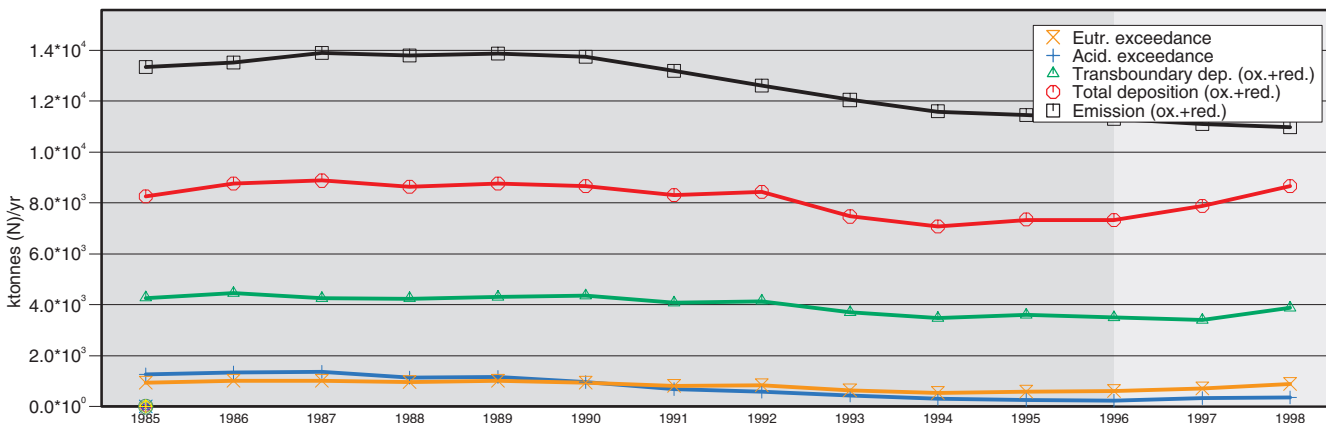
The second figure serves for the analysis of acidifying and eutrophying nitrogen. It has the same contents as the figure for sulphur trends, except that it includes two different lines to show the evolution of the total nitrogen mass in exceedance of the critical load of acidification and of nutrient nitrogen.

The third figure gives the time evolution of the area of ecosystems with exceedance of critical loads as percentage of the total country area. As a reference, the total ecosystem area with ecosystems sensitive to acidification and eutrophication are also given in the figure, as percentage of total country area. Here, the geographical distribution of the considered ecosystems plays an important role. Inter-annual meteorological variations can affect the pollution transport patterns, resulting in large changes in the percentage ecosystem area exposed to exceedances of critical loads. Larger deposition amounts over the country, do not necessarily imply larger ecosystem area with registered exceedances because both the

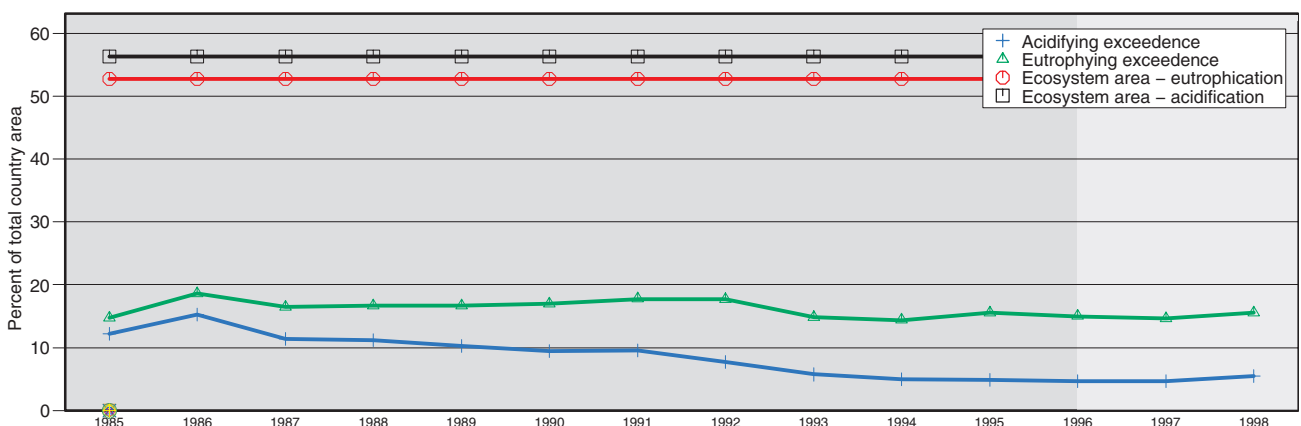
**a)**  
ACIDIFYING SULPHUR



**b)**  
ACIDIFYING AND EUTROPHYING NITROGEN



**c)**  
PERCENT OF COUNTRY AREA EXPOSED TO EXCEEDANCE OF CRITICAL LOADS



**Figure 1.8.** *a)* 1985-1998 trends of sulphur total deposition (red), transboundary deposition (green) and acidifying conditional exceedance (blue) for all countries in EMEP, *b)* trends of total nitrogen deposition (red), transboundary deposition (green), acidifying exceedance (blue) and eutrophying exceedance (yellow) for countries in EMEP area. Sulphur and nitrogen emissions (both as  $\text{NO}_x$  and  $\text{NH}_3$ ) are given in black curves. Units: 1000 tonnes (S or N)/year. *c)* ecosystem area and exceedance of critical loads as percentage of the total country area.

deposition levels and the geographical distribution of sensitive ecosystems determine the changes in the ecosystem area.

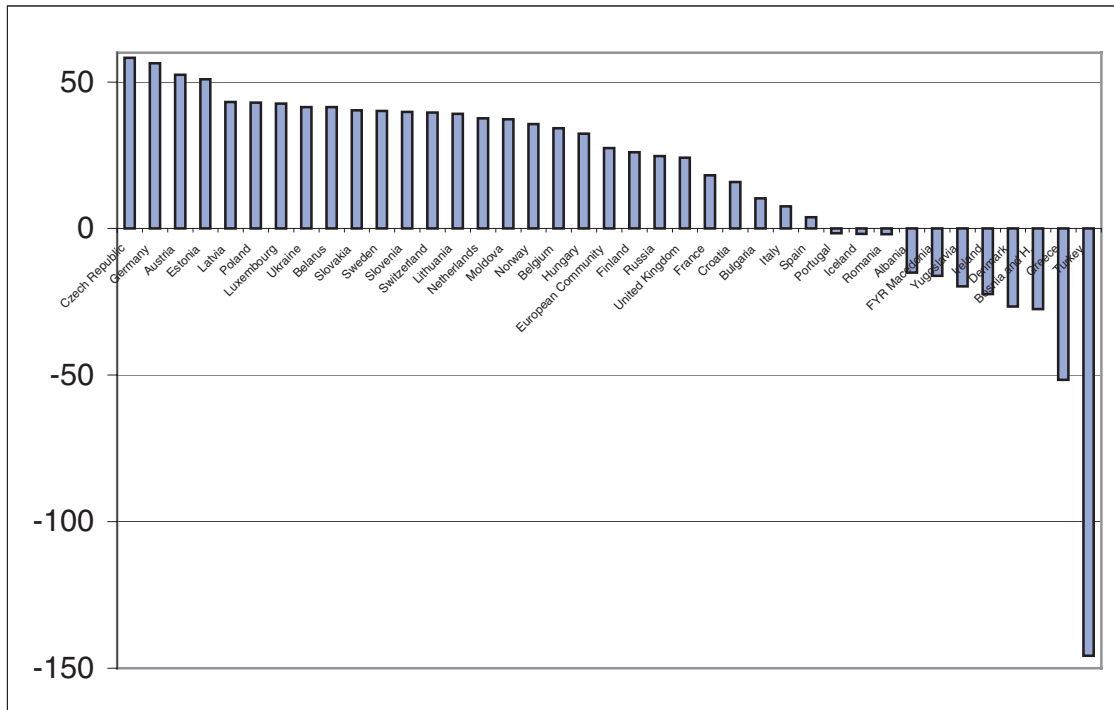
Again, there are significant differences in the timeseries from different countries. Changes with respect to 1990, the base year of the Gothenburg Protocol are indicated in Figures 1.9 to 1.18. Countries included in Figures 1.9 to 1.14 are those for which there are available estimates of critical load data.

Figure 1.9 shows the percentage reduction of total sulphur deposition in 1998 as compared to 1990 values. Central European countries have generally experienced the largest reductions in sulphur deposition. Sulphur deposition has increased since 1990 in some countries in the south-east of Europe. This is related partly to the increase in sulphur emissions by Turkey, Cyprus and Greece, partly to the introduction of boundary conditions in the calculations of transboundary exchange. The case of Turkey and Denmark deserve a special note. The increase in calculated depositions in these two countries is larger than it would be if the same country area was considered for the comparison of 1990 and 1998 values. With the extension of the EMEP grid, these two countries have increased considerably the national area included in the calculations.

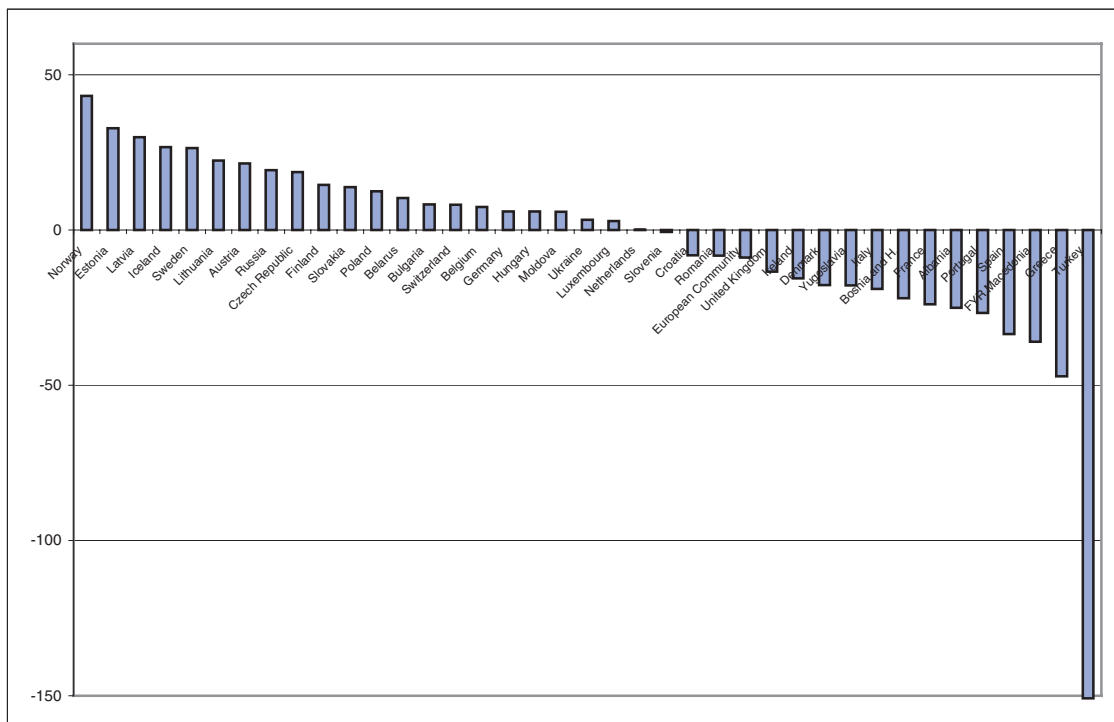
Figure 1.10 shows the percentage reduction of total nitrogen deposition in 1998 as compared to 1990 values. In this case, total nitrogen deposition corresponds to the sum of both oxidised and reduced nitrogen. In general, the reduction of nitrogen deposition in European countries is smaller than for sulphur deposition in agreement with the emission reduction trends (depicted in Figures 1.16 and 1.17). Even though emissions of nitrogen have increased in Norway since 1990, Norway is still the country in Europe that has experienced the largest reduction of nitrogen deposition since 1990. In general, northern European countries appear to have experienced largest reductions in nitrogen deposition. This is related to the changes in supply of pollution from transboundary fluxes.

Figures 1.11 and 1.12 show respectively the changes experienced by countries in depositions from transboundary origins. In about 50% of the countries considered there has been an increase in the total nitrogen deposition since 1990 to 1998. This is mostly related to the increase in emissions in neighbouring areas. Similar changes are calculated with respect to exceedances to critical loads. Figures 1.13 and 1.14 show how the percentage area of ecosystems exposed to exceedances of critical load for nutrient nitrogen has increased since 1990 in 50% of the countries.

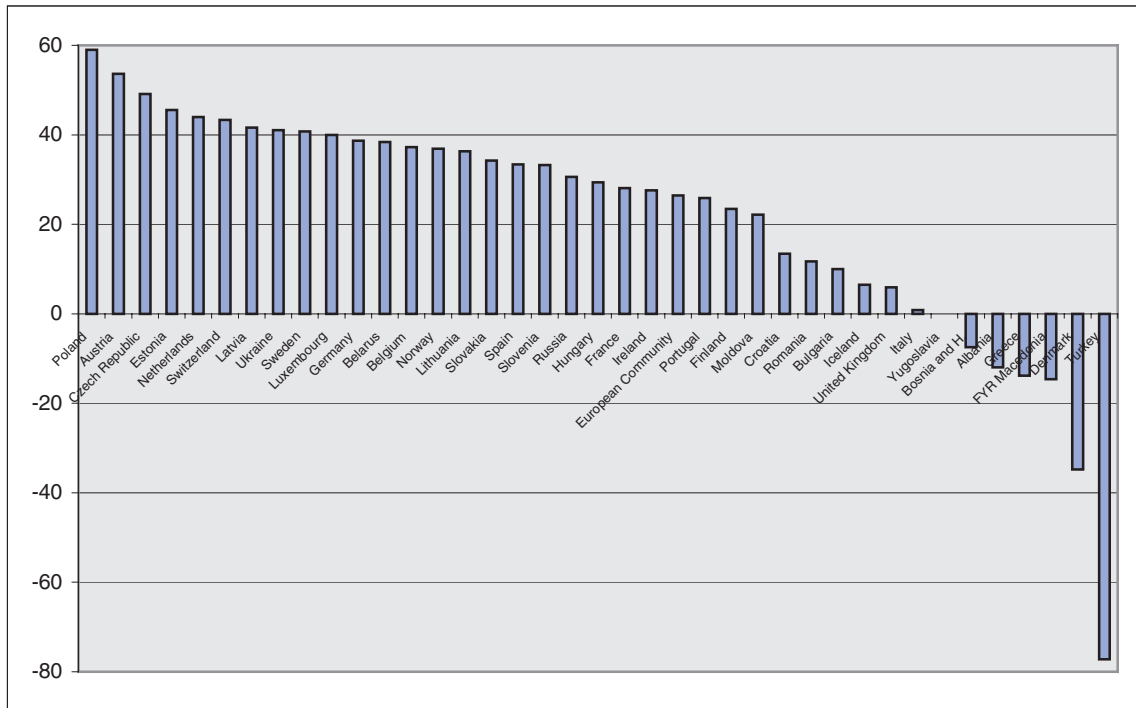
Finally, Figure 1.18 illustrates the non-linearity of the environmental impact with respect to emission changes. It is necessary to determine the extent of atmospheric transport and transboundary exchange in order to provide a credible interpretation of the effect of emission reductions in different areas.



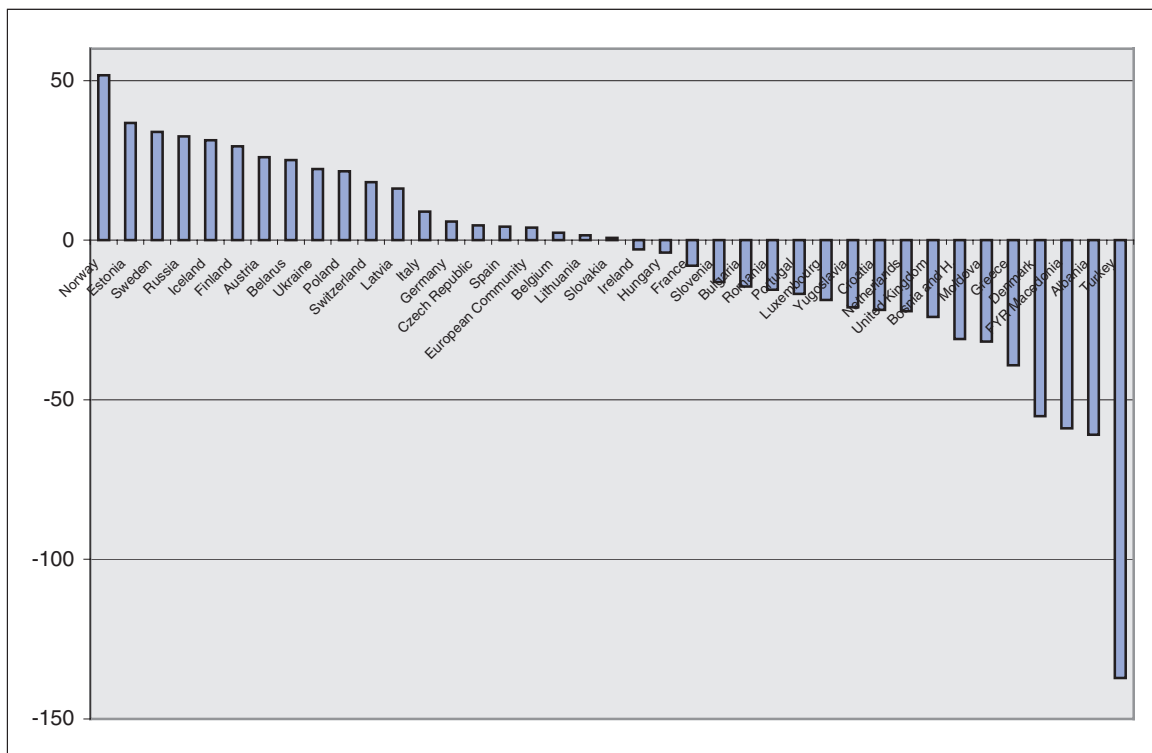
**Figure 1.9.** Percentage reduction of **total sulphur deposition** in 1998 as compared to 1990 values. Negative values mean that sulphur deposition has increased since 1990.



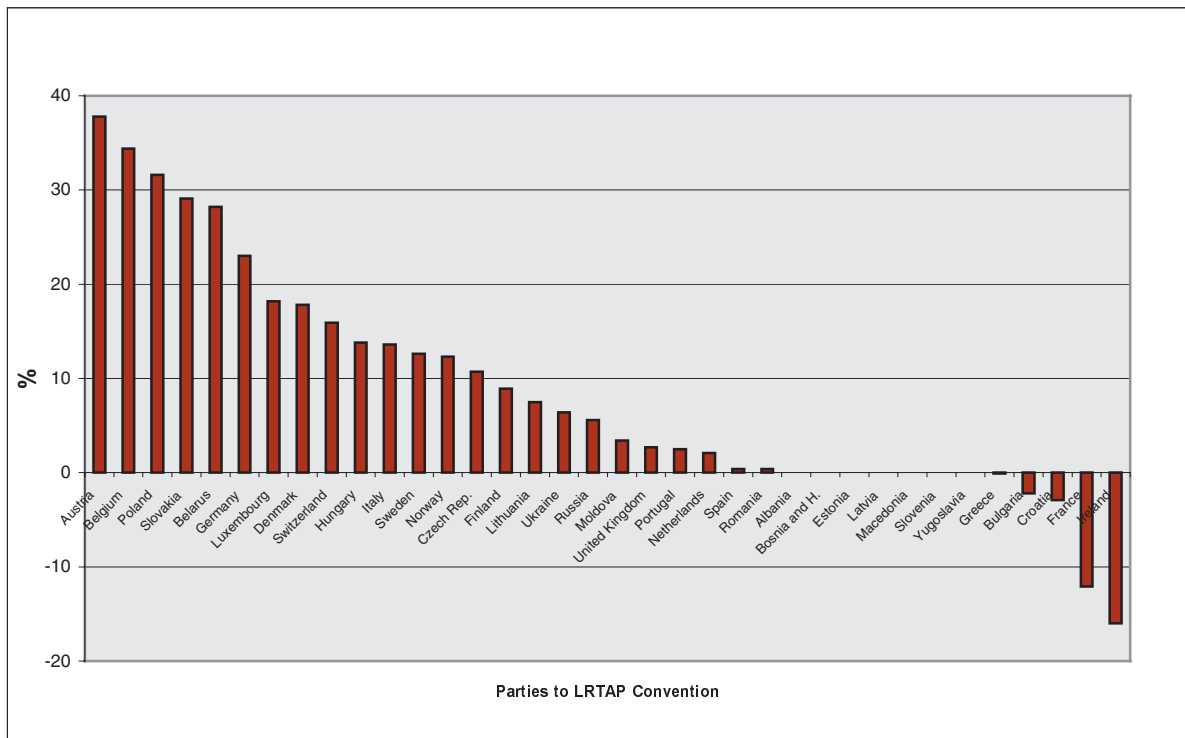
**Figure 1.10.** Percentage reduction of **total nitrogen deposition** in 1998 as compared to 1990 values. Negative values mean nitrogen deposition has increased since 1990.



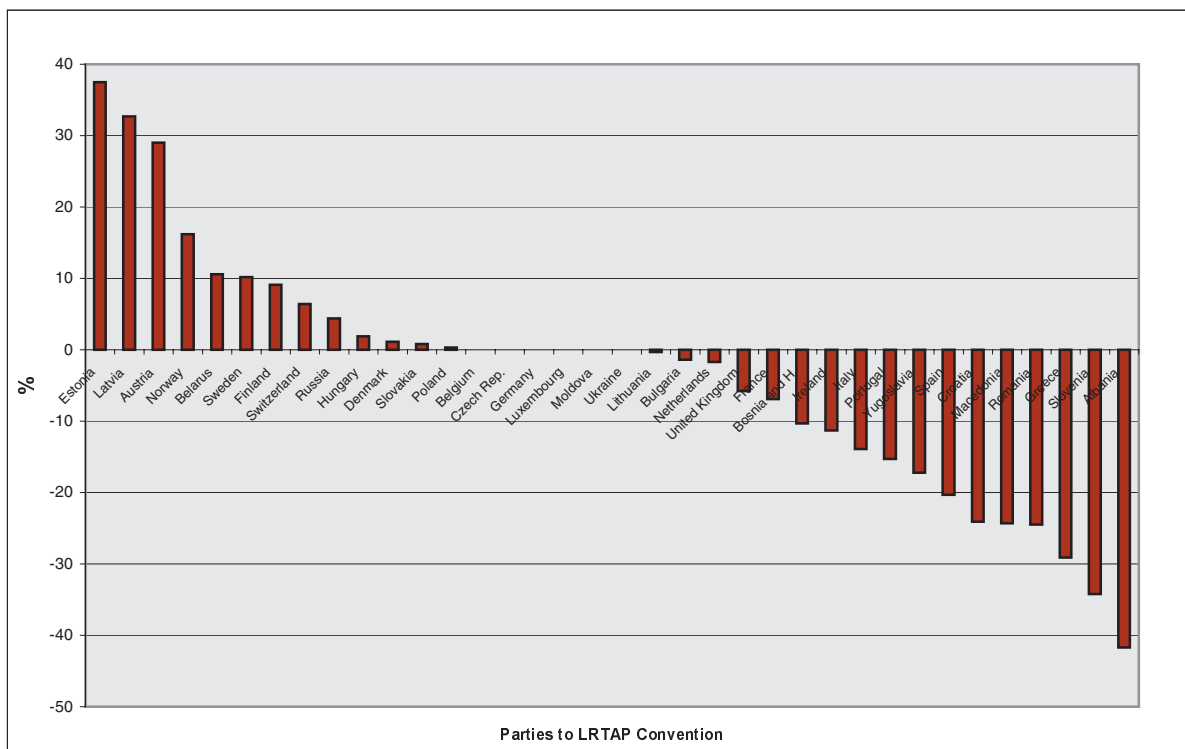
**Figure 1.11.** Percentage reduction of **transboundary sulphur deposition** in 1998 as compared to 1990 values (1998-1990)



**Figure 1.12.** Percentage reduction of **transboundary nitrogen deposition** in 1998 as compared to 1990 values (1998-1990).



**Figure 1.13.** Percentage difference (1990-1998) of ecosystem areas that are exposed to exceedance of critical load of acidification . (Critical Load data processed by CCE).



**Figure 1.14.** Percentage difference (1990-1998) of ecosystem areas that are exposed to exceedance of critical load of eutrophication . (Critical Load data processed by CCE).

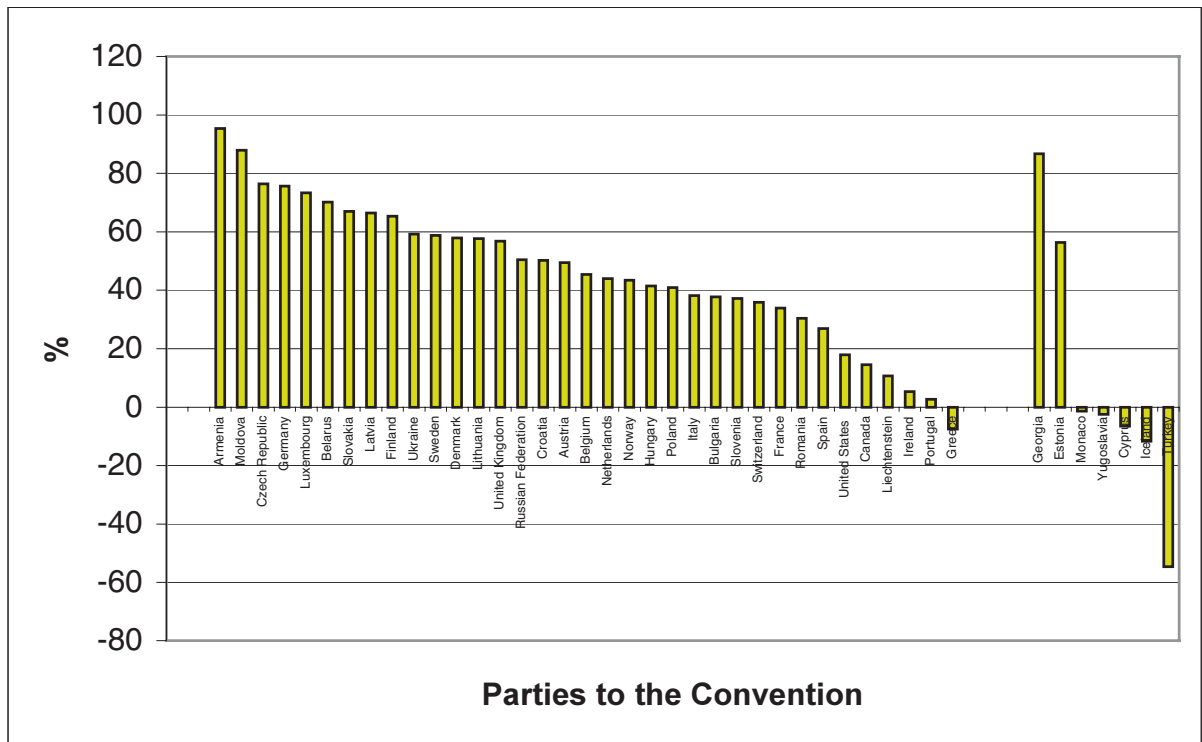


Figure 1.15. Emissions reductions of sulphur in the UNECE region from 1990-1998.

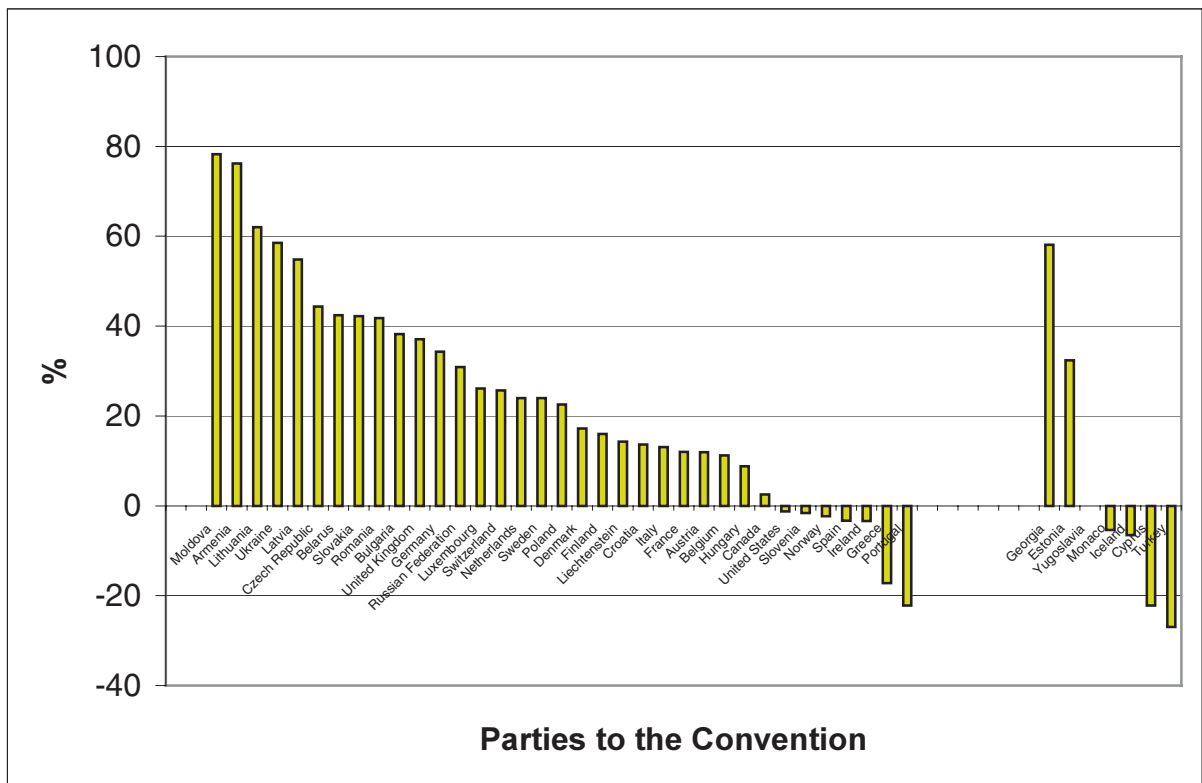


Figure 1.16. Emissions reductions nitrogen oxides in the UNECE region from 1990-1998.





**Source-receptor calculations for 1998**  
**as calculated by the EMEP Eulerian Acid Deposition model**  
**(Tables A1 to A5)**

All Parties to the LRTAP Convention, except four, are included in the calculations. These are: Canada and United States of America, Monaco and Liechtenstein. The first two countries are not included because they lie outside the EMEP area domain. Monaco and Liechtenstein are not included because their emissions and geographical extents are below the accuracy of the source-receptor calculations.

Although Albania is not a Party to the LRTAP Convention, its situation in Europe and the extent of its estimated emissions justify a separate study of this country as emitter and receptor.

Country/Region	Code	Country/Region	Code
Albania	AL	Poland	PL
Armenia	AM	Portugal	PT
Austria	AT	Republic of Moldova	MD
Belarus	BY	Romania	RO
Belgium	BE	Russian Federation	RO
Bosnia and Herzegovina	BA	Slovakia	SK
Bulgaria	BG	Slovenia	SI
Croatia	HR	Spain	ES
Cyprus	CY	Sweden	SE
Czech Republic	CZ	Switzerland	CH
Denmark	DK	The FYR of Macedonia	MK
Estonia	EE	Turkey	TR
Finland	FI	Ukraine	UA
France	FR	Yugoslavia	YU
Georgia	GE	United Kingdom	GB
Germany	DE	European Union	EU
Greece	GR		
Hungary	HU	Baltic Sea	BAS
Iceland	IS	Black Sea	BLS
Ireland	IE	Mediterranean Sea	MED
Italy	IT	North Sea	NOS
Kazakhstan	KZ	Remaining N.E. Atlantic	ATL
Latvia	LV	Boundary and Initial conditions	BIC
Lithuania	LT	North Africa	NOA
Luxembourg	LU	Remaining Asian Areas	ASI
Malta	MT	Remaining Land Areas	REM
Netherlands	NL	Natural marine emissions	NAT
Norway	NO	Volcanic emissions	VOL

*Russian Federation means the part the Russian Federation inside the EMEP domain of calculations. The same applies to the Remaining N.E. Atlantic region and Natural marine emission area.*

*North Africa means parts of Morocco, Algeria, Tunisia, Libya and Egypt. Remaining Asian Areas include Kazakhstan, Azerbaijan, Syria, Lebanon, Israel, parts of Uzbekistan, Turkmenistan, Iran, Iraq and Jordan.*

*Remaining Land Areas includes both North Africa and Remaining Asian Areas. (REM=NOA+ASI)*

*European Union includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden and United Kingdom.*

At difference from previous years, Malta is now introduced for the first time as receptor country. The estimated emissions from Malta are below the accuracy limits of the source-receptor calculations and do not justify a separate study of Malta as emitter country. Georgia and Kazakhstan are only considered as emitters regions but we are confident that Georgia will be included as receptor region in next years calculations.

**Table A1: 1998 country-to-country blame matrices for oxidised sulphur computed with the EMEP Eulerian Acid Deposition model. Units: 100 tonnes of S.**

		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
<b>R</b>	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
<b>E</b>	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
<b>C</b>	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
<b>E</b>	MT	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	0	MT
<b>P</b>	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
<b>T</b>	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
<b>O</b>	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
<b>R</b>	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
<b>S</b>	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 A1 (cont.):** 1998 country-to-country blame matrices for **oxidised sulphur** computed with the EMEP Eulerian Acid Deposition model. Units: 100 tonnes of S.

		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	NOA	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
<b>R</b>	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
<b>E</b>	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
<b>C</b>	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
<b>E</b>	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
<b>P</b>	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
<b>T</b>	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
<b>O</b>	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
<b>R</b>	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
<b>S</b>	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	26716	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	NOA	REM	VOL	

**Table A2: 1998 country-to-country blame matrices for oxidised nitrogen computed with the EMEP Eulerian Acid Deposition model. Units: 100 tonnes of N.**

		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	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	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	
<b>R</b>	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	
<b>E</b>	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	
<b>C</b>	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	
<b>E</b>	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	
<b>P</b>	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	
<b>T</b>	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	
<b>O</b>	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	
<b>R</b>	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	
<b>S</b>	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 A2 (cont.):** 1998 country-to-country blame matrices for **oxidised nitrogen** computed with the EMEP Eulerian Acid Deposition model. Units: 100 tonnes of N.

		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	NOA	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
<b>R</b>	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
<b>E</b>	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
<b>C</b>	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
<b>E</b>	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
<b>P</b>	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
<b>T</b>	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
<b>O</b>	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
<b>R</b>	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
<b>S</b>	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	18824	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	NOA	REM	VOL	

**Table A3: 1998 country-to-country blame matrices for reduced nitrogen computed with the EMEP Eulerian Acid Deposition model. Units: 100 tonnes of N.**

		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	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	0	AL	
	AM	0	74	0	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		
<b>R</b>	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		
<b>E</b>	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		
<b>C</b>	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		
<b>E</b>	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		
<b>P</b>	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		
<b>T</b>	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		
<b>O</b>	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		
<b>R</b>	PT	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1	0	0	0	1	0	0	0	0	0	0	0	PT		
<b>S</b>	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 A3 (cont.):** 1998 country-to-country blame matrices for **reduced nitrogen** computed with the EMEP Eulerian Acid Deposition model. Units: 100 tonnes of N.

		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	NOA	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	0	17	0	2330	IT	
<b>R</b>	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	0	223	LV	
<b>E</b>	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	0	401	LT	
<b>C</b>	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	0	40	LU	
<b>E</b>	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	0	0	MT
<b>P</b>	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	0	892	NL	
<b>T</b>	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	0	266	NO	
<b>O</b>	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	0	1	0	2764	PL	
<b>R</b>	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	0	1	0	454	PT	
<b>S</b>	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	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	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	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	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	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	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	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	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	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	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	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	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	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	0	56	0	21421	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	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	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	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	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	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	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	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				

**Table A4: Import-Export Budgets for 1998 computed with the EMEP Eulerian Acid Deposition model (Bartnicki, 2000)**

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	9164	34	32	93	19051	59	5580	30	26	83	9516	32	959	4	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

**Emission values used by EMEP/MSC-W  
for 1998 model calculations for acidification and eutrophication  
(Tables A5 to A7)**

In the following, emission data officially reported to UNECE/EMEP data are printed inside grey-shaded boxes. Data inside white boxes have not been officially reported to UNECE/EMEP, instead data have been drawn from open sources. Data has been adapted from Vestreng and Støren (2000).

Changes and Updates from last year's reporting (EMEP Report 1/99; EMEP/MSC-W Note 1/99) are printed in bold to facilitate comparison.

The same definition of areas applies here as described in A1 -A4.

For all tables, the following notes indicated as super-indexes are made as necessary:

- (1) The part inside the EMEP domain of calculation.
- (2) Emission ceilings for 2010 according to the 1999 Gothenburg Protocol (G.P.).
- (3) Regional division of emissions estimated by MSC-W.
- (4) National emissions are estimated as the sum of sector data.
- (5) Emission ceiling (G.P.) figure for whole Germany. Germany has reported also emission projections of 275 000 tonnes (S), 329 000 tonnes (N)
- (6) Natural emissions reported by Italy

**Table A5: Emissions of sulphur dioxide (100 tonnes as S per year)**

	1980	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2005	2010
Africa, north <sup>1</sup>	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065
Albania	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360
Armenia	705	500	555	555	520	315	360	300	220	30	20	15	10	2	15	2	2
Austria	1925	950	855	765	575	510	455	410	315	300	285	280	275	245	230	195	195 <sup>2</sup>
Belarus	3700	3450	3450	3805	3600	3340	3185	3260	2290	1910	1620	1375	1230	1045	950	2450	2400 <sup>2</sup>
Belgium	4140	2000	1885	1835	1770	1625	1860	1670	1590	1485	1265	1230	1200	1100	1015	1160	530 <sup>2</sup>
Bosnia and Herzegovina	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
Bulgaria	10250	11570	11835	12100	11140	10900	10040	8385	5640	7130	7400	7485	7100	6825	6255	4450	4280 <sup>2</sup>
Croatia	750	825	840	855	870	885	900	540	535	570	445	350	330	400	450	625	350 <sup>2</sup>
Cyprus	185	170	185	190	205	210	230	160	190	210	210	210	225	235	245	185	195
Czech Republic	11285	11385	10885	10820	10330	9990	9380	8880	7690	7095	6350	5455	4730	3505	2215	1250	1415 <sup>2</sup>
Denmark	2260	1715	1460	1290	1270	985	915	1205	940	770	780	745	895	550	385	310	250
Estonia	1435	1270	1280	1275	1270	1270	1260	1230	935	770	745	590	625	595	550	1260	1260
Finland	2920	1910	1655	1640	1510	1220	1300	970	705	615	570	480	525	495	450	580	580 <sup>2</sup>
France	16040	7360	6690	6610	6070	6865	6340	6895	6000	5200	4925	4625	4525	3820	4185	3250	2000 <sup>2</sup>
Georgia	1150	1365	1275	1290	1275	1245	1240	970	675	355	235	100	150	165	165	1240	1240
Germany, former East <sup>3</sup>	21750	26825	27065	26700	23420	22255	19210	14425	11940	10630	8930	7560	5330	4905	4665	3575	2825 <sup>4</sup>
Germany, former West <sup>3</sup>	15820	11835	11140	10280	9015	8570	7395	5555	4595	4095	3440	2910	2050	1890	1795	1375	
Greece	2000	2500	2510	2520	2525	2535	2510	2745	2780	2755	2630	2755	2700	2655	2700	2900	2730 <sup>2</sup>
Hungary	8165	7020	6810	6425	6090	5510	5050	4565	4135	3810	3705	3525	3365	3295	2955	4080	275 <sup>2</sup>
Iceland	90	90	90	80	90	85	120	115	120	125	120	120	120	125	135	145	145
Ireland	1110	700	810	870	760	810	930	900	860	805	875	805	735	830	880	775	210 <sup>2</sup>
Italy	18785	9505	9645	10145	9815	9270	8255	7695	6970	6665	6355	6610	5615	5105	5105	4235	4210
Kazakhstan <sup>1</sup>	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700
Latvia	595	595	595	595	595	595	595	450	395	365	430	295	295	220	200	570	785
Lithuania	1555	1520	1580	1580	1500	1490	1110	1170	695	625	585	470	465	385	470	775	725 <sup>2</sup>
Luxembourg	120	80	80	80	80	75	75	75	75	75	65	45	40	30	20	20	20 <sup>2</sup>
Netherlands	2450	1290	1320	1315	1250	1020	1010	865	860	820	730	735	675	590	565	250	250 <sup>2</sup>
Norway	685	490	455	365	340	290	265	220	180	175	175	170	165	150	150	110	110 <sup>2</sup>
Poland	20500	21500	21000	21000	20900	19550	16050	14975	14100	13625	13025	11880	11840	10905	9485	6985	6985 <sup>2</sup>
Portugal	1330	990	1170	1090	1020	1645	1715	1665	1980	1700	1605	1825	1670	1670	1670	1470	1470
Republic of Moldova	1540	1410	1485	1585	1365	1190	1325	1300	840	780	540	320	335	180	160	675	675 <sup>2</sup>
Romania	5275	6275	6465	6525	7345	7585	6555	5205	4755	4640	4560	4560	4560	4560	4560	6555	6555
Russian Federation <sup>1</sup>	35805	30955	28535	28110	25725	23385	22300	21960	19195	17280	14915	14190	13425	12245	11040	21485	21485
Slovakia	3900	3065	3020	3070	2945	2865	2715	2225	1900	1625	1195	1195	1135	1010	895	1050	1050
Slovenia	1170	1205	1235	1110	1050	1055	980	900	930	915	885	625	560	590	615	390	135 <sup>2</sup>
Spain <sup>2</sup>	14180	11965	11335	10695	8935	10610	10245	10250	10200	9595	9375	8605	7490	7490	7490	10715	10715
Sweden	2455	1330	1360	1140	1120	800	595	480	440	435	410	395	415	255	245	335	335 <sup>2</sup>
Switzerland	580	380	340	310	280	245	215	205	190	170	155	170	150	130	140	130	130 <sup>2</sup>
The FYR Macedonia	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85
Turkey <sup>4</sup>	1025	2600	3370	3265	2490	3960	4165	4545	4480	4220	5345	5130	5985	6280	6440	4950	4975
Ukraine	19245	17315	16965	16320	16055	15365	13910	12690	11880	10970	8575	8195	6465	5660	5660	11550	11550
United Kingdom	24355	18670	19475	19460	19110	18500	18685	17760	17310	15720	13445	11780	10090	82350	8075	5100	4250
Yugoslavia	2030	2390	2350	2420	2510	2530	2540	2230	1740	2005	2120	2310	2170	2610	2605	4445	5675
Remaining Asian Areas <sup>1</sup>	4345	4345	4345	4345	4345	4345	4345	4345	4345	4345	4345	4345	4345	4345	4345	4345	4345
Baltic Sea	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140	1140
Black Sea	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285	285
Mediterranean Sea	5945	5945	5945	5945	5945	5945	5945	5945	5945	5945	5945	5945	5945	5945	5945	5945	5945
North Sea	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270
Rem. N.E. Atlantic <sup>1</sup>	4505	4505	4505	4505	4505	4505	4505	4505	4505	4505	4505	4505	4505	4505	4505	4505	4505
Natural marine	3715	3715	3715	3715	3715	3715	3715	3715	3715	3715	3715	3715	3715	3715	3715	3715	3715
Volcanic <sup>6</sup>	10720	10720	10720	10905	10565	12465	14035	8225	11175	10135	9590	10000	10000	10000	10000	10000	10000
<b>Total</b>	<b>301795</b>	<b>265505</b>	<b>261590</b>	<b>258805</b>	<b>245115</b>	<b>241430</b>	<b>227835</b>	<b>206085</b>	<b>190260</b>	<b>179015</b>	<b>166445</b>	<b>157975</b>	<b>147480</b>	<b>138795</b>	<b>133645</b>	<b>149775</b>	<b>143615</b>

**Table A6: Emissions of nitrogen oxides (100 tonnes as N per year)**

	1980	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2005	2010
Africa, north <sup>1</sup>	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292	292
Albania	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73
Armenia	46	137	161	158	170	155	140	122	67	37	37	46	33	46	33	140	140 <sup>2</sup>
Austria	694	660	648	639	615	593	587	600	569	533	554	520	517	520	517	469	326 <sup>2</sup>
Belarus	712	724	785	800	797	800	867	855	682	630	618	593	527	575	499	560	548
Belgium	1345	989	965	1029	1050	1087	1032	1020	1044	1038	1041	1023	962	931	916	551	551 <sup>2</sup>
Bosnia and Herzegovina	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243	243
Bulgaria	1266	1266	1266	1266	1263	1251	1099	810	727	737	700	810	788	685	679	822	809 <sup>2</sup>
Croatia	183	225	234	243	250	259	268	198	170	180	201	201	210	222	231	265	265 <sup>2</sup>
Cyprus	43	43	49	49	55	58	55	49	58	58	61	58	64	64	67	70	70
Czech Republic	2852	2529	2514	2483	2611	2800	2258	2207	2124	1747	1324	1254	1315	1287	1257	1943	870 <sup>2</sup>
Denmark	831	907	971	953	922	867	849	980	840	837	810	755	877	755	703	484	405
Estonia	213	213	213	213	213	210	207	192	119	116	125	128	134	137	140	207	207
Finland	898	837	843	877	892	916	913	883	864	858	858	785	816	791	767	682	682
France	6178	5560	5436	5527	5536	5682	5713	5910	5722	5384	5293	5217	5159	5000	5028	3652	2617 <sup>2</sup>
Georgia	368	426	408	408	411	399	396	344	146	100	64	82	152	167	167	396	396
Germany, former East <sup>3</sup>	2182	2240	2252	2045	1972	1838	1665	1537	1421	1351	1257	1223	1181	1135	1096	1309	3548 <sup>4</sup>
Germany, former West <sup>3</sup>	7965	7730	7749	8080	7791	7259	6580	6075	5612	5338	4961	4830	4660	4483	4322	5174	
Greece	931	931	943	956	968	980	992	1013	1017	1007	1041	1038	1150	1099	1163	1047	1047 <sup>2</sup>
Hungary	831	797	803	807	785	749	724	618	557	560	572	578	597	609	660	639	603 <sup>2</sup>
Iceland	64	64	67	73	76	76	79	82	85	88	88	85	91	88	85	88	91
Ireland	222	277	304	350	371	387	359	365	396	362	350	350	365	359	371	320	198 <sup>2</sup>
Italy	4985	4912	5143	5512	5643	5834	5898	6038	6117	6057	5445	5381	5344	5128	5128	4590	4370
Kazakhstan <sup>1</sup>	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231
Latvia	283	283	283	283	283	283	283	186	161	140	146	128	107	134	128	213	247
Lithuania	463	505	514	520	523	527	481	505	298	237	234	198	198	173	183	335	335 <sup>2</sup>
Luxembourg	70	64	64	67	67	70	70	70	70	70	70	64	67	55	52	33	33 <sup>2</sup>
Netherlands	1774	1793	1787	1823	1832	1777	1765	1729	1692	1628	1552	1516	1525	1379	1342	758	809 <sup>2</sup>
Norway	572	642	691	688	676	673	667	639	633	657	648	648	673	679	682	475	475 <sup>2</sup>
Poland	3740	4565	4596	4657	4717	4504	3896	3667	3439	3409	3363	3409	3512	3390	3016	2453	2675 <sup>2</sup>
Portugal	505	292	335	353	371	651	931	983	1053	1047	1077	1126	1138	1138	1138	931	931
Republic of Moldova	177	204	219	216	225	213	304	295	204	161	140	116	116	110	67	107	274 <sup>2</sup>
Romania	1592	1650	1701	1765	1796	1762	1662	1412	1087	968	971	971	971	971	968	1662	1662
Russian Federation <sup>1</sup>	5277	5792	5694	8074	7177	7770	10957	10120	9413	9295	8172	7822	7508	7240	7572	10957	10957
Slovakia	600	600	600	600	645	691	685	621	578	557	527	551	396	374	396	685	685
Slovenia	155	161	177	173	180	177	192	177	177	192	201	204	213	216	195	186	137 <sup>2</sup>
Spain <sup>1</sup>	3101	2843	2913	3053	3135	3442	3518	3683	3774	3658	3695	3701	3634	3634	3634	2715	2715
Sweden	1230	1297	1315	1330	1315	1272	1029	1032	1001	986	1007	916	919	822	782	590	450 <sup>2</sup>
Switzerland	517	545	539	530	523	517	505	487	466	441	423	414	396	380	374	335	240 <sup>2</sup>
The FYR Macedonia	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Turkey <sup>4</sup>	1132	1473	1619	1793	1814	1927	2039	2060	2109	2350	2298	2450	2602	2620	2590	4517	6221
Ukraine	3485	3223	3384	3330	3317	3241	3339	3010	2526	2130	1729	1616	1421	1385	1385	3330	3330
<b>United Kingdom</b>	<b>7870</b>	<b>7746</b>	<b>7995</b>	<b>8333</b>	<b>8500</b>	<b>8625</b>	<b>8485</b>	<b>8138</b>	<b>7873</b>	<b>7320</b>	<b>7006</b>	<b>6489</b>	<b>6251</b>	<b>5685</b>	<b>5338</b>	<b>3941</b>	<b>3533</b>
Yugoslavia	143	177	177	183	192	189	201	173	152	164	158	180	173	201	201	350	447
Remaining Asian Areas <sup>1</sup>	645	645	645	645	645	645	645	645	645	645	645	645	645	645	645	645	645
Baltic Sea	1071	1071	1071	1071	1071	1071	1071	1071	1071	1071	1071	1071	1071	1071	1071	1071	1071
Black Sea	262	262	262	262	262	262	262	262	262	262	262	262	262	262	262	262	262
Mediterranean Sea	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988
North Sea	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972
Rem. N.E. Atlantic <sup>1</sup>	3853	3853	3853	3853	3853	3853	3853	3853	3853	3853	3853	3853	3853	3853	3853	3853	3853
Natural marinec	0	0	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	0	0
<b>Total</b>	<b>81126</b>	<b>80954</b>	<b>81993</b>	<b>85874</b>	<b>85318</b>	<b>86150</b>	<b>87329</b>	<b>84524</b>	<b>80687</b>	<b>78071</b>	<b>74459</b>	<b>73118</b>	<b>72407</b>	<b>70320</b>	<b>69521</b>	<b>72632</b>	<b>67550</b>

**Table A7: Emissions of ammonia (100 tonnes as N per year )**

	1980	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2005	2010
Africa, north <sup>1</sup>	1935	1935	1935	1935	1935	1935	1935	1935	1935	1935	1935	1935	1935	1935	1935	1935	1935
Albania	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
Armenia	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206	206 <sup>2</sup>
Austria	651	675	675	667	659	659	659	651	634	626	626	609	601	593	593	544	544 <sup>2</sup>
Belarus	1804	1804	1804	1804	1804	1804	1804	1804	1804	1804	1804	1804	1804	1804	1804	1804	1804
Belgium	733	733	758	782	807	832	881	766	758	799	791	799	815	815	815	609	609 <sup>2</sup>
Bosnia and Herzegovina	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
Bulgaria	1186	1186	1186	1186	1186	1186	1186	1021	914	898	832	815	684	634	544	931	889 <sup>2</sup>
Croatia	305	305	305	305	305	305	305	264	222	214	198	206	189	189	189	272	247 <sup>2</sup>
Cyprus	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Czech Republic	1285	1285	1285	1285	1285	1285	1285	1104	947	815	749	708	667	667	659	1285	1285
Denmark	1029	947	914	881	865	856	824	824	856	856	824	824	824	840	856	848	848
Estonia	239	239	239	239	239	239	239	239	239	239	239	239	239	239	239	239	239
Finland	321	329	338	329	321	321	313	305	305	296	296	288	288	313	313	189	189
France	6852	6835	6852	6819	6662	6671	6695	6662	6564	6481	6531	6596	6704	6769	6811	6588	6423 <sup>2</sup>
Georgia	799	799	799	799	799	799	799	799	799	799	799	799	799	799	799	799	799
Germany, former East <sup>3</sup>	2166	2215	2191	1375	1359	1334	1244	1095	2054	1038	1038	1029	1029	1013	1013	4529	4529 <sup>2</sup>
Germany, former West <sup>3</sup>	4711	4842	4776	5592	5526	5444	5056	4447	4291	4216	4225	4192	4192	4134	4134		
Greece	651	651	651	651	651	651	651	642	618	618	601	700	601	585	609	601	601 <sup>2</sup>
Hungary	1293	1235	1400	1235	1318	1400	1021	766	692	634	626	634	642	626	609	824	741 <sup>2</sup>
Iceland	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Ireland	922	922	922	922	922	922	922	947	964	964	980	988	1005	1013	1046	1038	955 <sup>2</sup>
Italy	3945	4011	4076	4093	4109	3961	3838	3714	3624	3698	3780	3796	3796	3846	3846	3673	3698
Kazakhstan <sup>1</sup>	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148
Latvia	362	362	362	362	362	362	362	346	272	165	140	140	132	124	107	362	362 <sup>2</sup>
Lithuania	700	733	733	741	733	708	692	700	667	659	659	313	296	288	288	692	692 <sup>2</sup>
Luxembourg	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58 <sup>2</sup>
Netherlands	1927	2042	2125	2125	1952	1911	1861	1878	1482	1573	1367	1202	1202	1548	1458	675	1054 <sup>2</sup>
Norway	189	189	189	189	173	189	189	198	206	206	206	214	222	214	222	189	189 <sup>2</sup>
Poland	4529	4529	4529	4529	4529	4529	4184	3706	3681	3146	3162	3129	2998	2882	3055	3854	3854 <sup>2</sup>
Portugal	807	807	807	807	807	807	807	807	791	774	774	799	799	799	799	807	807
Republic of Moldova	436	478	461	445	428	412	404	404	382	305	288	272	255	206	206	346	346 <sup>2</sup>
Romania	2800	2825	2882	2709	2792	2808	2471	2199	2100	1836	1820	1820	1820	1820	1820	2471	2471
Russian Federation <sup>1</sup>	9792	10204	10591	10516	10451	10360	9808	9561	8927	7436	6358	6786	6168	6012	5559	9808	9808
Slovakia	519	519	519	519	519	519	519	486	420	371	354	338	338	313	288	519	519
Slovenia	198	198	198	198	198	198	198	189	189	189	181	181	181	156	156	181	164 <sup>2</sup>
Spain <sup>1</sup>	3261	3459	3582	3904	3912	4011	3887	3854	3854	3689	3871	3846	4258	4258	4258	3887	3887
Sweden	445	445	445	445	445	445	502	420	502	502	502	502	502	486	486	478	469 <sup>2</sup>
Switzerland	634	609	609	601	601	593	593	502	511	519	585	585	585	585	585	519	519 <sup>2</sup>
The FYR Macedonia	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140
Turkey	2644	2644	2644	2644	2644	2644	2644	2644	2644	2644	2644	2644	2644	2644	2644	2644	2644
Ukraine <sup>7</sup>	6004	6004	6004	6004	6004	6004	6004	6004	6004	6004	6004	6004	6004	6004	6004	6004	6004
United Kingdom	3014	3014	3014	3014	3014	3014	3014	2965	2841	2841	2858	2792	2759	2833	2882	3014	3014
Yugoslavia	741	741	741	741	741	741	741	741	741	741	741	741	741	741	741	741	741
Remaining Asian Areas <sup>1</sup>	2495	2495	2495	2495	2495	2495	2495	2495	2495	2495	2495	2495	2495	2495	2495	2495	2495
Baltic Sea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black Sea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mediterranean Sea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Sea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rem. N.E. Atlantic <sup>1</sup>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural marine	0	0	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	0	0
<b>Total</b>	<b>75422</b>	<b>76350</b>	<b>77141</b>	<b>76994</b>	<b>76657</b>	<b>76461</b>	<b>74139</b>	<b>71192</b>	<b>69019</b>	<b>66138</b>	<b>64994</b>	<b>64880</b>	<b>64329</b>	<b>64338</b>	<b>63985</b>	<b>69518</b>	<b>67496</b>

*An evaluation of trends  
for concentrations in air and precipitation*

Kevin Barrett, Wenche Aas, Anne Gunn Hjellbrekke,  
Leonor Tarrasón and Jan Schaug



## ***2. An evaluation of trends for concentrations in air and precipitation***

A main task under the LRTAP Convention is to establish the success of the emission reduction Protocols. In this context, the EMEP monitoring network should be suitable to determine whether the reported reductions in emissions have been translated into a visible improvement of the observed air quality levels in different European areas.

This year's summary report focuses on the study of trends. This chapter presents as an example an analysis of trends at selected stations in four countries: Germany, Poland, Norway and Sweden. Trends are determined with Mann-Kendall's test and are quantified by use of Sen's estimator for slopes and confidence intervals.

The study of the representativeness of the derived trends requires further effort. It is desirable that such effort is carried out as a co-operation with the Parties to the Convention.

As a first step, monitored trends and confidence intervals have been compared here with modelled trends for the countries under consideration. This approach has recognised limitations but it is intended to stimulate further evaluation by the Parties and encourage the discussions on station representativeness and trend evaluation under the forthcoming meeting of the Task Force on Measurements and Modelling.

### ***2.1. The suitability of the EMEP monitoring network for trend analysis***

The EMEP monitoring network has been active since 1978. The number of stations, their position, the compounds actually measured in programme, and the sampling and analysis methods used in the EMEP network have evolved with time. The evolution of the position of EMEP monitoring stations since 1985 is depicted in Figure 2.1.1. The suitability of the monitoring network for trend analysis of long-range transport is dictated by the quality and representativeness of the data according to the following criteria:

- a) Absence of influence from local sources
- b) Consistency of the data series with parallel sampling and analysis when changes occur
- c) Temporal data completeness

#### ***a) Absence of influence from local sources***

The EMEP programme and its monitoring network focus on long-range transport at regional scale. Thus a site should not be subject to local influence, rather should be indicative of regional levels. While the EMEP monitoring programme has been designed to monitor in regional or "background" areas, review of data is needed to confirm this expectation. For

virtually all EMEP sites this criteria is appears to be met. Exceptions include some Spanish sites which are found to monitor elevated concentrations of pollutants, and the Polish station PL1, Suwalki, which seems to be affected by local sources. This criteria is in general more readily attained for sulphur and oxidised nitrogen components than for reduced nitrogen for which sources are often diffuse and poorly recognised.

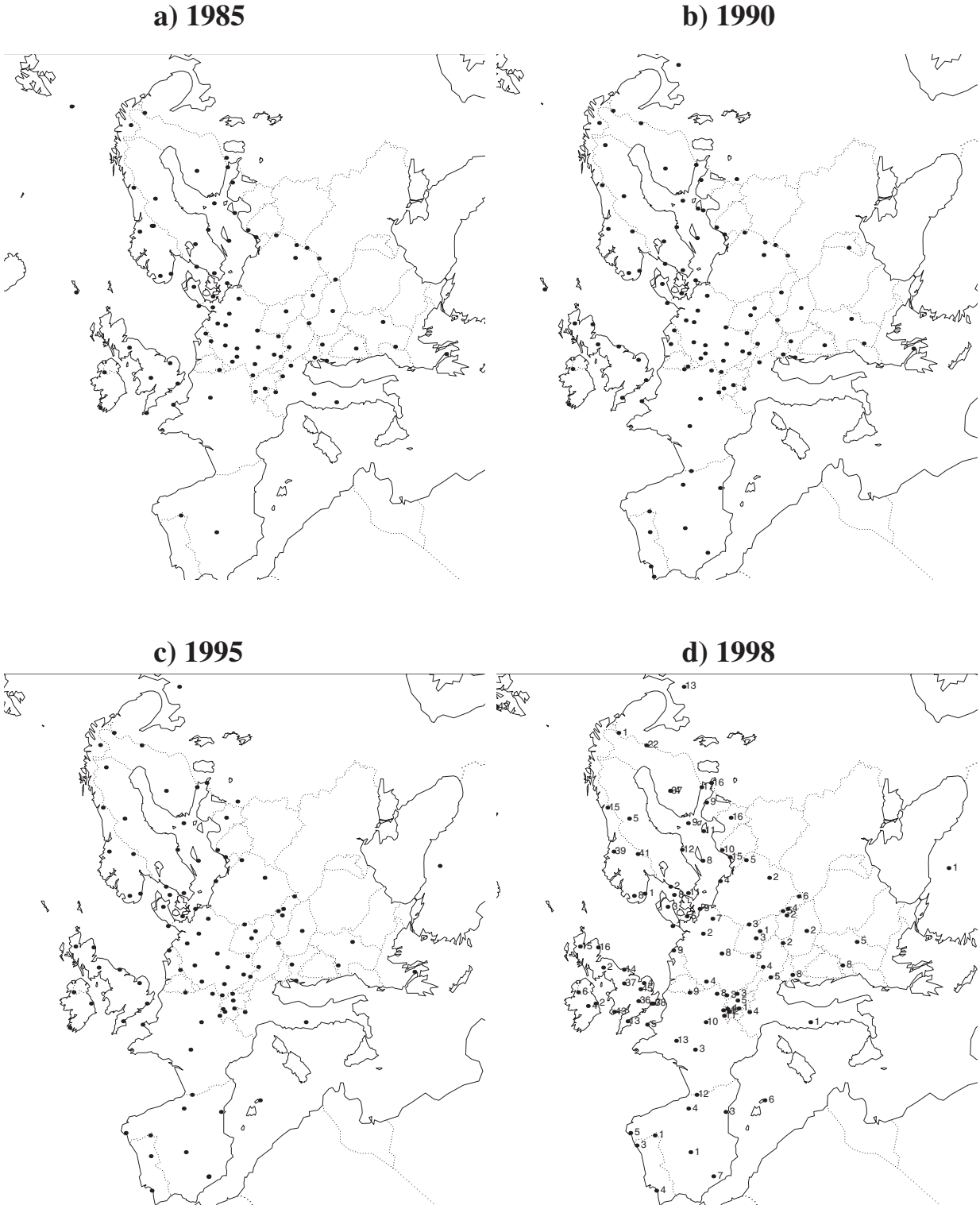


Figure 2.1.1. Evolution of EMEP stations since 1985 to 1998.

The requirement for EMEP stations to represent pollution levels over a larger area demands an analysis of the site representativeness. This is an extensive evaluation task that should be carried in conjunction with modelling studies and in co-operation with national experts.

### ***b) Consistency of the data series with appropriate documentation of changes***

Continuous evaluation of the monitoring data, quality control and intercomparison exercises are expected to lead to improved surveillance of the state of the environment. However, as a consequence of improvements in sampling and analytical techniques, changes in the data series can be introduced.

Changes in measurement method, e.g. switching from bulk collectors to wet-only collectors, or changes in analytical techniques, e.g. from the Thorin method to IC for sulphate and SO<sub>2</sub> should not introduce measurable discontinuities if the data is to be used successfully for trend analysis. The EMEP programme has, in contrast to many other programmes, traditionally recommended daily precipitation sampling rather than weekly. This practice will minimize the problems derived from a shift from bulk samplers to wet-only samplers for sulphate and nitrate.

It should also be born in mind that the TCM method used for sulphur dioxide until recently, underestimates sulphur dioxide concentrations (Aas et al., 1999). It is assumed here that this does not have a serious influence on trends, but it seems important to continue comparisons with more accurate methods in order to have this clarified or quantified. The Saltzmann method for nitrogen dioxide, not used any more in EMEP, overestimates low concentrations, and a correction factor has often been applied. In this study, Swedish NO<sub>2</sub> data were corrected for this type of underestimation. A correction factor was also used for particulate sulphate to account for the changes from using X-ray fluorescence to IC analysis (Kindbom et al., 1994).

Ultimately, documentation of changes and parallel tests for comparison of methods are important requirements for a successful trend analysis. The EMEP network has a good record of this type of information thus facilitating the use of correction factors for trend analysis if necessary. Appendix B, at the end of this chapter, provides an overview of the sampling and analytical methods employed each year at the sites selected in this study.

### ***c) Temporal data completeness***

Sufficient data completeness is a natural requirement for long term trend analysis. However, it must be recognised that the longer the data series under consideration, the greater the likelihood that there will be missing data. On one side any number of practical problems may interrupt measurement or analysis. On the other, quality control of data may reveal uncertainties that recommend the exclusion of data. There are some cases where the overall frequency of missing data may lead to uncertain time series estimates, as with Aliartos, GR1. In general, however the temporal data coverage in the EMEP network is good (above 70%) as documented in CCC's annual data reports (Hjellbrekke, 2000).

## 2.2. Sites selected for examination

Four countries have been selected in the present study: Germany, Poland, Norway and Sweden. German and Poland were chosen to reveal the changes which have occurred in the principal source region for acidifying and eutrophying pollutants in Europe. Through the long period of modelling these countries have been found to export more pollution than they import and are expected to represent the situation in Central Europe. Southern Norway and Sweden were selected to depict the changes in a receptor region. Modelling results show that acidifying and eutrophying deposition in these countries is dominated by transboundary deposition.

Following the selection criteria described above, 11 different sites were selected for this study and are given in Table 2.2.1. The sites were not selected to demonstrate the homogeneity which may be found in the regions (tests for homogeneity are outside this exploratory review), but quite intentionally to indicate the variety which such labels as ‘source region’ or ‘receptor region’ can obscure. Some sites below started earlier than indicated as part of national monitoring programmes.

**Table 2.2.1** Sites used in this study and dates when monitoring commenced as part of EMEP

	SO <sub>2</sub> /SO <sub>4</sub> in air	SO <sub>4</sub> in precip.	NO <sub>3</sub> /HNO <sub>3</sub> in air	NO <sub>3</sub> in precip.	NH <sub>x</sub> in air	NH <sub>x</sub> in precip.
NO1 NO8 NO41	1978	1978	1986	1978	1986	1978
SE2 SE5 SE12	1978	1978	1986	1978	1986	1978
DE2 DE4 DE5	1978	1978	-	1978	-	1978
PL2	1985	1978	1991	1978	1986	1978

The stations selected to explore the source region of central Europe are: DE2 Langenbrugge, DE4 Deuselbach, and DE5 Brotjackriegel situated respectively in north, west and east Germany; and PL2 Jarczew in eastern Poland. Selected sites across southern Scandinavia are: NO8 Skreådalen, in south-western Norway; NO41 Osen, in east-mid Norway; NO1 Birkenes in south Norway, SE2 Rörvik, in south-west Sweden; SE5 Bredkålen, in the middle of the country and SE12 Aspvreten on the Swedish east coast. This spread stretches a slightly shorter distance than in the central European source region, but still reveals clear differences in the experienced trends.

Originally, it was intended to extend this example analysis to Mediterranean countries. However, the number of sites in this region is generally small, and only one station in Spain, ES1 Toledo, had long enough data records to be used in this study. The site was not included in this study because of inconsistencies in the first years of the record. Comparison with reference methods, in a similar way as it was organised in Portugal in 1997 (Schaug et al., 1998), could be useful in Spain.

### ***2.3. Methodology for calculation of trends***

Examinations of trends in the monitoring data collected under the EMEP programme have been presented earlier (e.g. Schaug et al., 1996; Schaug et al., 2000) and have been compared with long-term modelled calculations (Tsyro, 1998; Berge et al., 1999). Although it is recognised that many different aspects can be investigated through analysis of the temporal trends in observed air pollution, the purpose of this chapter is to comment on two of the essential features of Europe's air pollution environment:

- Firstly, the concurrence between claimed emission reductions of sulphur and nitrogen and observed levels of these contaminants will be explored. Studies of observations at high temporal resolution can reveal the relations between source regions and monitored values (e.g. Tørseth et al., 2000), but here it is intended to analyse the overall changes experienced in the environment.
- Secondly, the relevance of long range transport to observed air pollution will be discussed. This is closely linked to comment on emission changes, and thus provides a coherent initial exploration of data which should encourage further more specific analysis.

In the past EMEP has presented time series of its measurement and modelling results. However, whilst this is an essential first step, trend analysis implies something further. An important aspect, for instance, is to establish the degree confidence with which that an apparent trend can be confirmed. Many circumstances, of course, can be unequivocal, especially when changes are of a sufficient magnitude. But with environmental data it is entirely possible that natural variability at various time scales can obscure the underlying trend. A common approach is to deal statistically with time series of data in order to determine the probability of finding significant systematic patterns in the data.

The Mann-Kendall test to establish the likelihood of a trend has been selected for the present study. This is a non-parametric test which puts minimal requirements upon the characteristics of the data. Missing data is permitted, and there are no requisites for a given distribution, e.g. normal distribution. The only necessity is that the slope is monotonic, that is, that it proceeds in only one direction without changing from increase to decrease during the time period examined. The methodology is explained in many statistical texts (p.e. Gilbert, 1987). We have selected a 0.10 significance level as the standard for determining a significant trend. This means that there is estimated to be 10% likelihood that the resulting data pattern does not reflect an underlying trend.

The magnitude of the trend is not determined by the Mann-Kendall test. Once again, various approaches can be used for this, and Sen's estimator of slope has been used here. The Sen estimator determines the slope of median change through the whole data period. This naturally implies that the actual change rate may be underestimated or overestimated at any particular point. However, the method is quite robust as it can accept missing data and it is not over-influenced by gross outliers.

The best estimate of the Sen's slope is used in the analysis below to calculate a percentage change from the original concentrations across the period of interest. Definition of initial concentration can be made by various techniques. The mean of the first two years in the timeseries has been selected here. It has been pointed out that Sen's estimator will over and underpredict trends at specific times as the actual rate of change deviates from the overall

median. To express the median annual slope during the period as a percentage of the original concentration will also involve the same type of problem. Nevertheless it provides a ready means of comparing sites at different European regions. Detailed resolution of such issues goes beyond this summary report and is a proper subject for further evaluation within EMEP.

In this exploratory examination, annual mean values have been selected for statistical testing. Seasonality is a strong feature in atmospheric data, which annual averaging can negate. Seasonal versions of both the Mann-Kendall and Sen's tests could possibly have been used. However, tests for seasonal trends will only be meaningful when the trends are homogenous in all seasons, i.e. are all in the same direction and with the same magnitude.

## 2.4. Trend Analysis in a Source Region: Central Europe

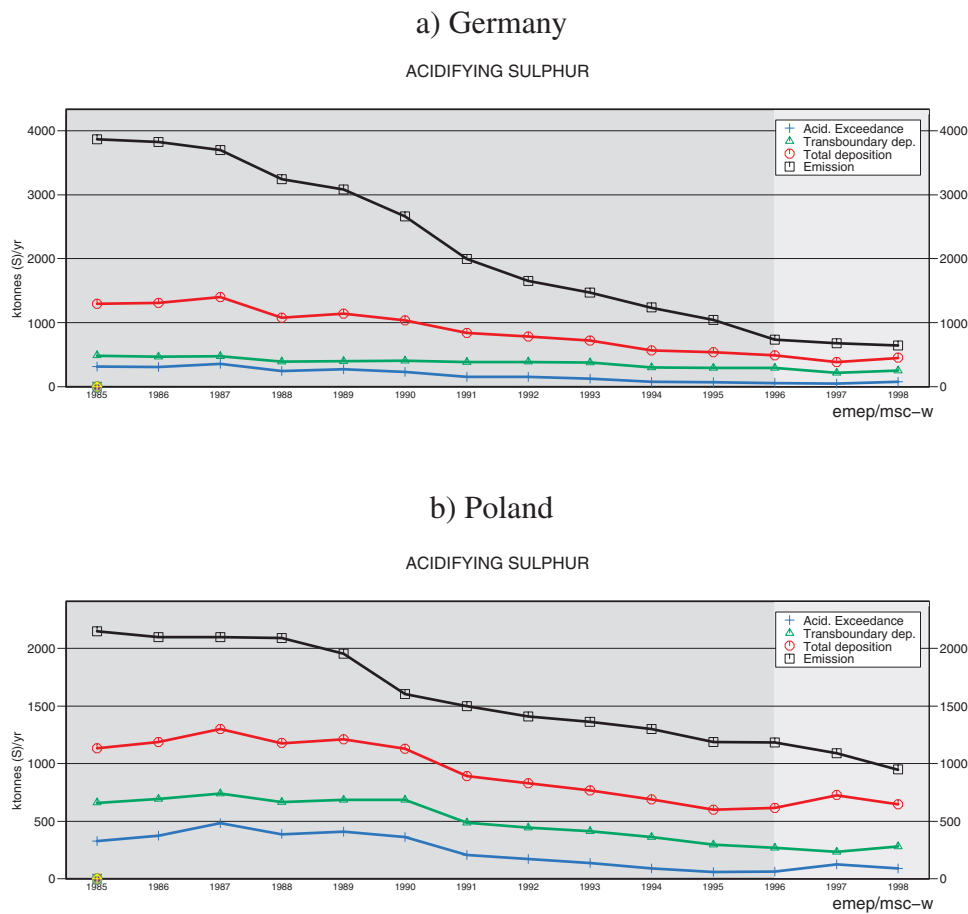
Estimation of the rate of change in sulphur compounds from 1985 to 1998 are presented for the Central European region in Table 2.4.1. In the table, the rate of change, i.e. the Sen slope, has been used to calculate the percentage change and it is also given in original units. The percentage corresponds to the rate of change in observed concentrations and modelled depositions expressed as percentage of initial values, i.e. mean of first two years. 90% confidence limits about Sen's slope are given in concentration./deposition units per year.

**Table 2.4.1.** Results of Sen slope for sulphur concentrations and modelled depositions.

Country	loc	site	period	SO <sub>2</sub>	SO <sub>4</sub>	SO <sub>4</sub> in precip.	SO <sub>4</sub> wet dep.	S total dep.	S trans. dep.
				%	%	%	%	%	%
				90% confidence range	90% confidence range	90% confidence range	90% confidence range	90% confidence range	90% confidence range
				mg m <sup>-3</sup> yr <sup>-1</sup>	mg m <sup>-3</sup> yr <sup>-1</sup>	mg l <sup>-1</sup> yr <sup>-1</sup>	mg m <sup>-2</sup> yr <sup>-1</sup>	ktonnes yr <sup>-1</sup>	ktonnes yr <sup>-1</sup>
<b>Central European Source Region</b>									
Germany	N	DE2	85-98	-92	-81	-60	-67		
				-0.793 - -0.619	-0.170--0.133	-0.045 - -0.027	-51 - -40		
	W	DE4	85-98	-60	-63	-33	-51	-76.8	51.0
				-0.602 - -0.235	-0.115--0.092	-0.031 - -0.020	-27 - -20	-92.3 - -72.4	-22.9 - -14.4
	E	DE5	85-98	-75	-54	-59	-69		
				-0.394 - -0.261	-0.087--0.065	-0.076 - -0.060	-73 - -62		
Poland	E	PL2	85-98	-46	-75	-51	-53	-66.2	-80.9
				-0.311 - -0.254	-0.314--0.230	-0.170 - -0.110	-85 - -50	-74.4 - -43.8	-50.1 - -34.4

The rate of change in modelled total and transboundary depositions has been calculated based on the values for Germany and Poland given in Figure 2.4.1. As the modelled total deposition changes correspond to values integrated over the whole country area, the modelled data is not directly comparable with the observed data. To study the comparability of modelled and observed data more detailed studies are required. The same applies for an adequate analysis of station representativeness which is beyond the intention of the present study.

Sulphur emission across Europe, already falling during the 1980s, accelerated their decline sharply into the 1990s. From 1985 to 1998, German sulphur emissions have fallen by 80%, and Polish releases by around 50%. Countries close-by, such as the Czech Republic and Hungary, have also seen reductions of approximately 50% in SO<sub>2</sub> release.



**Figure 2.4.1.:** Modelled sulphur emissions (black line), depositions (red line), depositions caused by transboundary exchange (green line) and exceedances to critical loads for acidification (blue line) in **a)** Germany and **b)** Poland as calculated by EMEP/MSC-W models. Critical loads values are provided by CCE.

The observed concentrations of sulphur dioxide in air in Germany would appear to confirm the scale of the reported emission changes. In Germany observed air concentration levels have declined by approximately 60-90% during the monitoring period; declines in western regions are less strong but still substantial.

Sulphur dioxide is the primary released form of sulphur, so that changes in its air concentrations largely reveal changing releases of sulphur in reasonably close proximity to the point of measurement. For this reason it is quite possible for a single site to demonstrate much greater or much lesser change than the overall change in national sulphur release. The trends in sulphur dioxide are determined by emission changes in Germany itself which determine also the modelled deposition trends in Figure 2.4.1. a) for the whole country.

It is interesting to compare these changes with those for SO<sub>4</sub> concentrations in air (Figure 2.4.2). Being largely a secondary form transformed from primary SO<sub>2</sub> during transport, its

occurrence is often a consequence of sources more remote from the point of measurement. Over Germany we find that air concentrations of sulphate have declined substantially, but not to the same degree as for sulphur dioxide. Sulphate concentrations are to a large extent determined by long-range transport. Therefore the observed trends in sulphate correspond well with the rate of change of modelled transboundary deposition. In the north the decrease remains high, at around 80%, whilst in western and eastern areas the figure is approximately 50-60%.

It appears that changes in air concentrations of sulphur dioxide are broadly in the range of reported national emission changes, while air concentrations of sulphate are being clearly affected by changes from beyond the borders.

These conclusions confirm the modelling results presented in Appendix II and depicted also in Figure 2.4.1. In Germany, the change in total deposition of sulphur has been primarily driven by the decrease in German national sulphur emissions. It is interesting to note that the relative importance of transboundary deposition has increased in Germany in recent years,.

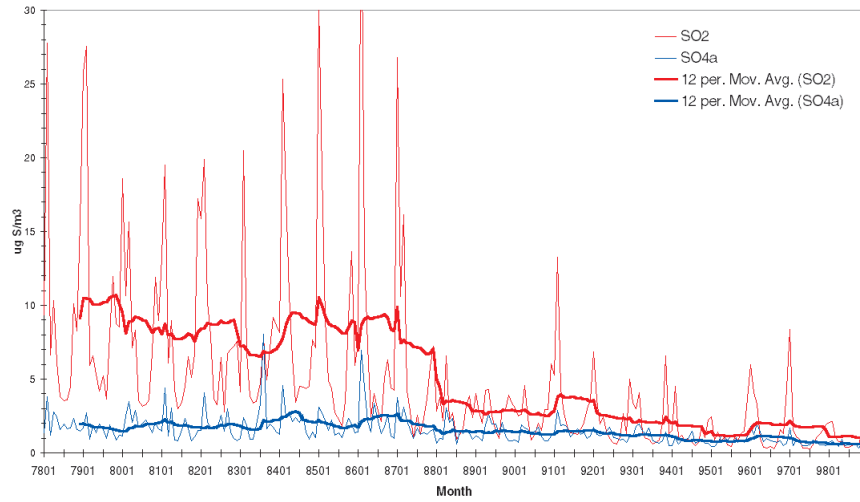
Poland, on the other hand has largely benefited from the reduction of emissions beyond its national borders. Transboundary deposition dominates the decline in modelled sulphur deposition in agreement with the observed changes in the concentrations of airborne sulphate. It is interesting to note that at Jarczew sulphur dioxide concentrations have declined by a lesser fraction than airborne sulphate - under 50% and over 70% respectively. Polish emissions have fallen to a slightly lesser degree, and with this the Polish sulphur dioxide decrease does not match the German decline. Polish airborne SO<sub>4</sub> concentrations, which will largely reflect more distant sources, show stronger declines comparable to reported German emission changes. Germany is in fact a main contributor to sulphur pollution levels in Poland. Source-receptor contribution trends in Appendix II, page 180 shows that the reduction of the German export to Poland determines the reduction of sulphur deposition in Poland.

The changes in the atmospheric nitrogen environment are less pronounced. Across Europe as a whole releases of both oxidised and reduced nitrogen have declined only very slightly since 1985 and before. In Germany, however, there has been approximately a fall of one third since 1985 in NO<sub>2</sub> emissions whilst Polish releases have declined by around a quarter. The lesser change in much of the rest of Europe is perhaps exemplified by France in which releases of oxidised nitrogen have not changed strongly during this period. Being downwind of the central region, French emissions could be expected to have a noticeable influence on observed NO<sub>x</sub> levels due to transboundary transport, in particular during winter (see also Appendix II p.132).

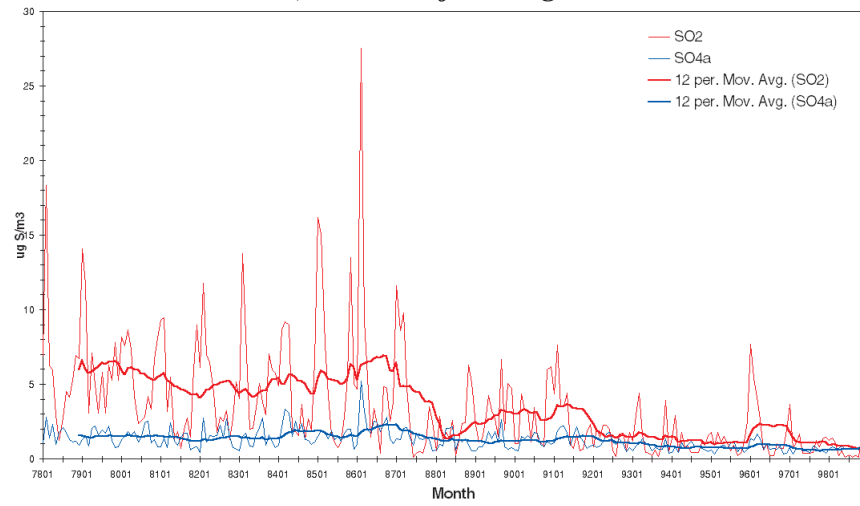
The EMEP monitoring network for nitrogen compounds is far less complete than for sulphur components (Tarrasón and Schaug, 1999). Also for the selected stations, monitoring of nitrogen compounds is not complete. The primary oxidised nitrogen form, NO<sub>2</sub>, is monitored at all sites selected in this study. The observations show some variability (to be expected in a primary compound) but at all sites there is a statistically significant downward trend. The best estimate of the Sen slope varies from ~25% in eastern Germany to ~60% in eastern Poland.

For secondary nitrogen compounds, which may better reveal long-range transport, only the Polish site PL2 has conducted monitoring of total airborne nitrate (NO<sub>3</sub> + HNO<sub>3</sub>). At this site no significant trend was found, despite strong apparent changes in NO<sub>2</sub> concentrations.

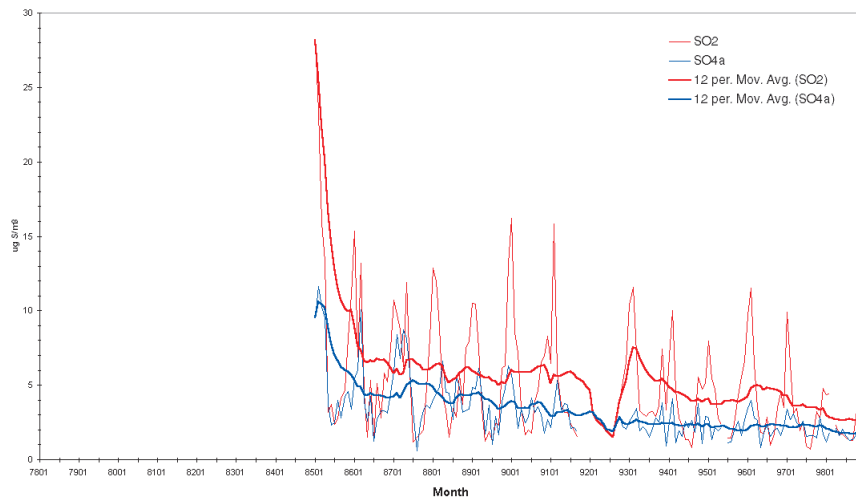
**a) DE4 Deuselbach**



**b) DE5 Brotjacklriegel**



**c) PL2 Jarczew**



**Figure 2.4.2.:** Observed trends in air concentrations of sulphur dioxide (SO<sub>2</sub>) and particulate sulphate (SO<sub>4</sub>) at selected stations in Germany and Poland. Units:  $\mu\text{g (S) m}^{-3}$

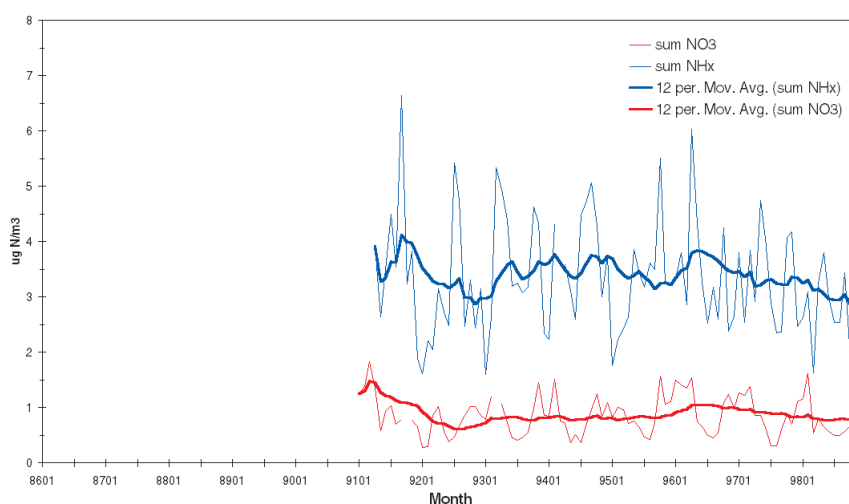
**Table 2.4.2.** Results of Sen slope for nitrogen concentrations and modelled depositions

Country	loc	site	period	NO <sub>2</sub>	NO <sub>3</sub> + HNO <sub>3</sub>	NO <sub>3</sub> in precip.	NO <sub>3</sub> wet dep	NH <sub>x</sub>	NH <sub>x</sub> wet dep	N tot.dep.	N trans.dep.
				%	%	%	%	%	%	%	%
				+ 90% confidence <sup>2</sup> -	+ 90% confidence <sup>2</sup> -	+ 90% confidence <sup>2</sup> -	+ 90% confidence <sup>2</sup> -	+ 90% confidence <sup>2</sup> -	+ 90% confidence <sup>2</sup> -	+ 90% confidence <sup>2</sup> -	+ 90% confidence <sup>2</sup> -

**Central European Source Region**

Germany	N	DE2	85-98	-43		-26	not significant		-21		
				-0.139 - -0.107		-0.018 - -0.009			-13 - -4		
-	W	DE4	85-98	-45		not significant	-15		not signific.	-27	-21
				-0.153 - -0.116			-6 - -2			-26 - -11	-9 - -2
	E	DE5	85-98	-26		-30	-38		-31		
				-0.054 - -0.029		-0.024 - -0.010	-25 - -14		-24 - -15		
Poland	E	PL2	85-98	-57	not sign	-36	-26	-17	-35	-24	-32
				-0.204 - -0.088		-0.028 - -0.018	-11 - -5	-0.081 - -0.064	-37 - -11	-22 - -2	-11 - -2

Oxidised nitrate in precipitation has been monitored at all sites, although this will naturally also reflect the influence of precipitation variability. Total wet deposition of nitrate was found to vary between no significant trend in northern Germany to approaching a 40% decrease in eastern Germany, east Poland and west Germany falling between these. As for reduced nitrogen, only the Polish site monitored ammonia and ammonium air concentrations. All sites monitored precipitation, and wet deposition was found to show no significant trend in reduced nitrogen in west Germany, but it showed trends of around 20% in north Germany, 30% in east Germany and up to around 35% in east Poland.



**Figure 2.4.3.:** Observed trends in air concentrations of sum of nitrate and sum of ammonium at Polish station PL2 Jarczew. Units:  $\mu\text{g (N) m}^{-3}$

## ***2.5. Trend Analysis in a Receptor Region: Southern Scandinavia***

Norwegian sulphur releases have reportedly decreased by 70%, whilst Swedish emissions have fallen by approximately a half during the period. European-wide emissions are particularly important here, as southern Scandinavia is a receptor area of long range transboundary air pollution. While the west of Norway is particularly exposed to cyclonic systems, the south and east of Scandinavia are frequently subjected to north and easterly extending anticyclonic systems. Thus, it is interesting to consider influences of emission sources to the west - releases from the UK falling by over 50% - and from the central European source region whose emission releases were described above - approximately two thirds in Germany and approximately 50% elsewhere in the region. (See Appendix II, pages 176 and 212 for identification of largest contributors to deposition over Norway and Sweden).

Sulphur dioxide levels at the Norwegian sites show significant downward trends, with concentrations generally falling by 60-90% during the period modelled by EMEP. This is similar to percentage changes in the central European source region, which supports the modelling results in the Appendix where German sources are identified as important contributors to sulphur pollution in Southern Scandinavia. Table 2.5.1. shows also how trends in transboundary sources determine the trends in total deposition in these two countries, in agreement with observed sulphate values.

It is interesting that the trends found across Sweden in the east of the region are of similar percentage to those in Norway and central Europe despite local emission changes not being so great. This underpins that SO<sub>2</sub> affecting the region is partly transported from outside. Changes in Swedish stations are larger than in Norwegian stations despite the fact that emission reductions have been more pronounced in Norway during the period. Swedish and Norwegian sulphur trends are determined primarily by transboundary sources. Central European sources, Germany in particular, have relatively more influence in Sweden than in Norway and this can explain the difference in trends in the two countries. Sulphur levels in Norway are also considerably determined by emissions from the Russian Federation in the northernmost parts, and transatlantic transport, so that emission trends in central Europe have less visible effect in Norway than in Sweden.

Wet deposited sulphur at the two southern Norwegian stations indicate around a fifty percent decline (comparing with reported changes in emissions in the UK), whilst the decline at NO41 in mid-Norway reaches 70%. Interestingly in Sweden the change at the mid-Swedish site SE5 is also stronger (approaching 90%) than in the south and also the east coast. From the end of the eighties to the end of the nineties there are observed additional decreases in precipitation amounts at NO41 and SE2, increasing the downward trends in wet-deposition of sulphate at the two sites compared to the concentration trends.

Nitrogen emissions, as with central Europe, do not reveal the declines apparent for sulphur. Norwegian NO<sub>x</sub> emissions are reported as essentially unchanging, with ammonia releases showing a marginal increase. In Sweden there has been a decline in oxidised nitrogen emission of around 25%, with a smaller decrease in releases of NH<sub>3</sub>. The downwind UK sources of NO<sub>x</sub> are reported as having fallen by around one fifth, although initially underwent a rise up to the turn of the decade, whilst reduced nitrogen emission is believed to have risen slightly. The trend of nitrogen dioxide concentrations at the Swedish and Norwegian sites investigated here is rather uniform showing a more or less pronounced increase until the end of the eighties

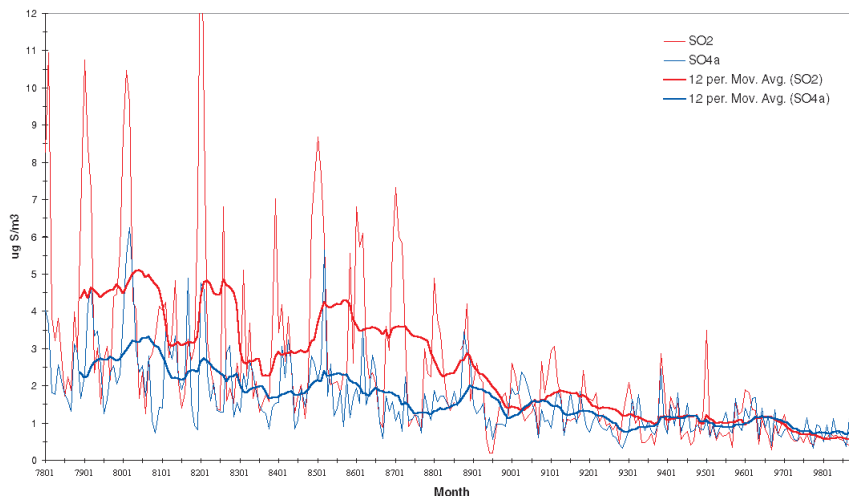
followed by a decrease. A change in methods at the Norwegian sites in 1994, which is not corrected for here, may however interfere with the temporal trends, and the trend at the southwestern Norwegian site is not significant. Except for this all sites show significant trends in NO<sub>2</sub> concentrations, ranging from a 40% change in southern Norway to 40 - 45% in mid-Sweden and - Norway.

**Table 2.5.1.** Results of trend analysis on sulphur observations and modelled depositions.

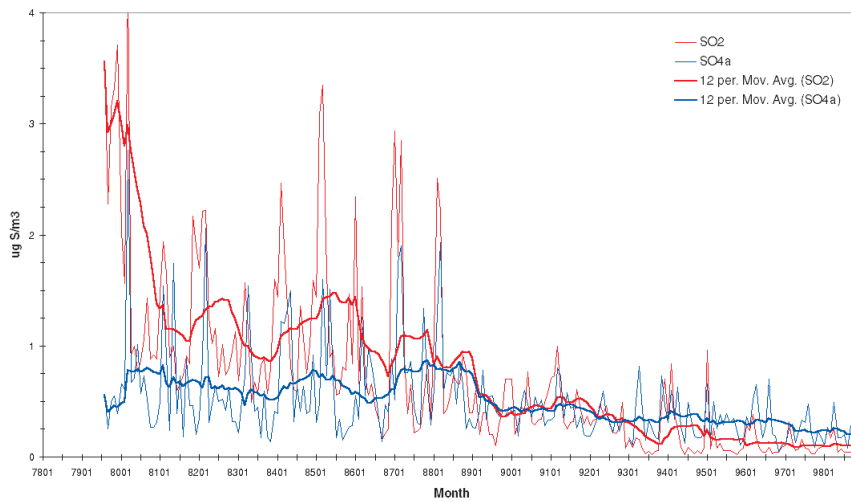
Country	loc	site	period	SO <sub>2</sub>	SO <sub>4</sub>	SO <sub>4</sub>	SO <sub>4</sub>	S	S
						in precip.	wet dep.	total dep.	trans. dep.
				%	%	%	%	%	%
				90%	90%	90%	90%	90%	90%
				confidence range	confidence range	confidence range	confidence range	confidence range	confidence range
				mg m <sup>-3</sup> yr <sup>-1</sup>	mg m <sup>-3</sup> yr <sup>-1</sup>	mg l <sup>-1</sup> yr <sup>-1</sup>	mg m <sup>-2</sup> yr <sup>-1</sup>	ktonnes yr <sup>-1</sup>	ktonnes yr <sup>-1</sup>
<b>Southern Scandinavia Receptor Region</b>									
Norway	S	NO1	85-98	-79	-44	-50	-56		
				-0.044 - -0.035	-0.031 - -0.024	-0.051 - -0.033	-80 - -57		
	SW	NO8	85-98	-89	-55	-53	-58	-52	-54.5
				-0.052 - -0.039	-0.035 - -0.028	-0.029 - -0.021	-66 - -40	-10.8 - -6.2	-10 - -6
	E	NO41	88-98	-60	-50	-51	-70		
				-0.034 - -0.029	-0.030 - -0.028	-0.022 - -0.015	-31 - -30		
Sweden	SW	SE2	85-98	-89	-63	-48	-72		
				-0.027 - -0.023	-0.114 - -0.055	-0.071 - -0.044	-62 - -49		
	mid	SE5	85-98	-98	-67	-87	-90	-66	-65
				-0.105 - -0.069	-0.038 - -0.023	-0.051 - -0.034	-39 - -30	-20 - -13	-18 - -12
	E	SE12	85-98	-87	-50	-70	-72		
				-0.152 - -0.117	-0.051 - -0.032	-0.108 - -0.075	-48 - -35		

Only one site in southern Norway shows a significant trend in air concentrations of total nitrate(-35%). In Sweden all sites are significant, falling between 1/3 in southern and mid-Sweden to around 2/3 in the east. As far as wet deposited nitrogen is concerned, mid-Norway shows no significant trend in either oxidised or reduced nitrogen, and south-western Norway (NO8) is only significant for oxidised nitrogen, with around a 20% change comparable to UK changes in emissions. In Sweden all sites show significant trends for wet deposited oxidised and reduced nitrogen. The east and south coasts show 50-60% changes for both components, whilst the mid-Swedish site (SE5) once again indicates that the greatest trends have occurred in inland areas of the region.

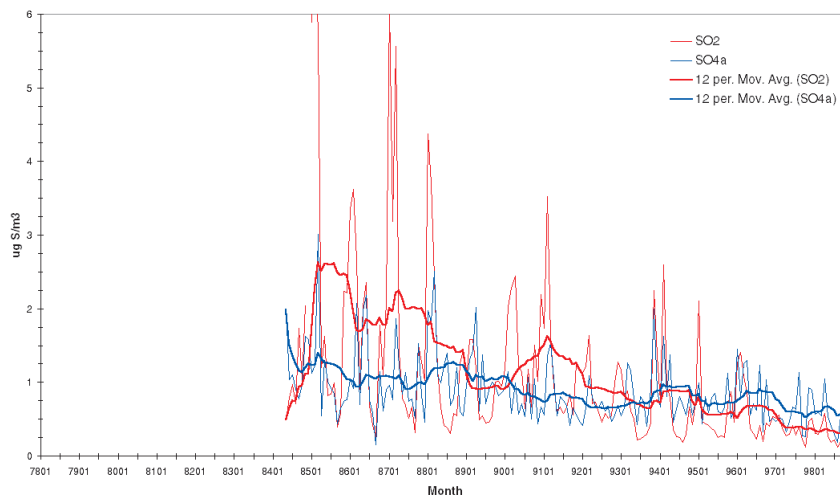
**a) SE2 Rörvik**



**b) SE5 Bredkålen**

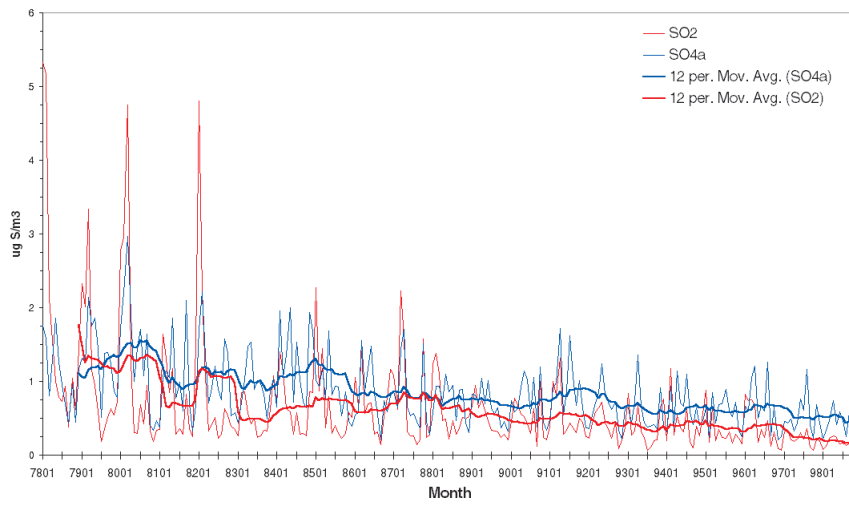


**c) SE12 Aspvreten**

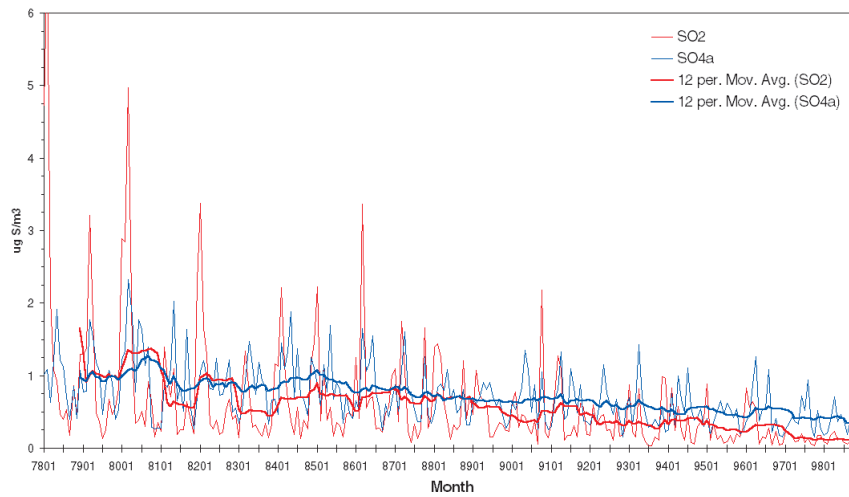


**Figure 2.5.1.:** Observed sulphur trends in air concentrations of sulphur dioxide (SO<sub>2</sub>) and particulate sulphate (SO<sub>4</sub>) at selected stations in Sweden. Note that these trends have been corrected for changes in sampling and analysis methods. Units:  $\mu\text{g (S) m}^{-3}$

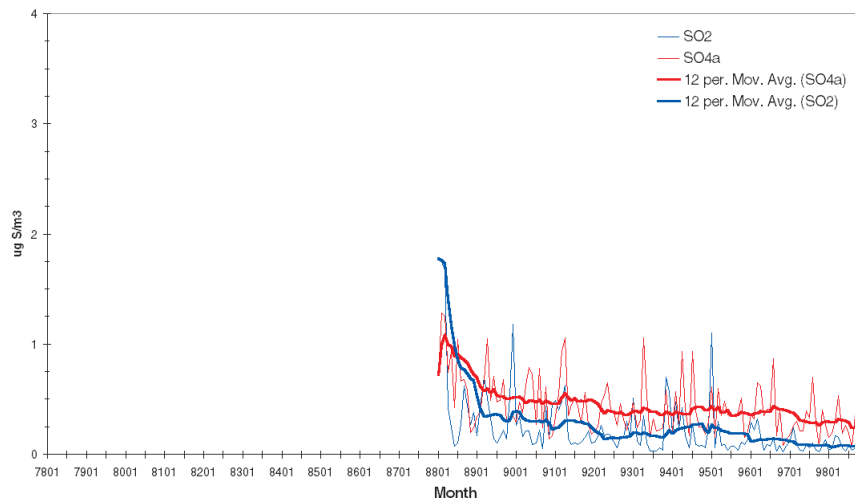
**a) NO1 Birkenes**



**b) NO8 Skreådalen**



**c) NO41 Osen**

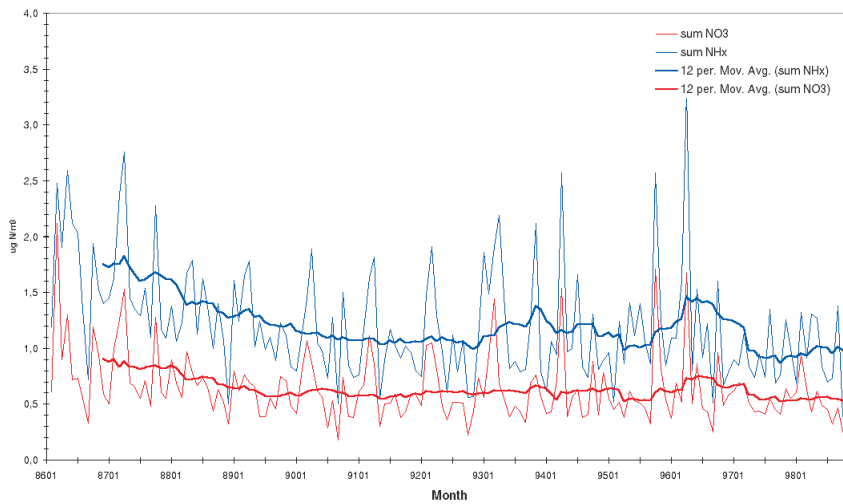


**Figure 2.5.2.:** Observed sulphur trends in air concentrations of sulphur dioxide (SO<sub>2</sub>) and particulate sulphate (SO<sub>4</sub>) at selected stations in Norway. Units:  $\mu\text{g (S)} \text{ m}^{-3}$

**Table 2.5.2.**Results of Trend Analysis on Nitrogen Observations\* period: 1989 - 1998

Country	loc	site	period	NO <sub>2</sub>	NO <sub>3</sub> +HN O <sub>3</sub>	NO <sub>3</sub> in precip.	NO <sub>3</sub> wet dep	NH <sub>x</sub>	NH <sub>x</sub> wet dep	N tot.dep.	N trans.dep.
				%	%	%	%	%	%	%	%
				+ 90% confidence <sup>2</sup> -		+ 90% confidence <sup>2</sup> -		+ 90% confidence <sup>2</sup> -		+ 90% confidence <sup>2</sup> -	
<b>Southern Scandinavia Receptor Region</b>											
Norway	S	NO1	85-98	-42*	-35	-28	-27	-32	-33		
				-0.075 - -- 0.049	-0.011 - -- 0.007	-0.017 - -0.007	-31 - -14	-0.022 - -0.012	-31 - -15		
	SW	NO8	85-88	not signifi- cant*	not signifi- cant	-22	-32	not significant	not signifi- cant	-50	--52
				-0.029 - -0.013		-0.009 - -0.003	-20 - -7			-6.4 - -2	-6.7 -2.3
	E	NO41	88-98	-43*	not sig.	not significant	-42	not significant	not signifi- cant		
				-0.058 - -0.037			-10 - -9				
Sweden	SW	SE2	85-98	-24*	-33	-33	-52	-38	-55		
				-0.113 - -0.006 0.012	-0.032 - - 0.012	-0.032 - -0.009	-29 - -19	-0.064 - -0.033	-29 - -19		
	mid	SE5	86-98	-47*	-37	-47	-66	-53	-89	-35	-21
				-0.020 - -0.010 0.002	-0.002 - - 0.002	-0.010 - -0.006	-9 - -6	-0.019 - -0.018	-13 - -11	-8.5 -4.8	-8.1 -4.6
	E	SE12	85-98	-28*	-65	-50	-55	-58	-62		
				-0.081 - -0.025 0.017	-0.023 - - 0.017	-0.035 - -0.023	-17 - -11	-0.054 - -0.045	-22 - -12		

*a) SE2 Rörvik*



**Figure 2.5.3.:** Observed nitrogen trends in air concentrations . Units:  $\mu\text{g (N) m}^{-3}$

## ***2.6. Conclusions***

The observed concentrations of sulphur dioxide in Germany and Poland appear to confirm the scale of the reported emission changes.

It appears that changes in the observed air concentrations of sulphur dioxide are broadly in the range of reported national emission changes while concentrations of sulphate in air and precipitation are clearly affected by emission changes beyond the borders. The observations seem to confirm the modelling conclusions depicted in Appendix II.

Changes in the sulphur pollution levels of Germany have largely been caused by the decrease of German national emissions. The decrease in German emissions have also largely contributed to the decrease in Polish sulphur depositions. Poland is in fact the country in Europe that shows largest percentage reduction of transboundary deposition and has largely benefited from the reduction of emissions beyond its national borders. Changes in transboundary air pollution seems to determine the observed air concentrations in Poland.

The measurements of oxidized nitrogen components reveal downward trends both in central parts of Europe and in southern parts of Sweden and Norway, thus reflecting reductions in the releases of nitrogen compounds.

In contrast to the long data series for the sulphur components the nitrogen data series are shorter, and there are less air data available to quantify decreases in air and precipitation concentrations and deposition. Although nitrogen dioxide can be transported across national boundaries its lifetime is relatively short, in particular during summer, thus emphasizing the importance of measurements of nitrate and nitric acid in air.

In general for all measurements the importance of good documentation of measurement changes and sufficiently long periods of parallel measurements should be stressed. This is particularly important for trend analysis since it allows for a quantification of measurement differences and prevents discontinuities which may distort trend estimates.

## **Appendix I. Measurement methods**



**Table 1: Sampling methods applied in Sweden**

Year	SO2	SO4a	SO4p	NO2	ΣNO3	ΣNHx	NO3p	NH4p
1978	7	9	bulk				bulk	bulk
1979	7	9	bulk				bulk	bulk
1980	7	9	bulk				bulk	bulk
1981	7	9	bulk				bulk	bulk
1982	7	9	bulk				bulk	bulk
1983	7	9	w-o				w-o	w-o
1984	7	9	w-o				w-o	w-o
1985	7/2*	9	w-o				w-o	w-o
1986	7/2*	9	w-o	8	2	3	w-o	w-o
1987	7/2*	9	w-o	8	2	3	w-o	w-o
1988	7/2*	9/2*	w-o	8/10/	2	3	w-o	w-o
1989	7/2*	9/2*	w-o	10	2	3	w-o	w-o
1990	7/2*	9/2*	w-o	10	2	3	w-o	w-o
1991	7	9	w-o	10	2	3	w-o	w-o
1992	7	9	w-o	10	2	3	w-o	w-o
1993	2	9	w-o	10	2	3	w-o	w-o
1994	2	11	w-o	10	2	3	w-o	w-o
1995	2	11	w-o	10	2	3	w-o	w-o
1996	2	11	w-o	10	2	3	w-o	w-o
1997	2	11	w-o	10	2	3	w-o	w-o
1998	2	11	w-o	10	2	3	w-o	w-o

Legend: (2) Whatman 40 KOH imp filter, 18 - 24 m3/day; (3) Whatman 40 H2Ox imp filter, 18 - 24 m3/day; (7) Abs. sol. H2O2, 1-2 m3/day 8: Abs. sol. Saltzmann, < 1 m3/day; (9) Whatman 40 filter, 1-2 m3/day; (10) Iodide imp glass sinter, < 1m3/day; (11) Gelman Zefluor 2u,18-24 m3/day; (\*) means at Aspvreten (SE12).

**Table 2: Chemical analytical methods applied in Sweden**

Year	SO2	SO4a	SO4p	NO2	ΣNO3	ΣNHx	NO3p	NH4p
1978	1	11	1				1	5
1979	1	11	1				1	5
1980	1	11	1				1	5
1981	1	11	1				1	5
1982	1	11	1				1	5
1983	1	11	1				1	5
1984	1	11	1				1	5
1985	1	11	1	12			1	5
1986	1	11	1	12	1	6	1	6
1987	1	11	1	12	1	6	1	6
1988	1	1	1	12	1	6	1	6
1989	1	1	1	12/14	1	6	1	6
1990	1	1	1	14	1	6	1	6
1991	1	1	1	7	1	6	1	6
1992	1	1	1	7	1	6	1	6
1993	1	1	1	7	1	6	1	6
1994	1	1	1	7	1	6	1	6
1995	1	1	1	7	1	6	1	6
1996	1	1	1	7	1	6	1	6
1997	1	1	1	7	1	6	1	6
1998	1	1	1	7	1	6	1	6

Legend: (1) Ion chromatography; (5) Gas sensitive electrode; (6) Flow injection analysis, spectrophotometric; (7) Griess spectrophotometric method with cadmium reduction; (11) X ray fluorescence analysis, (12) Saltzmann method; (14) NEDA.

**Table 3: Sampling methods applied in Norway**

Year	SO2	SO4a	SO4p	NO2	ΣNO3	ΣNHx	NO3p	NH4p
1978	2	1	bulk				bulk	bulk
1979	2	1	bulk				bulk	bulk
1980	2	1	bulk				bulk	bulk
1981	2	1	bulk	6			bulk	bulk
1982	2	1	bulk	6			bulk	bulk
1983	2	1	bulk	6			bulk	bulk
1984	2	1	bulk	6			bulk	bulk
1985	2	1	bulk	6			bulk	bulk
1986	2	1	bulk	6	2	3	bulk	bulk
1987	2	1	bulk	6	2	3	bulk	bulk
1988	2	1	bulk	6	2	3	bulk	bulk
1989	2	1	bulk	6	2	3	bulk	bulk
1990	2	1	bulk	6	2	3	bulk	bulk
1991	2	1	bulk	6	2	3	bulk	bulk
1992	2	11	bulk	6	2	3	bulk	bulk
1993	2	11	bulk	6	2	3	bulk	bulk
1994	2	11	bulk	10	2	3	bulk	bulk
1995	2	11	bulk	10	2	3	bulk	bulk
1996	2	11	bulk	10	2	3	bulk	bulk
1997	2	11	bulk	10	2	3	bulk	bulk
1998	2	11	bulk	10	2	3	bulk	bulk

**Legend:** (1) Whatman 40 filter, 18 - 24 m3/day; (2) Whatman 40 KOH imp filter, 18 - 24 m3/day; (3) Whatman 40 H2Ox imp filter, 18 - 24 m3/day; (6) Abs. sol. TGS, 1-2 m3/day; (10) Iodide imp glass sinter, < 1m3/day; (11) Gelman Zefluor 2u, 18-24 m3/day.

**Table 4: Chemical analytical methods applied in Norway**

Year	SO2	SO4a	SO4p	NO2	ΣNO3	ΣNHx	NO3p	NH4p
1978	2	1	1				1	3
1979	2	1	1				1	3
1980	2	1	1				1	3
1981	2	1	1	13			1	3
1982	2	1	1	13			1	3
1983	2	1	1	13			1	3
1984	2	1	1	13			1	3
1985	1	1	1	13			1	3
1986	1	1	1	13	1	3	1	3
1987	1	1	1	13	1	3	1	3
1988	1	1	1	13	1	3	1	4
1989	1	1	1	13	1	3	1	4
1990	1	1	1	13	1	3	1	4
1991	1	1	1	7	1	3	1	4/1
1992	1	1	1	7	1	1	1	1
1993	1	1	1	7	1	1	1	1
1994	1	1	1	7	1	1	1	1
1995	1	1	1	7	1	1	1	1
1996	1	1	1	7	1	1	1	1
1997	1	1	1	7	1	1	1	1
1998	1	1	1	7	1	1	1	1

**Legend:** (1) Ion chromatography; (2) Thorin spectrophotometric method; (3) Indophenol spectrophotometric method, automatic; (4) as (3) but with sodium salicylate replacing phenol; (7) Griess spectrophotometric method with cadmium reduction; (13) ANSA

**Table 5: Sampling methods applied in Poland**

Year	SO2	SO4a	SO4p	NO2	ΣNO3	ΣNHx	NO3p	NH4p
1978	7	1	bulk				bulk	bulk
1979	7	1	bulk				bulk	bulk
1980	7	1	bulk				bulk	bulk
1981	7	1	bulk				bulk	bulk
1982	7	1	bulk				bulk	bulk
1983	7	1	bulk				bulk	bulk
1984	7	1	bulk				bulk	bulk
1985	7	1	bulk				bulk	bulk
1986	2	1	bulk	6			bulk	bulk
1987	2	1	bulk	6			bulk	bulk
1988	2	1	bulk	6			bulk	bulk
1989	2	1	bulk	6			bulk	bulk
1990	2	1	bulk	6			bulk	bulk
1991	2	1	bulk	6	14	3	bulk	bulk
1992	2	1	bulk	6	14	3	bulk	bulk
1993	2	1	bulk	6	14	3	bulk	bulk
1994	2	1	bulk	6	14	3	bulk	bulk
1995	2	1	bulk	6	14	3	bulk	bulk
1996	2	1	bulk	6	14	3	bulk	bulk
1997	2	1	bulk	6	2	3	bulk	bulk
1998	2	1	bulk	6	2	3	bulk	bulk

**Legend:** (1) Whatman 40 filter, 2-4 m3/day; (2) Whatman 40 KOH/NaOH imp filter, 3-4 m3/day; (3) Whatman 40 H2Ox imp filter, 3-4 m3/day; (6) Abs. sol. TGS, < 1m3/day; (7) Abs. sol. H2O2, 2-3 m3/day; (14) Whatman 40, NaF imp filter, 4 m3/day.

**Table 6: Chemical analytical methods applied in Poland**

Year	SO2	SO4a	SO4p	NO2	ΣNO3	ΣNHx	NO3p	NH4p
1978	2	2	2				7	9
1979	2	2	2				7	9
1980	2	2	2				7	9
1981	2	2	2				7	9
1982	2	2	2				7	9
1983	2	2	2				7	9
1984	2	2	2				7	9
1985	2	2	2				7	9
1986	2	2	2	14			8	9
1987	2	2	2	14			8	9
1988	2	2	2	14			8	9
1989	2	2	2	14			8	9
1990	2	2	2	14			8	9
1991	2	2	2	8	8	9	8	9
1992	2	2	2	8	8	9	8	9
1993	2	2	2	8	8	9	8	9
1994	2	2	2	8	8	9	8	9
1995	2	2	2	8	8	9	8	9
1996	2	2	1	8	8	9	1	9
1997	2	2	1	8	8	9	1	9
1998	2	2	1	8	8	9	1	9

**Legend:** (1) Ion chromatography; (2) Thorin spectrophotometric method; (7) Griess spectrophotometric method with cadmium reduction; (8) as (7) but with hydrazine reduction; (9) Chloramin T spectrophotometric method; (14) NEDA

**Table 7: Sampling methods applied in Germany, F.R.**

Year	SO2	SO4a	SO4p	NO2	ΣNO3	ΣNHx	NO3p	NH4p
1978	15	16	bulk	8			bulk	bulk
1979	15	16	bulk	8			bulk	bulk
1980	15	16	bulk	8			bulk	bulk
1981	15	16	bulk	8			bulk	bulk
1982	15	16	bulk	8			bulk	bulk
1983	15	16	bulk	8			bulk	bulk
1984	15	16	bulk	8			bulk	bulk
1985	15	16	bulk	8			bulk	bulk
1986	15	16	bulk	8			bulk	bulk
1987	15	16	bulk	8			bulk	bulk
1988	15	16	bulk	8			bulk	bulk
1989	15	16	bulk	8			bulk	bulk
1990	15	16	bulk	8			bulk	bulk
1991	15	16	bulk	8			bulk	bulk
1992	15	16	bulk	8			bulk	bulk
1993	15	16	bulk	8			bulk	bulk
1994	15	16	bulk	8			bulk	bulk
1995	15	16	bulk	8			bulk	bulk
1996	15	16	bulk	8			bulk	bulk
1997	15	16	bulk	8			bulk	bulk
1998	15	16	bulk	8			bulk	bulk

Legend: (8) Abs. sol. Saltzmann, 1 m3/day; (15) Abs.sol., TCM, 1 m3/day; (16) Schleicher & Shull 589/2L, 1 m3/day.

**Table 8: Chemical analytical methods applied in Germany, F.R.**

Year	SO2	SO4a	SO4p	NO2	ΣNO3	ΣNHx	NO3p	NH4p
1978	10	11		12				
1979	10	11		12				
1980	10	11		12				
1981	10	11	1	12			8	3
1982	10	11	1	12			8	3
1983	10	11	1	12			1	3
1984	10	11	1	12			1	3
1985	10	11	1	12			1	3
1986	10	11	1	12			1	3
1987	10	11	1	12			1	3
1988	10	11	1	12			1	3/6
1989	10	11	1	12			1	6
1990	10	11	1	12			1	6
1991	10	11	1	12			1	6
1992	10	11	1	12			1	6
1993	10	11	1	12			1	6
1994	10	11	1	12			1	6
1995	10	11	1	12			1	6
1996	10	11	1	12			1	6
1997	10	11	1	12			1	6
1998	10	11	1	12			1	6

Legend: (1) Ion chromatography; (3) Indophenol spectrophotometric method; (6) Flow injection analysis, spectrophotometric; (8) Griess spectrophotometric method with hydrazine reduction; (10) Pararosanilin method; (11) X ray fluorescence analysis; (12) Saltzmann method.

**Table 9: Sampling methods applied in Spain**

Year	SO2	SO4a	NO2	ΣNO3	ΣNHx
1978					
1979					
1980					
1981					
1982					
1983					
1984					
1985	7	12			
1986	7	12	13		
1987	7	12	13		
1988	7	12	13		
1989	7	12	13		
1990	7	12	13		
1991	7	12	13	2	3
1992	7	12	13	2	3
1993	7	12	13	2	3
1994	7	12	13	2	3
1995	7	12	13	2	3
1996	7	12	13	2	3
1997	7	12	13	2	3
1998	7	12	13	2	3

Legend: (2) Whatman 40 KOH/NaOH imp filter, 35m3/day; (3) Whatman 40 H2Ox imp filter, 35 m3/day; (7) Abs. sol. H2O2, 1-2 m3/day; (12) Whatman GF/A filter, 770 m3/day; (13) Abs. sol., triethanoleamine, 1 m3/day.

**Table 10: Chemical analytical methods applied in Spain**

Year	SO2	SO4a	NO2	ΣNO3	ΣNHx
1978					
1979					
1980					
1981					
1982					
1983					
1984					
1985	2	2			
1986	2	2	14		
1987	2	2	14		
1988	2	1	14		
1989	2	1	14		
1990	2	1	12	1	3
1991	2	1	7	1	3
1992	2	1	7	1	3
1993	2	1	7	1	3
1994	2	1	7	1	3
1995	2	1	7	1	3
1996	2	1	7	1	3
1997	2	1	7	1	3
1998	2	1	7	1	3

Legend: (1) Ion chromatography; (2) Thorin spectrophotometric method; (3) Indophenol spectrophotometric method; (7) Griess spectrophotometric method; (12) Saltzmann method; (14) NEDA



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***APPENDIX II***  
***1998 Status Review***  
***by Country***



## Overview of regions included in this Appendix

Country/Region	Code	Country/Region	Code
Armenia	AM	Norway	NO
Austria	AT	Poland	PL
Belarus	BY	Portugal	PT
Belgium	BE	Republic of Moldova	MD
Bosnia and Herzegovina	BA	Romania	RO
Bulgaria	BG	Russian Federation	RO
Croatia	HR	Slovakia	SK
Cyprus	CY	Slovenia	SI
Czech Republic	CZ	Spain	ES
Denmark	DE	Sweden	SE
Estonia	EE	Switzerland	CH
European Community	EU	The FYR of Macedonia	MK
Finland	FI	Turkey	TR
France	FR	Ukraine	UA
Germany	DE	Yugoslavia	YU
Greece	GR	United Kingdom	GB
Hungary	HU		
Iceland	IS	Albania	AL
Ireland	IE		
Italy	IT	Baltic Sea	BAS
Latvia	LV	Black Sea	BLS
Lithuania	LT	Mediterranean Sea	MED
Luxembourg	LU	North Sea	NOS
Malta	MT	Remaining N.E. Atlantic	ATL
Netherlands	NL		

**For Canada, Georgia, Liechtenstein, Monaco and United States only reported emission data are included.**

**Malta is introduced for the first time as receptor country.**

**The estimated emissions from Malta are below the accuracy limits of the source-receptor calculations and do not justify a separate study of Malta as emitter country**

**Although Albania is not a Party to the LRTAP Convention, its situation in Europe and the extent of its estimated emissions justify a separate study of this country as emitter and receptor.**



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Reported national emission totals	<i>vigdis.vestreng@dnmi.no</i>
Maps of allocated depositions and air concentration for 1998	<i>jerzy.bartnicki@dnmi.no</i> <i>egil.storen@dnmi.no</i>
<p>Source allocation of imported and exported pollution. Comparison for different years.</p> <p>Values for 1985, mean value for 1985-1996, and value for 1996 calculated with the Lagrangian Acid Deposition model. Values for 1997 and 1998 calculated with the Eulerian Acid Deposition model.</p>	<i>jerzy.bartnicki@dnmi.no</i> <i>hilde.lenschow@dnmi.no</i>
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