Chapter 3

Nitrogen oxides

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3.1 Emissions of nitrogen oxides to the atmosphere

3.1.1 The situation in Europe around 1980

The work on reducing long-range transboundary air pollution was initiated with a focus on sulphur compounds and the effects of acidification. It was soon realized, however, that the nitrogen oxides posed a pollution threat as serious as that of sulphur: Nitrogen oxides take part in a number of atmospheric processes. They contribute to acidification and eutrophication. The concentrations of nitrogen dioxide in cities were already high and increasing due to the expanding traffic, and threatened human health. The nitrogen compounds contribute considerably to the long-range transport of acidifying and fertilising nitrates, and are essential in the ozone formation process, so there were many good reasons to introduce the nitrogen oxides into EMEP.

The total emissions of nitrogen oxides in Europe in 1980 were estimated at around 26 million tons as NO_2, approximately equivalent to 8 million tons of nitrogen. Of this, emissions from shipping in international waters contributed around 4 million tons as NO_2, or 1.2 million tons of nitrogen. The natural emissions of nitrogen oxides are insignificant. Just as for sulphur, the largest emissions were seen in the large countries. More than 2 million tons of NO_2 were emitted in Germany, United Kingdom, Russian Federation and France. Between 1 and 2 million tons of NO_2 were emitted in Italy, Poland, Ukraine and Spain.

The spatial distribution of emissions in 1980 is seen in Figure 3.1. In contrast to sulphur emissions the high emission grids for nitrogen oxides are more frequently situated in western rather than in Eastern Europe.

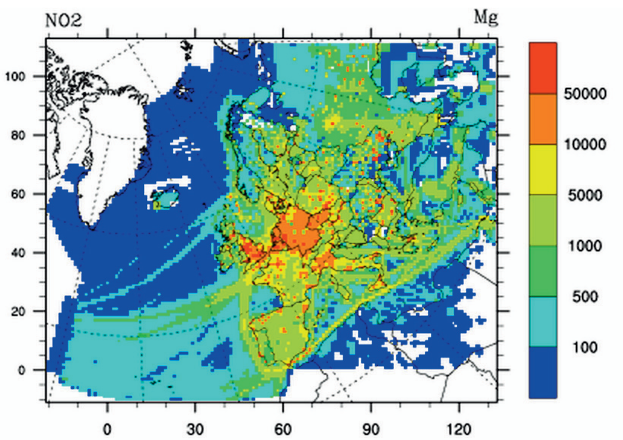


Figure 3.1 Spatial distribution of nitrogen oxides emissions in Europe 1980.
Units: tonnes/year/gridsquare

3.1.2 Sources of nitrogen emissions to the atmosphere

General

Nitrogen compounds are emitted to the atmosphere as nitrogen oxides and ammonia. Nitrogen oxides are emitted mainly via combustion for energy production and in vehicle engines. To a large degree the nitrogen oxides are the result of reactions between oxygen and nitrogen in the combustion air. Nitrogen in the fuel contributes, but only to some extent. Industrial processes, such as fertiliser production and production of some inorganic base chemicals, contribute in most areas to a minor extent to the total emission. Nitrogen monoxide is the main compound emitted together with small amounts of nitrogen dioxide.

The emission data for nitrogen oxides includes the emissions from a large number of anthropogenic activities, such as transport, heating and electricity generation and industry. In addition, ships contribute significantly to emissions of nitrogen oxides.

Emission estimates

Emission data are available in the EMEP database as officially submitted data and expert estimates data per country, per year and per sector (codes 1 - 11, see under sulphur emissions 2.1.2).

As mentioned in the sulphur chapter, emission data sector by sector is mainly available after 1990. For a few countries the sector emissions are reported from 1980. In most countries with data from 1980, the dominant contributions are from road transport and other mobile sources (sector 7 and 8, see the chapter on sulphur). In some countries such as Denmark and United Kingdom there are large contributions from stationary combustion as well (sector 1+2+3). In Austria and France, the combustion sources are not as dominant. France produces energy to a large extent by nuclear power and in Austria hydropower is important. In addition, there is a considerable contribution from industrial processes (sector 4) in Austria.

3.1.3 Time series for nitrogen oxides emissions 1980 - 2000

As for sulphur, the emissions in Europe show a downward trend for nitrogen oxides during the period, even if not as pronounced. In total the decrease in the officially reported data has been around 25% from 1990 to 2000 (Figure 3.2). In reality, the decrease has been larger, around 30%, because some sources were missing from the earlier estimates. The figure gives the emissions of nitrogen oxides in tons of nitrogen to make them comparable with the emissions of ammonia. In nitrogen units, the total European emissions of NO_x and ammonia are surprisingly equal.

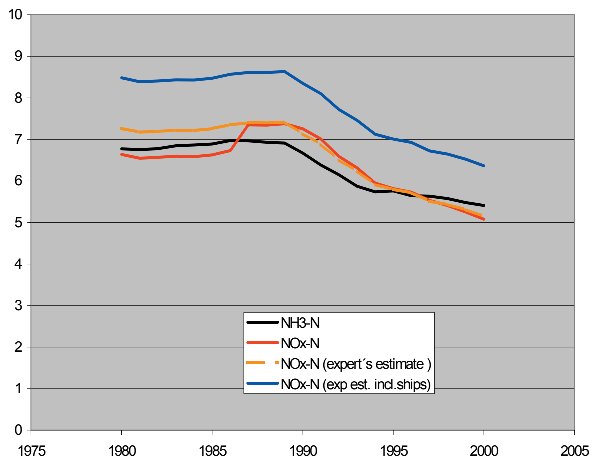
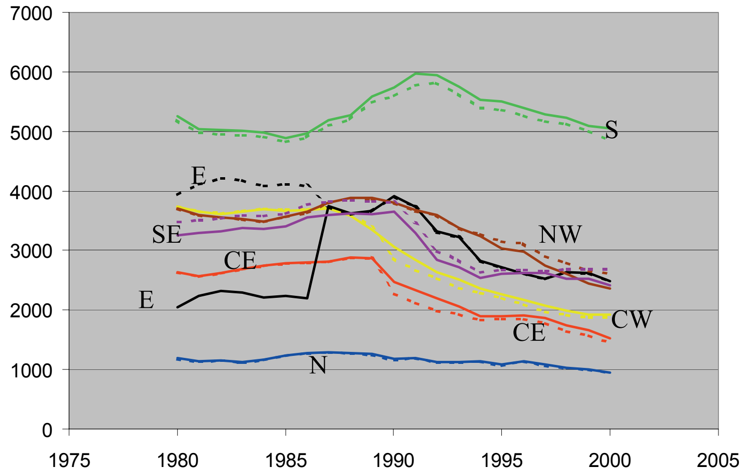


Figure 3.2 Annual NO_x emissions in the European countries 1980-2000, as officially reported total land-based emissions, as expert estimates of total land-based emissions and as total emissions incl. those from ships. Unit: million tons of NO_2-N /year. The emissions are given as nitrogen in order to make them easily comparable to ammonia emissions in NH_3-N per year.
The Russian emissions only include the European part.

The emissions of NO_x have decreased over CW, SE, NW, CE, and N Europe (Figure 3.3 and Table 3.1), while the emissions have been relatively unchanged in CE Europe.



CE = Czech Republic, Hungary, Poland, Slovakia

CW = Austria, Germany, Switzerland

E = Estonia, Latvia, Lithuania, Russian Federation (European part)
N = Finland, Iceland, Norway, Sweden, Denmark

NW = Belgium, Ireland, Luxembourg, Netherlands, United Kingdom

S = France, Greece, Italy, Portugal, Spain

SE = Albania, Armenia, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, Georgia, Kazakhstan, Republic of Moldova, Romania, Slovenia, The FYROM Macedonia, Turkey, Ukraine, Yugoslavia

Figure 3.3 Regional timeseries for nitrogen oxides emissions Solid line = Official data, Dotted line = Expert estimate data. Units: ktonnes of NO_2/ year.

The emission decreases between 1980 and 2000 in different regions are also presented in Table 3.1. Here are also the emission changes of sulphur and ammonia shown.

Table 3.1 Reductions in emissions betweeen 1980 and 2000 in different parts of Europe

Countries	Change in S emissions	Change in NO_x emissions	Change in NH3 emissions
Czech Rep., Hungary, Poland and Slovak Rep.	-73%	-42%	-46%
Austria, Switzerland and Germany	-89%	-49%	-23%
Estonia, Latvia, Lithuania and Russia (European part)*	-73%	+21%	-48%
Denmark Finland Iceland, Norway and Sweden	-87%	-21%	-10%
Belgium, Luxemburg, the Netherlands, Ireland and United Kingdom	-76%	-36%	-13%
France, Greece, Italy, Portugal and Spain	-62%	-4%	+1%
Albania, Armenia, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, Georgia, Kazakhstan, Republic of Moldova, Romania, Slovenia, The FYROM Macedonia, Turkey, Ukraine and Yugoslavia	-40%	-26%	-12%
TOTAL EUROPE, excluding ships.	**-67%**	**-24%**	**-20%**

* There is an increase in NO_x emissions in Russia due to specific sources which were not included in the earlier estimates for 1980.

For Europe as a whole, a considerable part of the emission decrease (37%) was due to stationary combustion sources (sectors 1+2+3). In 1980 these sources contributed around 40% of the emissions. The reduction has been more pronounced in countries where large point sources contributed to the emissions, than in countries where traffic has been the main source. Examples where combustion sources have been large contributors are Germany, United Kingdom, Czech Republic and Poland. By changing from coal burning to gas or to nuclear power, not only the sulphur but also the nitrogen oxides emissions have been reduced. In 2000 the emissions from combustion, sector 1-3, had decreased to be 26% of the total. The emissions from road transport (sector 7) and other mobile sources (sector 8) have decreased by 22%, approximately equal to the total decrease. The contribution changed from 42% to 44% for sector 7 and from 14% to 18% from sector 8. Figure 3.4 shows the reductions sector by sector between 1990 and 2000.

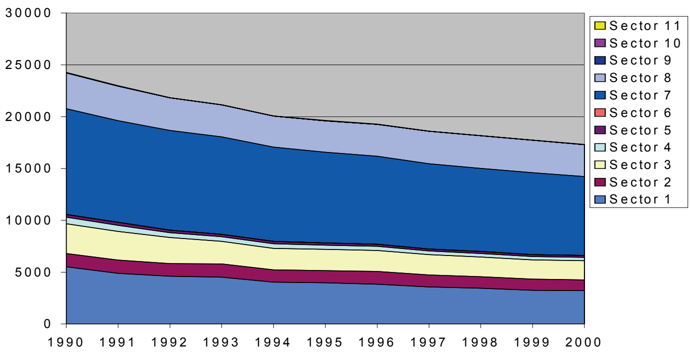
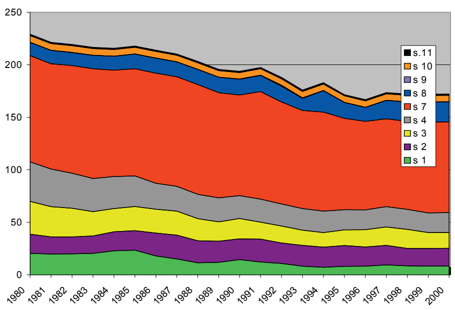


Figure 3.4 Emission reduction in all Europe between 1990 and 2000 Units: 1000 tons/year.

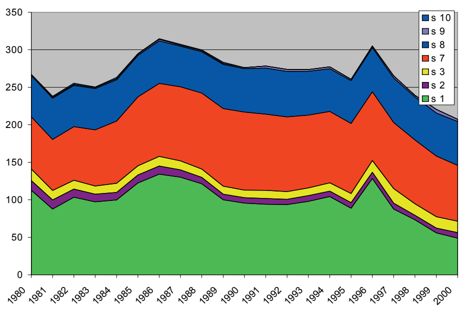
The emission sectors are defined on page 16 in Chapter 2.

For some countries, emission data per sector is available from 1980 onwards. For a selection of these, the development until 2000 can be seen in Figure 3.5. The development is quite different for the countries. There has been a steady decrease in Austria. In Denmark the emissions vary considerably between years but decrease after 1997. United Kingdom had a maximum in emissions in the late 1990s. Approximately the same is seen for France and Italy with a maximum in the beginning of the 1990s, while the Spanish NOx emissions have not decreased but remained throughout the 1990s at the level of 1990.

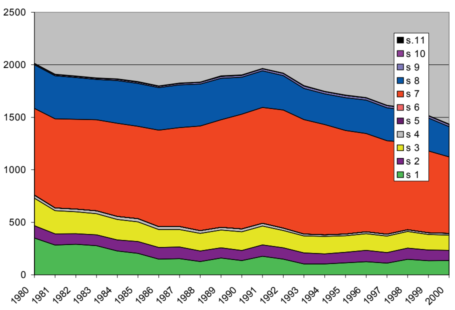
Figure 3.5 Sectorial emissions for a selection of countries reporting sector data from 1980. Units: 100 tons per year.



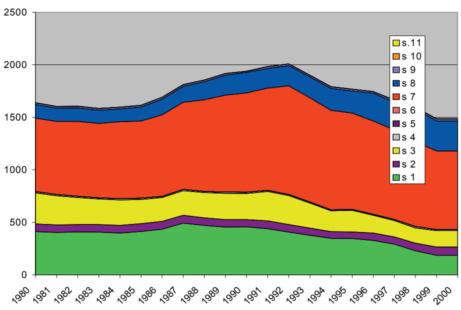
Austria



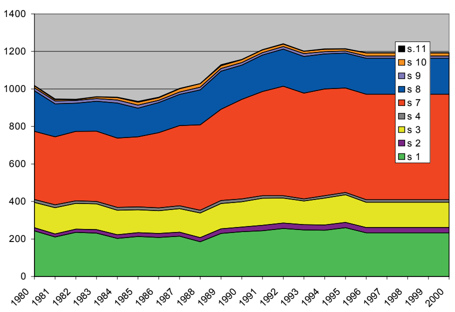
Denmark



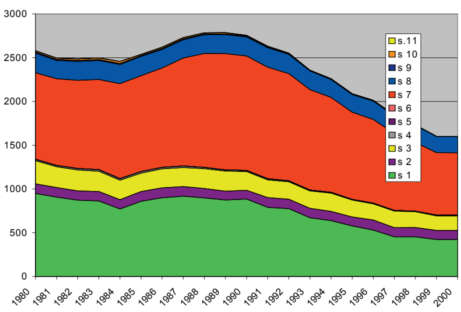
France



Italy



Spain



United Kingdom

3.1.4 Progress in emission reduction

The geographically distributed emissions of nitrogen oxides for 2000 are shown in Figure 3.6. This Figure can be compared to Figure 3.1, to show the progress over the twenty years.

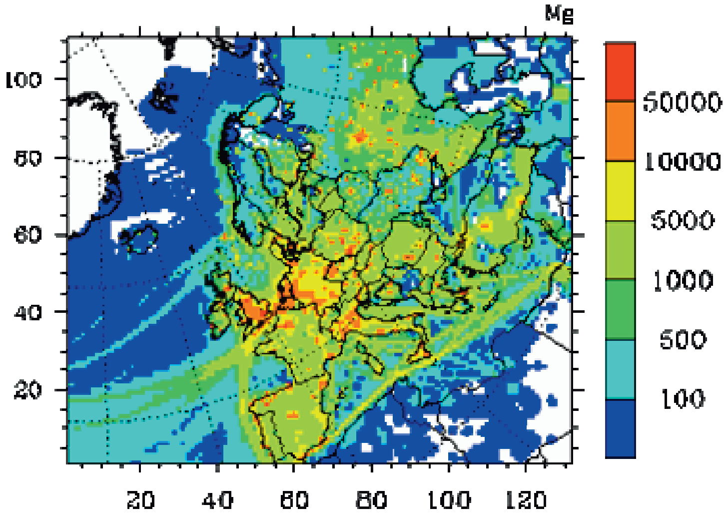


Figure 3.6 Spatial distribution of nitrogen oxides emissions in 2001
Units: Tonnes of NO_2/year/ grid square.

Although reductions have been achieved by 2000, the emission ceilings of the Gothenburg protocol for 2010 may be difficult to attain, especially in the western and south-western European countries (Figure 3.7). Most of the countries have obvious difficulties in decreasing traffic emissions. The further reductions necessary between 2000 and 2010, are given in Figure 3.7, in absolute amounts (a) and in percent of the total emissions reduction agreed to (b).

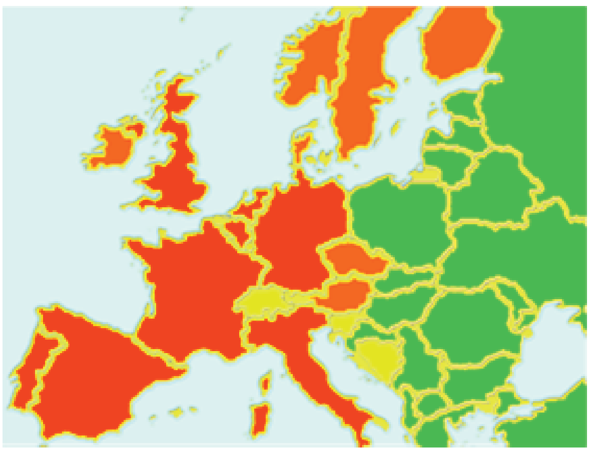


Figure 3.7a Emissions of NO_x necessary to reduce between 2000 and 2010 in order to fulfil the Gothenburg protocol:
Red = 100-800
Orange = 50-99
Yellow = 10-49
In the *green-marked* countries the necessary reduction is below 5 000 tons per year. Most of them have already in the year 2000 reached their goal for 2010

Units: 1000 tonnes per year.

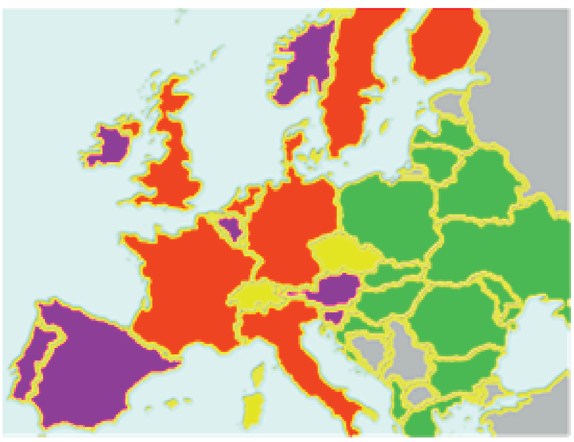


Figure 3.7b Emissions of NO_x left to reduce in 2000 in order to fulfil the agreement in the Gothenburg protocol 2010.
Violet = 60% or more
Red = 30 - 59%
Yellow = 1 - 29%
Green = the goal is achieved already 2000.
The *grey* countries are not included in the protocol or it is not possible to evaluate the progress in reduction.
Units: % of the total reduction required between 1990 and 2010.

3.2 Oxidised nitrogen compounds in air and precipitation

Emitted nitrogen oxides are dispersed, transported, oxidised and deposited to the environment. Within EMEP, these processes are analysed on a regional scale, the main objective being to quantify transboundary air pollution. The EMEP measurement stations are sited in rural areas remote from major sources in order to measure, as far as possible, the long range transported component of the air pollution. Higher concentrations than those measured in EMEP occur close to large sources such as cities, large roads and industrial areas.

THE FATE OF NITROGEN OXIDES IN THE ATMOSPHERE

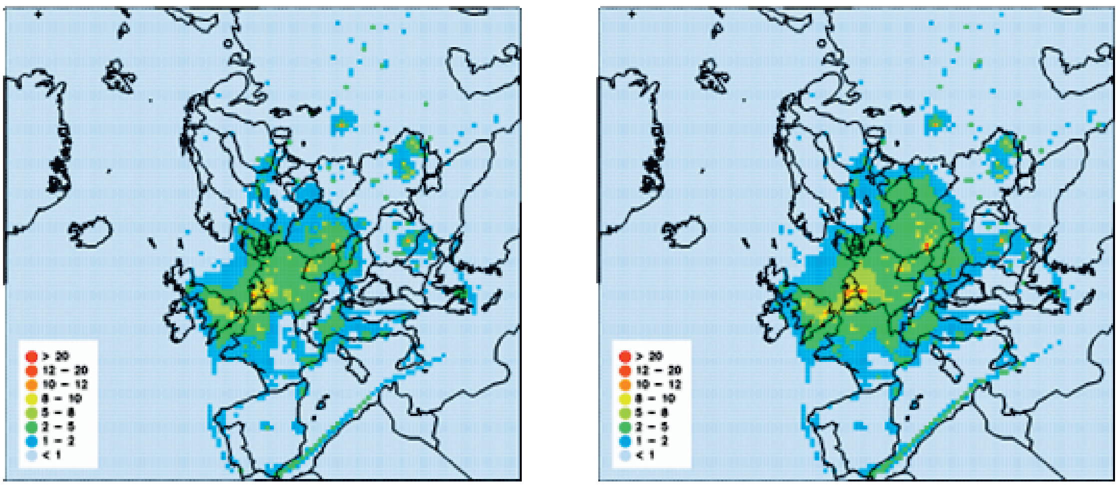
Nitrogen monoxide is the main compound emitted together with small amounts of nitrogen dioxide. The nitrogen monoxide is gradually oxidised to nitrogen dioxide and then further to nitric acid and nitrates in the atmosphere. Nitric acid readily reacts with gases and particles in the air, and is thus rapidly deposited onto vegetation and other surfaces. Nitrate particles formed, may - like the sulphate particles - be transported over large distances, before they are finally deposited to the ground.

The final fate of the nitrogen compounds in the environment depends on the nutrient status in the area where it is deposited. Most ecosystems suffer from nitrogen deficiency and any nitrogen deposited is readily taken up by vegetation. The uptake will in many cases lead to increasing growth. When nitrogen is present in amounts larger than what can be used by the ecosystem, nitrate will leach out with the soil water, with the same acidifying effect in the ecosystem as for sulphate.

3.2.1 Nitrogen oxides pollution in Europe during the 1980s

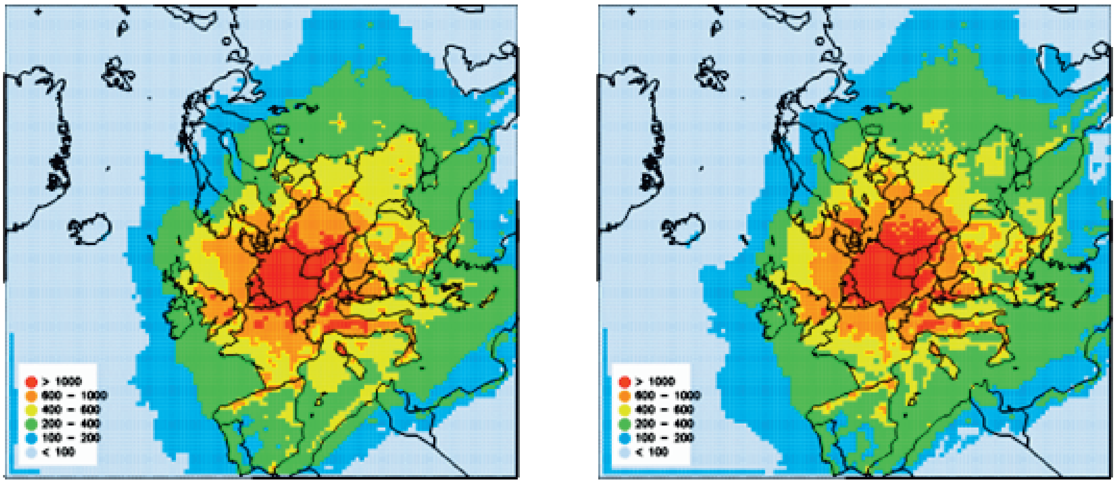
The nitrogen oxides emission in Europe reached its maximum in the late 1980s. Concentrations of nitrogen dioxide and deposition of nitrate (total = wet+dry) in 1980 and 1985 are shown in Figure 3.8 and 3.9, respectively.

Figure 3.8 Model-calculated annual NO_2 concentrations in rural air over Europe during 1980 and 1985. Units: µg NO_2 N/m^3.



1980 1985

Figure 3.9 Model-calculated annual average total (wet+dry) deposition of oxidised nitrogen over Europe. Units: mg N/m^2.



1980 1985

The deposition of oxidised nitrogen may also contribute to eutrophication of ecosystems. The important quantity in this case is the deposition of total nitrogen, which is given by the sum of oxidised nitrogen and ammonium (both measured in nitrogen units) If the deposition of total nitrogen exceeds a critical load of nutrients, eutrophication will occur.

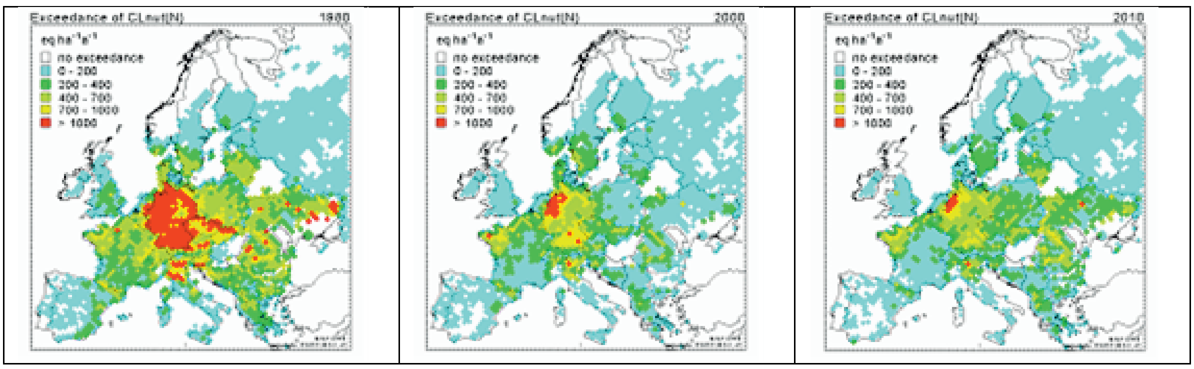
CRITICAL LOAD OF NUTRIENTS

The critical load of nutrients is defined as a metric of an acceptable nitrogen leaching from the system in addition to the deposition allowed considering nitrogen sinks, that is, a deposition in balance nitrogen uptake and immobilisation.

Nilsson (1986) and Nilsson and Grennfelt (1988)

Figure 3.10 shows areas in Europe where the critical load of nutrients was exceeded in 1990 due to deposition of total nitrogen. Main exceedances are seen in Germany and in areas along the Polish-Czech border.

Figure 3.10 Exceedance of critical loads of nutrient N due to N deposition in 1980 (left) and in 2000 (middle). A forecast for 2010 is also included (right). Units: eq/ha/year.



The change over the period from 1980 to 2000 can further be illustrated by the total ecosystem area in Europe which is protected against eutrophication. In 1980 68 % of the 5,386,093 km2 was protected. In 2000 the protected area had increased to 74 %. The prognoses for 2010 indicate that 70 % of the area will be protected.

3.2.2 Time series of nitrogen dioxide in air

The emission decreases for nitrogen oxides between 1980 and 2000 are smaller than the decrease for sulphur, and took place mainly throughout the 1990s. Many countries only had an ambition of freezing the nitrogen oxides emissions, as set out in the first NO_X protocol. Others had the ambition to reduce by 30%, and made this ambition known through a joint declaration, but had obvious problems to realize this, however. The overall emission reduction over this period is still estimated to around 30%, though the differences between countries are large.

Time series for nitrogen dioxide in air have been analysed from data in the EMEP database (Figure 3.11). Results from the national assessments are also shown (Figure 3.12). There are mostly decreasing trends even if the situation is not as clear and homogenuous as for sulphur. Besides the regional differences in emission development, the evaluation of trends is further complicated by the relatively few available long-term data series.

Figure 3.11 Trends in annual average concentrations of NO_2 at a number of EMEP sites with long-term data series over Europe. Units: µg N/m^3.

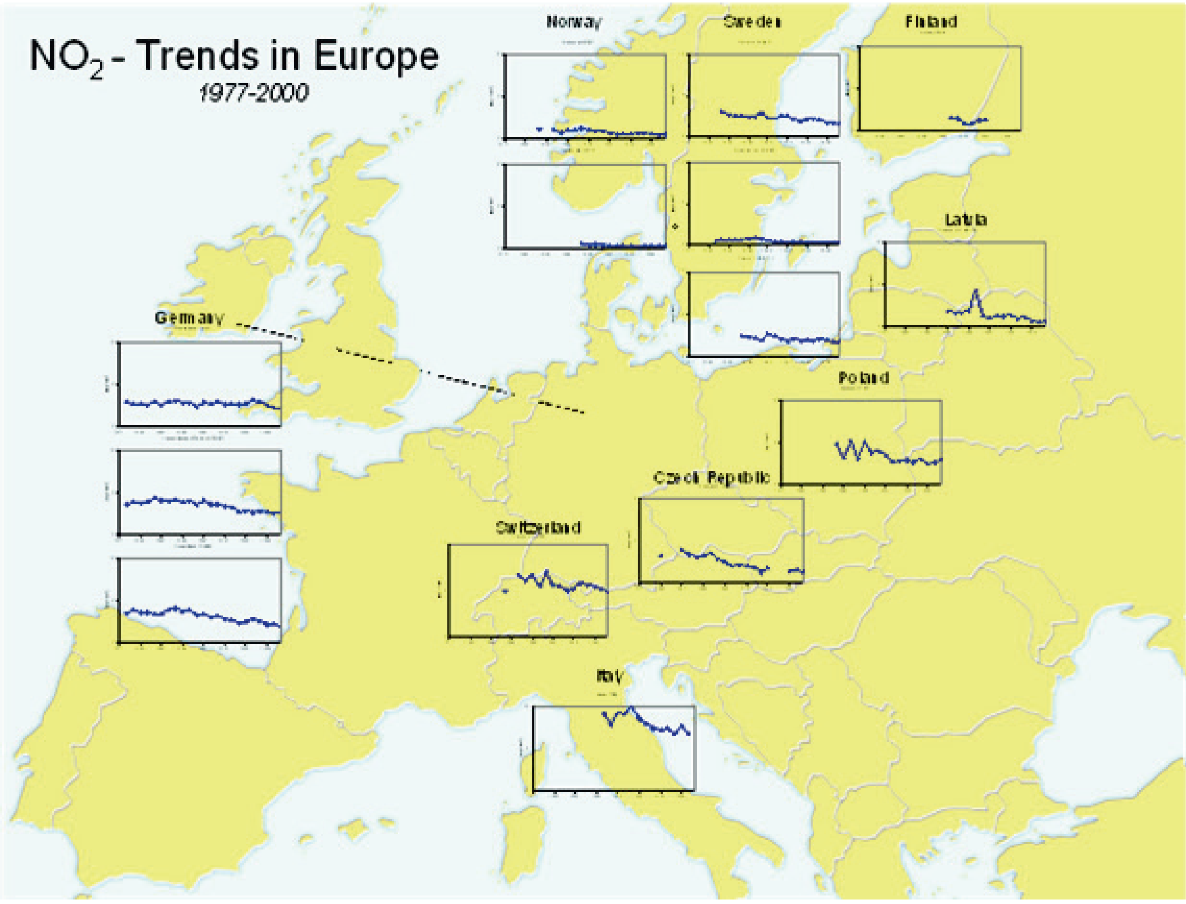
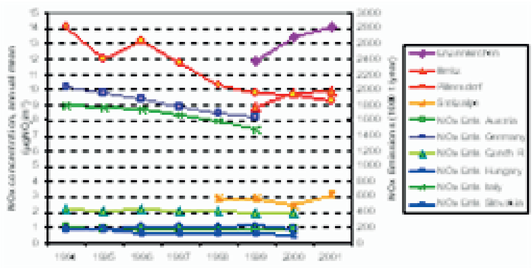
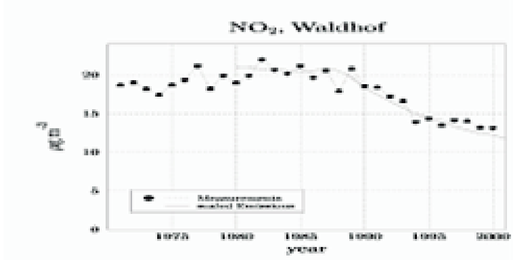


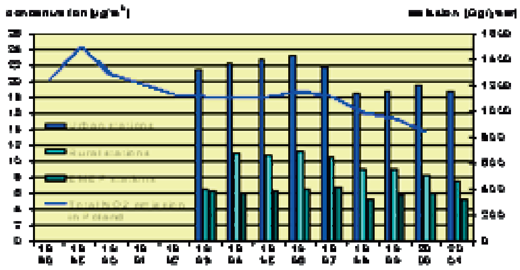
Figure 3.12 Trends in annual average NO_2 concentrations from some of the national assessments. The figures are taken from the national assessments and the units vary between countries as µg m^{-3} NO_2 or N.



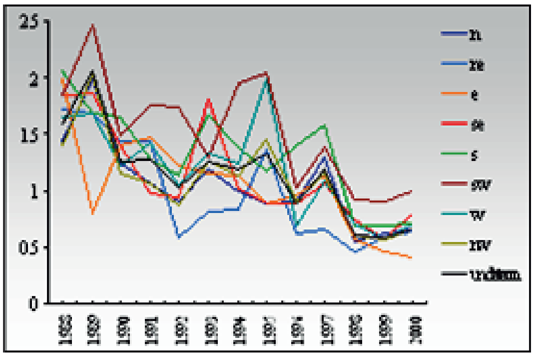
Austria (Spangl 2004)
Trends in NO_2 at a number of monitoring sites in relation to emission trends in Austria and neighbouring countries.



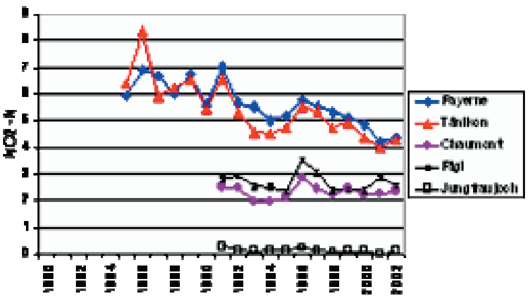
Germany (Wallasch 2004)
Trends in NO_2 at the EMEP site Waldhof in relation to the scaled national emission trend.



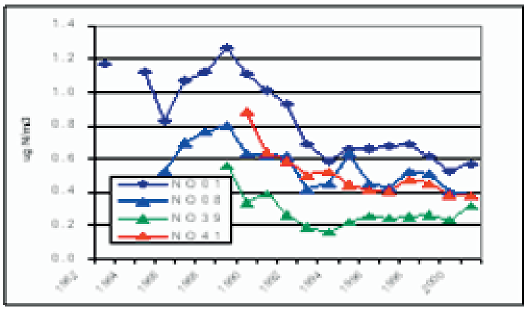
Poland (Mitosek et al., 2004)
Trends in NO_2 at urban, rural and EMEP sites in Poland in relation to national emissions.



Latvia (Lyulko et al., 2004)
Trends in NO_2-N (µg/m^3) at Rucava in air masses of different origin



Switzerland (Ballaman et al., 2004)
Trends in NO_2-N at some Swiss EMEP sites at different location and altitude.



Norway (Schaug et al., 2004)
Trends in NO_2-N at a number of Norwegian EMEP sites.

In Table 3.2 the observed changes in NO_2 concentrations over the period 1990-2000 are evaluated and compared to changes in emissions. The changes are estimated from the levels in the diagrammes. The evaluation of the trends is based on long-term data series from the EMEP measurement sites as well as on results from the national assessments. Countries not included in the table are mainly those that did not assess their situation and those lacking long-term monitoring data series. There is a considerable variation from one country to another, both in decreases of emissions and in trends of nitrogen oxides concentrations.

For NO_2 the table shows that for all countries, except Austria and Norway, there is some agreement between decrease in concentrations and reductions of national emissions. However, the picture is not completely clear. For nitrates in air there are only a few long-term data series available for analysis. It seems, however, that the decrease for nitrates is lower than for NO_2. This might be explained by a relatively constant oxidising capacity leading to more efficient oxidation when the concentrations of sulphur dioxide and nitrogen dioxide decrease as discussed in chapter 2.

Table 3.2 Changes in nitrogen oxides concentrations in relation to emission reductions between 1990 and 2000.

Country	Reduction in emission	Decrease in obs. NO_2	Decrease in obs. total-NO_3
Austria	10%*	80%	no data
Belarus	50%	75%	no data
Czech Republic	45-50%	50%	no data
Denmark	25%	no data	20%
Estonia	40%	>20%	no data
Finland	20%	no data	no trend
Germany	40%	50%	no data
Italy	20-25%	20-25%	no data
Latvia	65%	65%	no data
Lithuania	70%	50%	40%
Norway	1%	30-.50%	20%
Poland	35%	20-30%	no data
Slovak Republ.	50%	20%	30-60%
Switzerland	30%	35%	no data
Sweden	30%	40%	40-60%
United Kingdom	45%	40-50%	25%

* Larger decrease if also emissions during the end of the 1980s are included.

From the monitoring data available it is clear that the largest decreases in the concentrations of oxidised nitrogen have taken place in many of the central and eastern European countries, such as Czech Republic, Latvia, Poland, Slovak Republic and Germany. The reductions to a large extent arise from closing lignite-fired power plants, restructuring the energy sector and introducing flue gas cleaning technology. Large reductions have also been achieved in the Netherlands, Norway and Switzerland. The decreases of NO_2 concentrations in terms of the mean value, and three percentiles are given in Table 3.3 for selected EMEP sites.

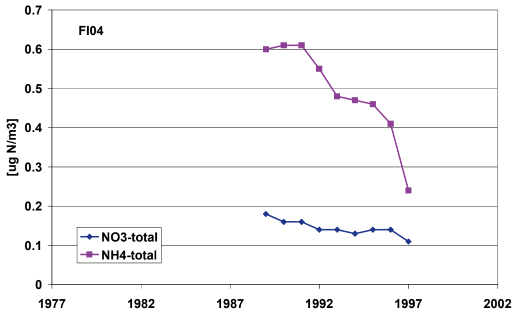
Table 3.3 Median (50%) and extreme NO_2 concentrations (70% and 95%) at a selection of EMEP monitoring sites in Europe for three years in the beginning and for three years in end of the monitoring period. The concentrations in 1999-01 are also given as percent of the levels around 1980.

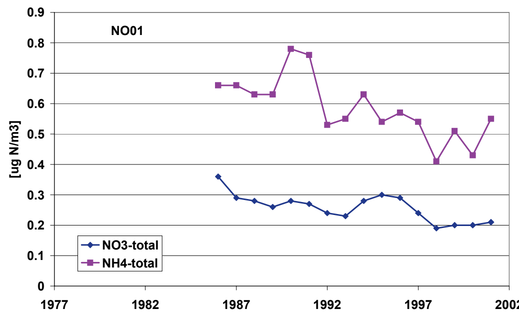
	Beginning of the period					End of the period				
Site		**Mean**	**50-%**	**70-%**	**95-%**		**Mean**	**50-%**	**70-%**	**95-%**
DE01, Westerland	78-80	2.7	1.8	3.0	7.9	99-01	2.1 (78%)	1.6 (89%)	2.3 (77%)	5.3 (67%)
DE02, Langenbrügge	79-80	3.7	3.0	4.4	8.4	99-01	2.5 (68%)	2.0 (67%)	2.7 (90%)	5.8 (69%)
NO01, Birkenes	80-82	1.2	0.5	1.0	4.7	99-01	0.52 (43%)	0.4 (80%)	0.6 (60%)	1.5 (32%)
CH02, Payerne	87-89	6.4	5.4	7.6	13.1	99-01	4.7 (73%)	4.0 (74%)	5.5 (72%)	9.9 (76%)
SE05, Bredkälen	82-84	0.5	0.5	0.65	1.3	97-99	0.17 (34%)	0.12 (24%)	0.18 (28%)	0.44 (34%)
SE02, Rörvik	82-84	2.6	2.0	2.5	7.8	99-01	1.5 (58%)	1.2 (69%)	1.7 (68%)	3.6 (46%)

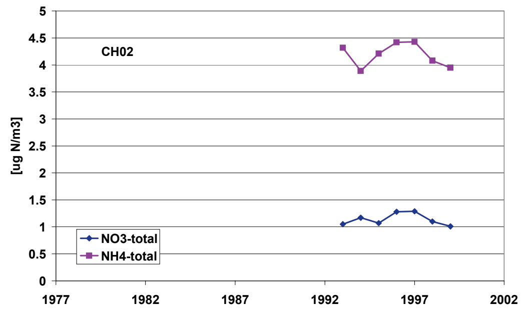
3.2.3 Concentrations of total nitrate in the air

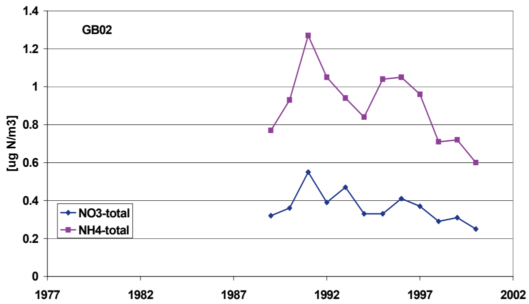
Nitrogen dioxide is a "middle product" in the atmospheric oxidation chain from emitted NOx, which is to 90% or more nitrogen monoxide. The final product is nitrate/nitric acid. The time necessary for NO_2 to be formed may vary due to the atmosperic mixture, but generally is of the order of one hour. NO_2 is thus a far more local compound than the nitrates, and trends in NO_2 may represent very local emission changes. Nitrates are on the contrary of a more long-range origin, and therefore trends in this parameter will be more representative for emission changes of distant sources. Trends in total nitrate in air at a selection of EMEP-sites are shown in Figure 3.13.

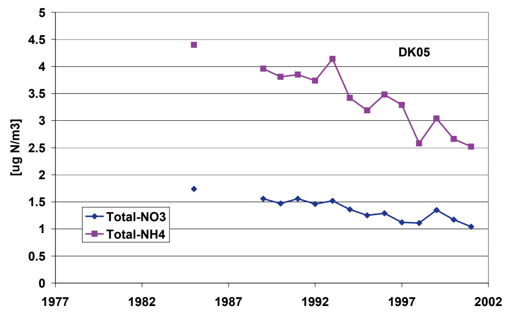
Figure 3.13 Time series for concentrations of total nitrate and total ammonium at some EMEP sites in Europe.











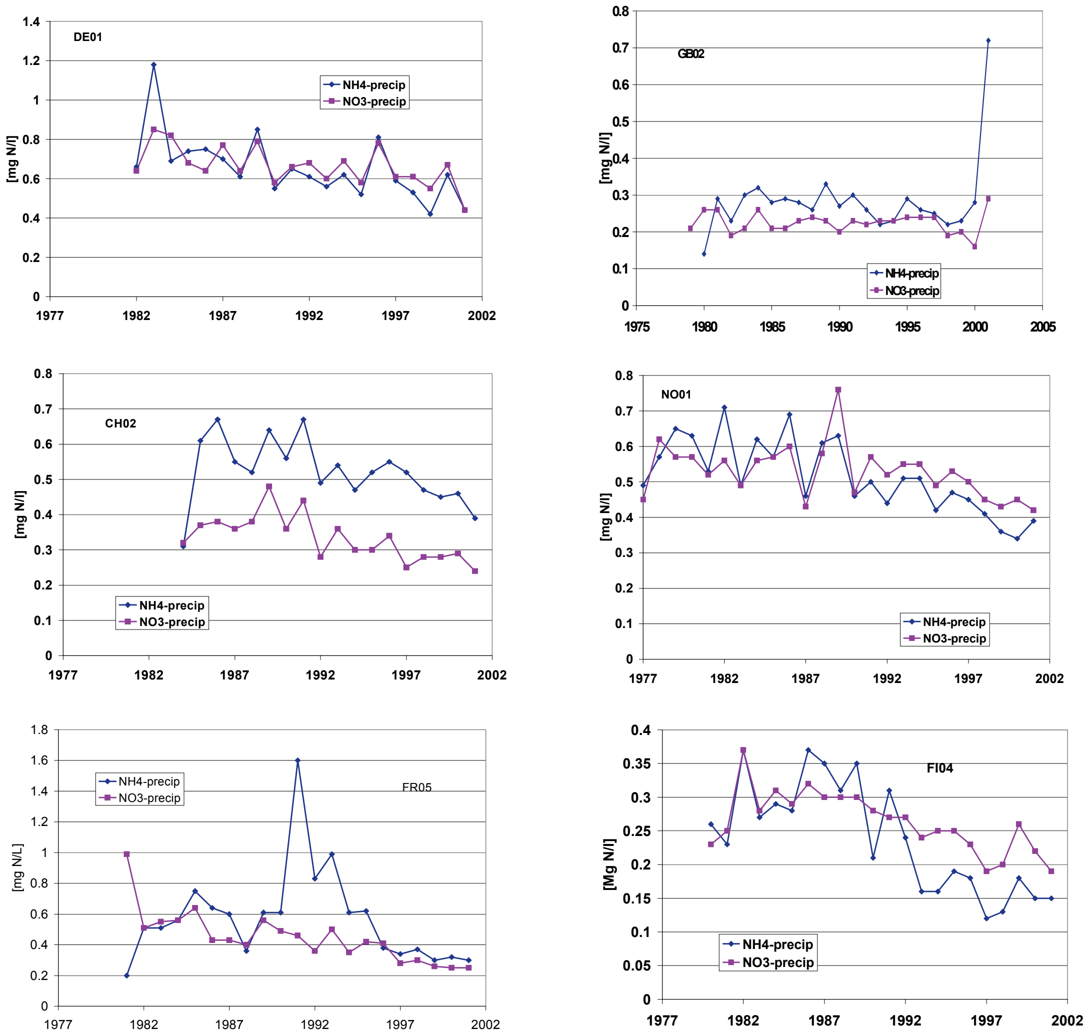
In Norway, Denmark and United Kingdom the data show a 20- 30% decrease in total nitrate. The decrease is approximately the same for total ammonium. The similar decreases of these two compounds may be due to similar decreases in emissions, or possibly an atmospheric-chemical process streamlining the trends even if emission trends are different. Over Europe as a whole, the emission trends for ammonia and nitrogen oxides are similar.

In remote areas, NO_3 concentrations have shown no or a very small decrease. This is an indication that non-linearity plays a role in determining source receptor relation so that while on a European scale the system appears to be linear, there may be changes in the patterns of emission and deposition within the region. Several assumptions have been postulated about the cause of the non-linear processes, see further under chapter 2, sulphur compounds.

3.2.4 Nitrate in precipitation

Concentrations of nitrate in precipitation (Figure 3.14) have generally decreased over the period 1980 - 2000, although the variations between years are large and trends in most cases are not statistically significant. Concentrations of ammonium in precipitation (Figure 3.14) also seem to decrease, almost to the same extent as nitrate, even if the local emissions are not decreasing to the same extent. Over longer distances, however, there is a similar emission trend. This trend is the same as for nitrate and ammonium in air.

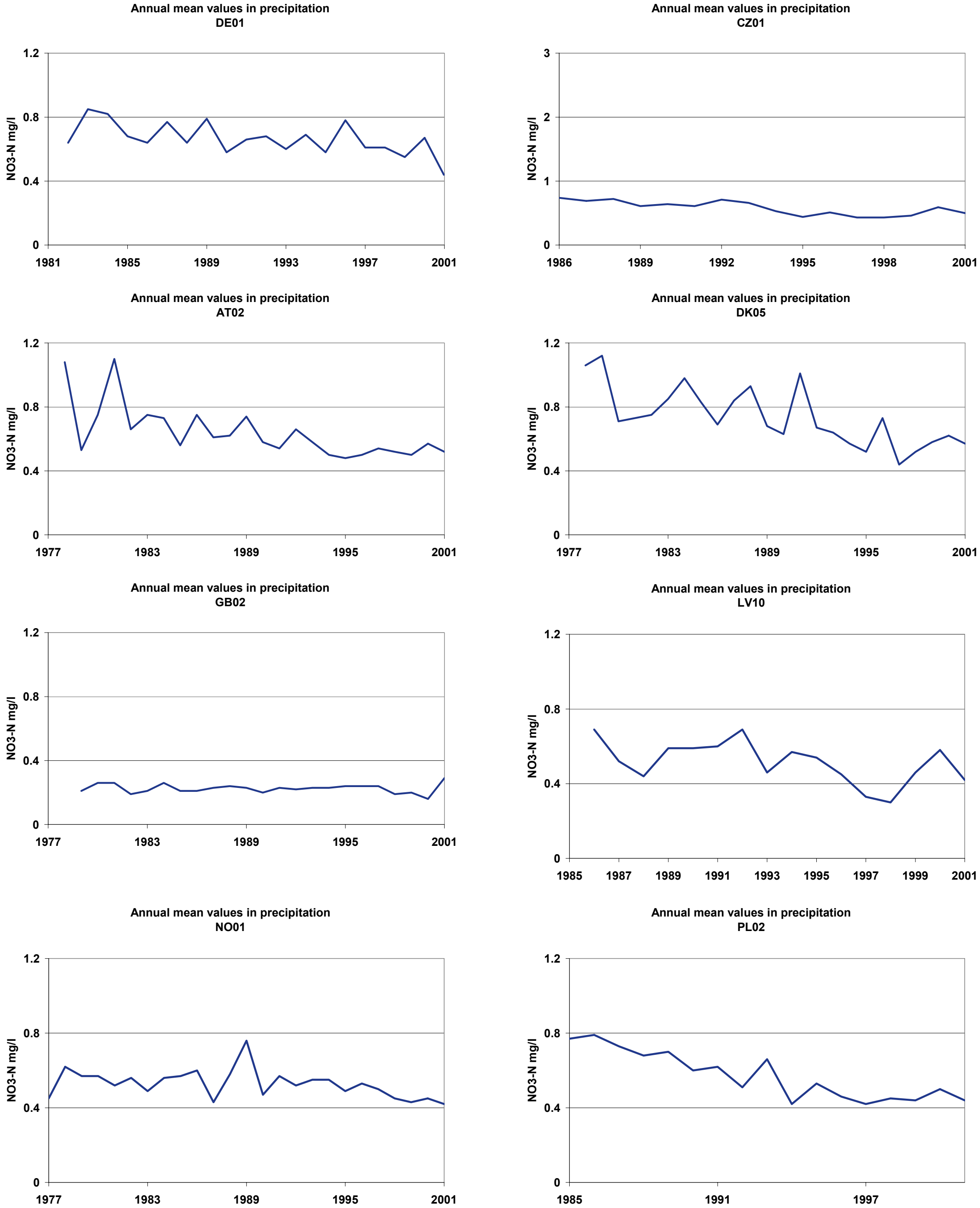
Figure 3.14 Time series for nitrate and ammonium annual average concentrations in precipitation at selected of EMEP sites



3.2.5 Trends in wet deposition of nitrate

Wet deposition of nitrate exhibits roughly the same deacreasing trends as the concentrations of nitrate in precipitation. The interannual variations are however, considerable due to changes in precipitation amount between years. The decreases at German, Austrian, Danish and Latvian sites are around 30%. The largest decreases have taken place in Denmark and Poland, see Figure 3.15.

Figure 3.15 Trends in annual average nitrate concentrations in precipitation at selected EMEP sites.

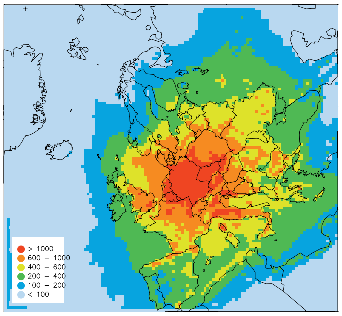


3.2.6 Dry and total deposition of oxidised nitrogen

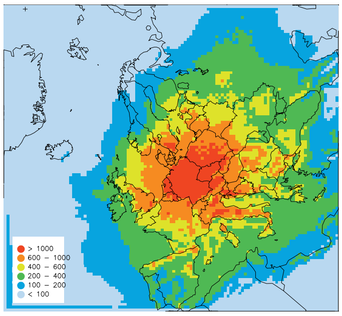
No routine monitoring data are available for dry deposition of nitrogen compounds. Dry and total (wet+dry) oxidised nitrogen deposition estimates over Europe have to be based on model calculations (Figure 3.16).

The calculations show that the maximum of total deposition was observed around 1985 and that subsequently a considerable decrease took place, mainly over Germnay, Poland and the Czech Republic.

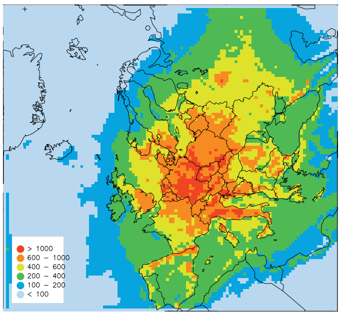
Figure 3.16 Development over time for model-calculated total deposition of oxidised nitrogen over Europe. Unit g/m²/year.



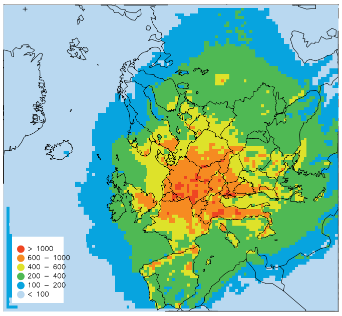
1980



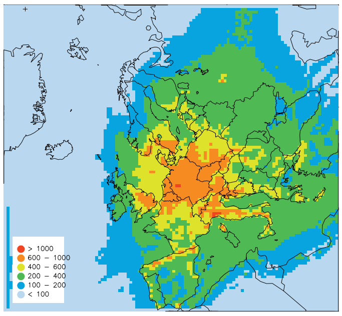
1985



1990



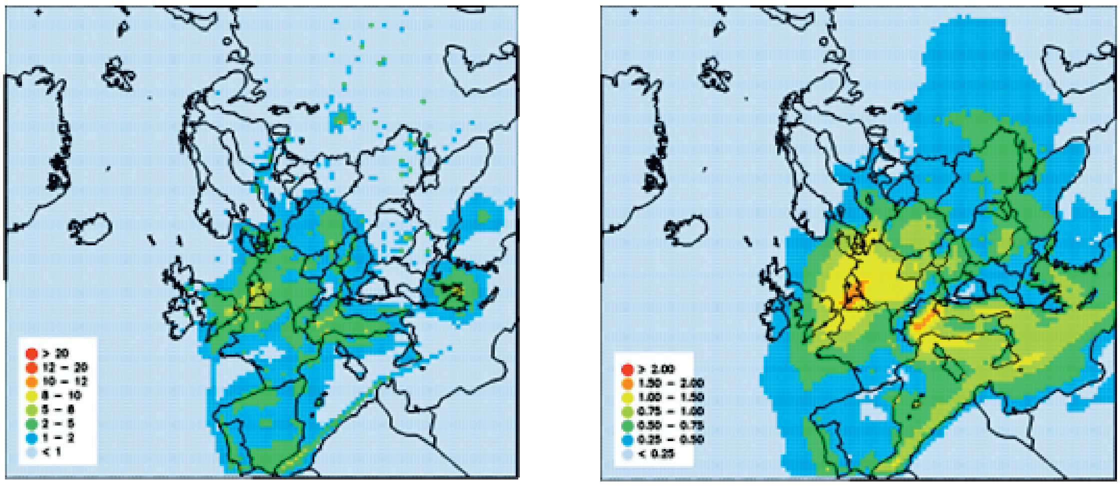
1995



2000

3.3 What has been achieved during 25 years? The need for further reduction of nitrogen oxides pollution.

The time series of NO_2 show that the levels have decreased roughly in proportion to the emission reductions. The levels of nitrates (gaseous and particulate) in air have also been reduced, although to a less extent than the emission reduction. Around 2000 the NO_2 concentrations in rural air were below 10 μg m^{-3} over all parts of Europe.



a) b)

Figure 3.17 Model-calculated annual concentrations of a) NO_2 in air b) NO_3 in air during 2000.

As can be seen from the maps in Figure 3.16 there has been a decrease in nitrogen oxides deposition over Europe since 1990. The achievement is positive, but the deposition of nitrogen oxides around 2000 in large parts of Europe still exceeds the critical loads defined to protect ecosystems from eutrophication (see Figure 3.10). In 2000 74% of the ecosystem area is protected against eutrophication, and towards 2010 the situation is not expected to improve. In some areas there will be an increasing exceedance. There is a consequently a need for continued reduction of nitrogen oxides emissions in order to protect the ecosystems.

3.4 Conclusions for the time series of nitrogen oxides pollution in the environment

- In parallel to the serious sulphur pollution, expanding traffic emissions of nitrogen oxides during the 1980s were observed as a growing threat. The work to reduce these emissions started in the middle of the 1980s, but was not very efficient until in the middle of the 1990s.

- During the period 1980 - 2000 there has been a decrease in nitrogen oxides emissions although the decrease has not been as large as for sulphur. The total decrease in nitrogen oxides emissions is around 25% in the officially reported emission data. When also experts´ estimates for one missing source category is are considered the total decrease is probably closer to 30%.

- The differences between regions are, however, far more significant than for sulphur. Some countries and regions have succeeded to reduce their NO_x emissions with 40-50%. The largest decrease has taken place in the former eastern European countries, and is a result of their thorough economical restructuring. Also Germany and Switzerland have achieved a nearly 50% reduction of the NO_x emissions. The decrease in the main part of western Europe is around 30%. In southern Europe as a whole, the emissions have not changed, and in several Mediterranean countries the NO_x emissions have actually increased.

- The main decrease during 1990 to 2000 has occurred for stationary combustion in power plants, industry and for residential heating, with almost 40% decrease. The decrease in transport emissions has been of the same order of magnitude as for the total NOx, around 25%. A growing concern is for the emissions on international waters due to shipping. These emissions increase in importance (20% of the total emission in 2000) when other emissions are reduced.

- As a result of the different achievements in emission reduction, the trends for nitrogen oxides in air and for nitrate deposition vary considerably. The trend evaluation is further complicated by the fact that there are less long-term monitoring data available than for sulphur. In several countries, the NO_2 trends observed are in line with the national emission reduction. The largest NO_2 decreases are seen at EMEP sites in countries such as Czech Republic, Slovak Republic and Germany, to a large part due to restructuring of the energy and industrial sectors, and to less intensive traffic. Large reductions have also taken place in Switzerland and United Kingdom. Around 30% reductions are seen in many countries including the Nordic, Italy, Netherlands and Switzerland. The introduction of catalysts on cars has been a major cause of decreasing NO_x emissions even if part of the achieved reduction, has been counteracted by increasing traffic.

- As for sulphur, the most oxidised nitrogen compound - nitrate - shows a less pronounced trend. This is most probably due to the fact that reduced sulphur emissions leave a potential for further oxidation in the atmosphere. Long-term monitoring data making trend studies possible are, however, to a large extent lacking. Reductions of 20 - 30% for total nitrate in air are observed at sites in the Nordic countries and United Kingdom. Nitrate in precipitation has decreased in a similar way at most sites, even though inter-annual variations are large.

- Deposition of oxidised nitrogen has decreased due to lower concentrations in air and in precipitation. Together with decreasing deposition of ammonium, the total nitrogen deposition has decreased. The nitrogen deposition is now in many areas approaching the critical loads for nutrients. Areas of exceedance as well as the magnitude of exceedance are decreasing. But, as for sulphur, the work on emission reduction must be continued in order to protect terrestrial and marine ecosystems.

3.5 References

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Data from EMEP emission database and monitoring database www.emep.int