

4. Atmospheric Supply of Nitrogen to the Baltic Sea in 2003

Nitrogen deposition to the Baltic Sea is caused mainly by the emission sources in the HELCOM countries and ship emissions. However, in some sub-basins and catchments especially in the Northern Baltic, emissions from other sources in the EMEP domain have also important contribution to the deposition. Therefore, in this chapter we present the recent emission data for individual HELCOM Parties, ship emissions on the Baltic Sea and all emission sources in the EMEP area of interest. All emission data presented here were published in the EMEP report (Vestreng *et.al.*, 2005).

2.1 Nitrogen emissions

Comparisons of annual emissions of nitrogen oxides, ammonia and total nitrogen (nitrogen oxides + ammonia) from individual HELCOM countries for the years 2002 and 2003, are shown in Table 4.1. These emissions were used for computing nitrogen depositions for the years 2002 and 2003.

Table 4.1. Annual emissions of oxidized nitrogen, ammonia and total nitrogen (nitrogen oxides + ammonia) from individual HELCOM Parties and from all HELCOM sources (sum of individual emissions) in the years 2002 and 2003. Differences between 2003 and 2002 are also shown in percent of 2002 emissions. Units: kt N/yr.

Emitter	Nitrogen oxides			Ammonia			Total nitrogen		
	2002	2003	Diff (%)	2002	2003	Diff (%)	2002	2003	Diff (%)
Denmark	60.9	63.6	4.4	83.2	80.7	-3.0	144.0	144.3	0.2
Estonia	12.2	11.9	-2.5	7.4	6.6	-10.8	19.6	18.5	-5.6
Finland	63.3	66.7	5.4	27.2	27.2	0.0	90.5	93.8	3.6
Germany	456.2	434.6	-4.7	505.6	494.9	-2.1	61.9	929.5	-3.4
Latvia	12.5	11.3	-9.6	9.1	12.4	36.3	21.5	23.6	9.8
Lithuania	15.5	16.1	3.9	42.0	28.0	-33.3	57.5	44.1	-23.3
Poland	245.0	242.3	-1.1	270.1	267.6	-0.9	515.1	509.9	-1.0
Russia	781.0	781.0	0.0	494.1	494.1	0.0	1275.1	1275.1	0.0
Sweden	73.7	62.7	-14.9	45.3	46.1	1.8	118.9	108.8	-8.5
HELCOM	1720.2	1690.0	-1.8	1484.0	1457.6	-1.8	3204.2	3147.7	-1.8

In case of nitrogen oxides emission, out of nine HELCOM countries, reductions between 1.1% and 14.9% can be noticed in five countries from the year 2002 to 2003. The largest relative emission reduction, 14.9%, can be seen in Sweden. In three countries, Denmark, Finland and Lithuania, emissions of nitrogen oxides increased by 4.4%, 5.4% and 3.9%, respectively. In Russia emissions remained on the same level in 2003 as in 2002.

In case of ammonia, compared to 2002, annual emissions in the year 2003 increased in two HELCOM Parties, Latvia and Sweden by 33.3% and 1.8%, respectively. In Denmark, Estonia, Germany, Lithuania and Poland, annual emissions were, 3.0%, 10.8%, 2.1%, 33.3% and 0.9% lower in 2003 than in 2002. Ammonia emissions in Finland and Russia remained on the same level in 2003 as in 2002.

Concerning total nitrogen emissions (sum of nitrogen oxides and ammonia shown in Table 4.1) reduction between 2002 and 2003 can be noticed for five HELCOM countries: Estonia, Germany, Lithuania, Poland and Sweden by 5.6%, 3.4%, 23.3%, 1% and 8.5%, respectively. Increase of annual emissions can be seen in three countries Denmark, Finland and Latvia by 0.2%, 3.6% and 9.8%, respectively. Total nitrogen emissions in Russia remained on the same level in 2003 as in 2002.

Annual emissions of oxidized nitrogen, ammonia and total nitrogen from all HELCOM sources (sum of emissions from nine HELCOM countries) in the years 2002 and 2003 are also presented in Table 4.1. The HELCOM emissions of nitrogen oxides, emissions of ammonia and emissions of total nitrogen decreased by 1.8% from 2002 to 2003.

It should be mentioned here that when EMEP Parties are submitting official nitrogen emissions every year the estimates for previous years can be updated as well. Therefore, for some countries the national emissions used in the model computations for 2002 are slightly different from those presented in the latest EMEP report (Vestreng et al., 2005).

Only a relatively small part of nitrogen emitted from the HELCOM Parties is deposited to the Baltic Sea basin. The percent of annual 2003 emission of total nitrogen from each HELCOM Party, which was deposited to the Baltic Sea in 2003 is shown in Figure 4.1.

The largest part of nitrogen emissions, 12.1% and 11.2% is deposited to the Baltic Sea from Sweden and Denmark, respectively, and lowest, 3.9% and 0.6% from Germany and Russian Federation, respectively.

Spatial distribution of annual 2003 emissions of nitrogen oxides on and around the Baltic Sea is shown in Figure 4.2. Emissions from the international ship traffic on the Baltic Sea, which are described in more detail later in this Chapter, are presented in Figure 4.6. Major local sources of nitrogen oxides are related to large cities around the Baltic Sea and to intensive ship traffic on the sea.

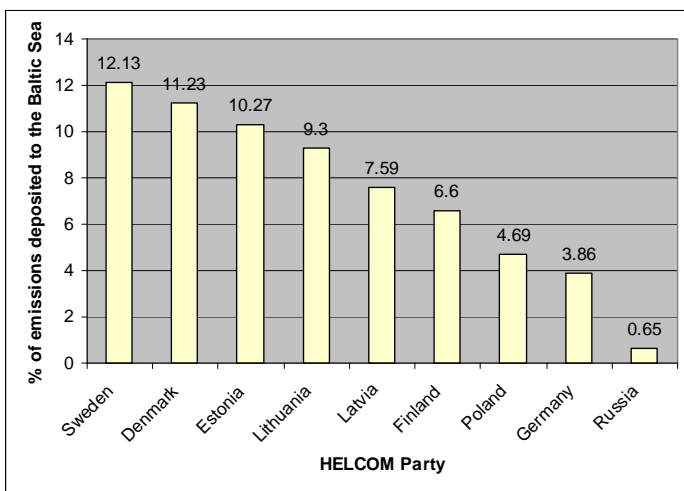


Figure 4.1. Percent of annual emissions of total (oxidized + reduced) nitrogen from the HELCOM Parties deposited to the Baltic Sea basin in 2003.

A map with spatial distribution of annual 2003 ammonia emissions is shown in Figure 4.3. Ammonia emission sources are mostly located in the south and south-west coast, mainly affecting Kattegat and the Belt Sea sub-basin of the Baltic Sea. In this case, there are no emission sources on the sea. A clear south to north gradient of emissions can be noticed in Figure 4.3.

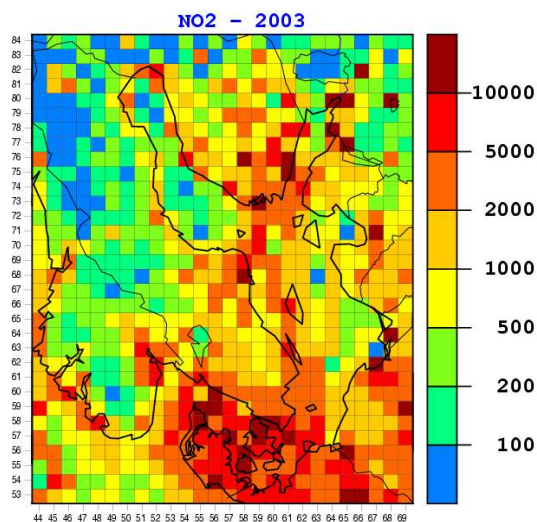


Figure 4.2. Map of annual emission of oxidized nitrogen in the Baltic Sea region in 2003. Units: Mg of NO₂ per year and per 50x50 km grid cell.

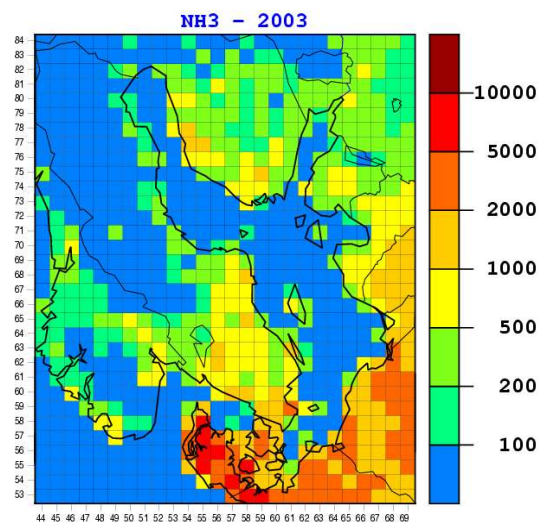


Figure 4.3. Map of annual emission of ammonia in the Baltic Sea region in 2003. Units: Mg of NH₃ per year and per 50x50 km grid cell.

Until 2002, national nitrogen emissions (NO₂ and NH₃) were reported to EMEP in 11 SNAP sectors. SNAP stands for Selected Nomenclature for Air Pollution and the SNAP sectors are defined in the EMEP-CORINAIR Emission Inventory Guidebook. Definitions of these sectors, used in the EMEP model computations are given in the Table 4.1.

Table 4.1. The list of 11 SNAP emissions sectors as specified in the EMEP-CORINAIR Emission Inventory Guidebook.

Sector 1	Combustion in energy and transformation industry
Sector 2	Non-industrial combustion plants
Sector 3	Combustion in manufacturing industry
Sector 4	Production processes
Sector 5	Extraction and distribution of fossil fuels and geothermal energy
Sector 6	Solvent and other product use
Sector 7	Road transport
Sector 8	Other mobile sources and machinery (including ship traffic)
Sector 9	Waste treatment and disposal
Sector 10	Agriculture
Sector 11	Other sources and sinks

Starting from 2002, most of the EMEP Parties have reported annual nitrogen emissions in so called NFR sectors. NFR stands for “Nomenclature for Reporting” and NFR emission sectors are defined in the ECE publication (ECE/EB.AIR.80, ECE 2003).

However, also for 2003 calculations, the EMEP model uses SNAP sectors as basis for e.g. definition of effective emission heights and distribution of emissions over the year. In addition, the distribution of the reported emissions into sectors is still based on SNAP sectors. Thus, we base our further discussion on the SNAP codes, as well.

Annual 2003 nitrogen oxides emissions from the HELCOM Parties split into SNAP sectors are presented in Figure 4.4. For all HELCOM Parties, transport (sectors 7 and 8) and combustion (sectors 1, 2 and 3) are the main sources of nitrogen oxides emissions into the Atmosphere. The transport sectors dominate in six HELCOM countries (Denmark, Finland, Germany, Latvia, Lithuania and Sweden) with the road transport (sector 8) being the major source of nitrogen oxides pollution. In Estonia, Poland and the Russian Federation, sector 1 (Combustion in energy and transformation industry) is the major contributor to emissions, however, road transport (sector 7) is the next on the list also in these three countries.

For the HELCOM Parties, there is not much difference between contributions to annual nitrogen emissions from different emission sectors of nitrogen oxides in 2002 (Bartnicki et al., 2004) and in 2003. Small changes can be noticed in the Russian Federation, where the contribution from sector 4 (Production processes) is slightly reduced, whereas contribution from sector 3 (Combustion in manufacturing industry) slightly increased.

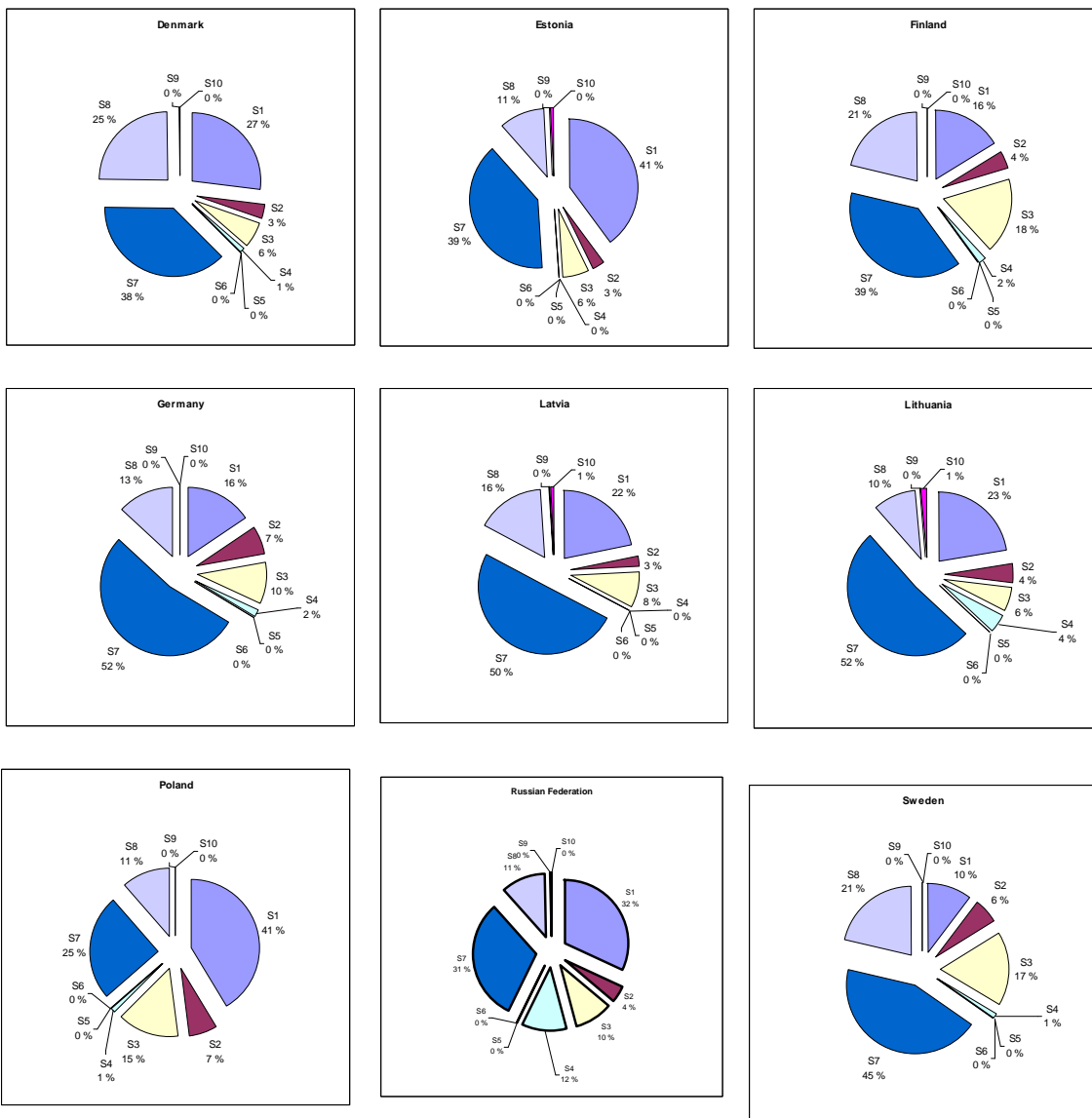


Figure 4.4. Annual 2003 nitrogen oxides emissions from the HELCOM Parties split into the SNAP sectors.

Annual 2003 ammonia emissions from the HELCOM Parties split into the SNAP sectors are presented in Figure 4.5.

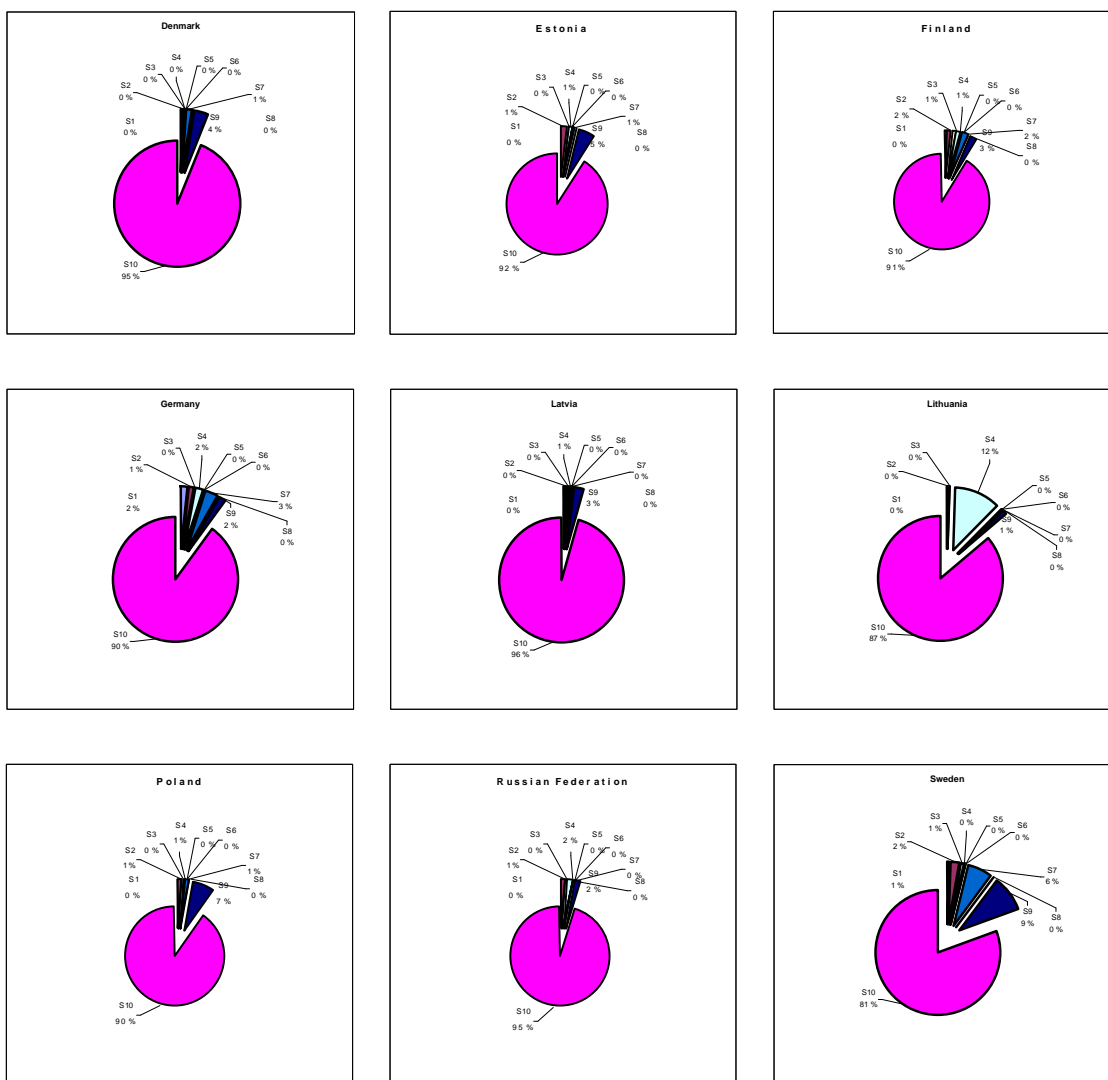


Figure 4.5. Annual 2003 ammonia emissions from the HELCOM Parties split into the SNAP sectors.

For ammonia, emissions from the agriculture (sector10) are much higher than emission from any other sector in all HELCOM countries. Contribution of agricultural emissions to annual total ammonia emissions in 2003 is: 95% for Denmark, 90% for Estonia, 91% for Finland, 90% for Germany, 96% for Latvia, 87% for Lithuania, 90% for Poland, 95% for Russia and 81% for Sweden. Contribution from other sectors to ammonia emission is one order of magnitude lower in all HELCOM countries. The countries with highest non-agricultural emissions are: Lithuania, 12% contribution from sector 4 (Industrial processes) and in Sweden, 9% contribution from sector 9 (Waste treatment and disposal).

No major changes can be noticed in contributions from different sectors to annual ammonia emissions between 2002 and 2003. The largest change could be observed in Estonia and Germany, where contributions of agriculture were reduced from 92% in 2002 to 90% in 2003.

In the previous EMEP calculations, the 1990 nitrogen oxides ship emissions had been used for all years until 2002. Nitrogen oxides emissions from the international ship traffic on the Baltic Sea have been updated for 2003 calculations. They have been increased by 2.5% per year, with 2000 as a reference year. Total annual emissions of nitrogen oxides from the international shipping operation on the Baltic Sea are relatively high, 380 ktonnes as NO_2 compared to annual emissions from the individual HELCOM countries, for the same year.

Map of annual nitrogen oxides emissions from the ship traffic on the Baltic Sea in 1990, used for 2002 calculations presented in this report is shown in Figure 4.6.

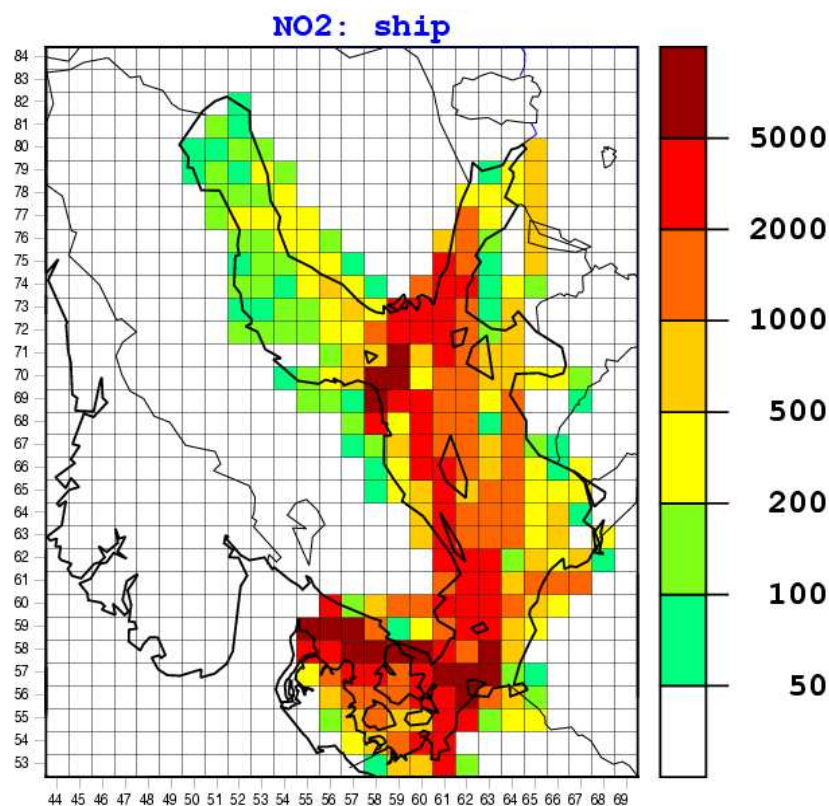


Figure 4.6 Map of annual emissions of nitrogen oxides from the international ship traffic on the Baltic Sea in 2003 used in the EMEP model calculations. Units: tonnes of NO_2 per year and per 50x50 km grid cell.

4.2 Annual deposition of nitrogen

Spatial distributions of annual 2003 deposition fluxes of oxidized, reduced and total (oxidized + reduced) nitrogen, on and around the Baltic Sea, are shown in Figures 4.7, 4.8 and 4.9, respectively. There is a clear south-East to North-West gradient in the deposition fluxes. For all three: oxidized, reduced and total nitrogen, the highest deposition fluxes can be noted in the Belt Sea (BES) sub-basin/catchment and the lowest in the Bothnian Bay (BOB) sub-basin/catchment.

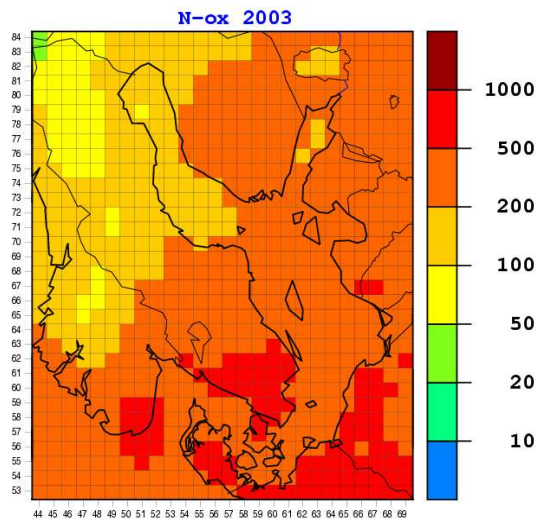


Figure 4.7. Map of annual deposition flux of oxidised nitrogen (dry + wet) in 2003. Units: $\text{mg N m}^{-2} \text{ yr}^{-1}$.

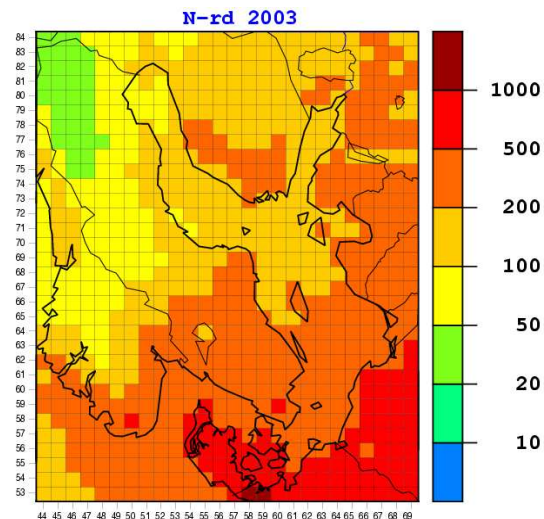


Figure 4.8. Map of annual deposition flux of reduced nitrogen (dry + wet) in 2003. Units: $\text{mg N m}^{-2} \text{ yr}^{-1}$.

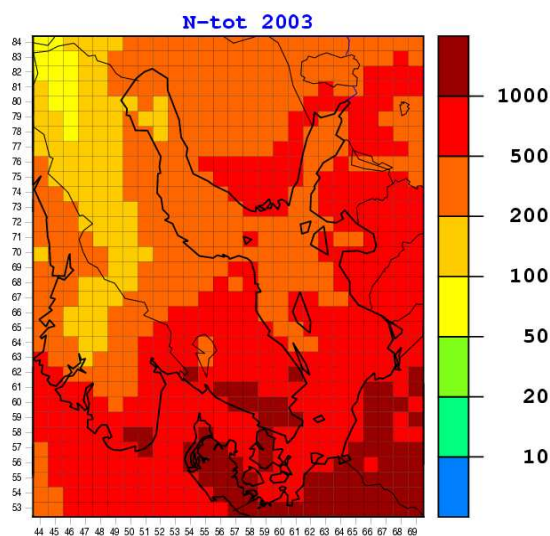


Figure 4.9. Map of annual deposition flux of total (oxidized + reduced) nitrogen in 2003. Units: $\text{mg N m}^{-2} \text{ yr}^{-1}$.

Dry and wet annual 2003 deposition fluxes of total (oxidized and reduced nitrogen), on and around the Baltic Sea, are shown in Figures 4.10 and 4.11, respectively. Wet deposition is much larger than dry deposition over the entire Baltic Sea region. Similar deposition patterns and similar relations between oxidized-reduced, dry-wet depositions have been observed for annual nitrogen depositions in 2002 (Bartnicki et. al., 2004).

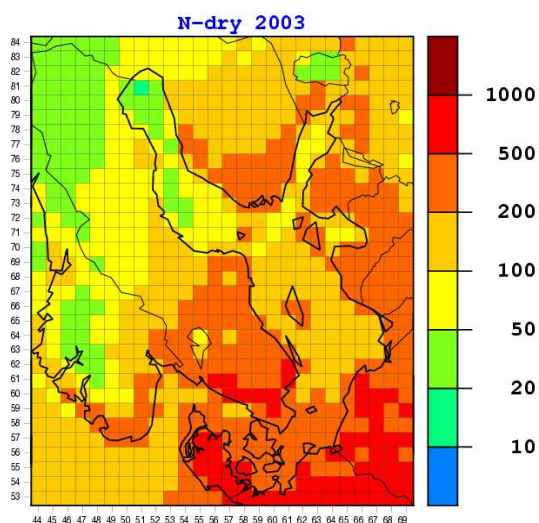


Figure 4.10. Map of annual dry deposition flux of total nitrogen (oxidized + reduced) in 2003. Units: $\text{mg N m}^{-2} \text{yr}^{-1}$.

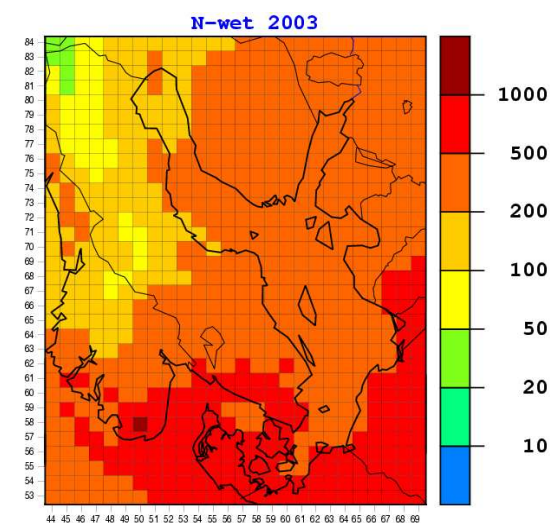


Figure 4.11. Map of annual wet deposition flux of total nitrogen (oxidized + reduced) in 2003. Units: $\text{mg N m}^{-2} \text{yr}^{-1}$.

Annual 2003 dry, wet and total depositions to the Baltic Sea sub-basins, as well as total deposition fluxes of oxidized, reduced and total nitrogen are given in Tables 4.2, 4.3 and 4.4 respectively. Table 4.5 presents annual 2003 nitrogen depositions and deposition fluxes of total nitrogen to all catchments of the Baltic Sea. These tables confirm the domination of wet deposition of nitrogen in all sub-basins and catchments of the Baltic Sea.

Table 4.2. Annual dry, wet, and total depositions (ktonnes year^{-1}) and total deposition fluxes ($\text{mg m}^{-2} \text{year}^{-1}$) of oxidized nitrogen to the Baltic Sea sub-basins in 2003.

Deposition	GUB	GUF	GUR	BAP	BES	KAT	Baltic Sea basin
Dry	7.0	3.0	2.3	25.8	3.2	3.3	44.7
Wet	13.6	4.7	3.3	44.2	5.5	6.2	77.4
Total	20.6	7.7	5.6	70.0	8.7	9.5	122.1
Flux	177	258	302	332	425	406	293

Table 4.3. Annual dry, wet, and total depositions (ktonnes year⁻¹) and total deposition fluxes (mg m⁻² year⁻¹) of reduced nitrogen to the Baltic Sea sub-basins in 2003.

Deposition	GUB	GUF	GUR	BAP	BES	KAT	Baltic Sea basin
<i>Dry</i>	2.2	0.8	0.7	13.7	5.2	3.5	26.2
<i>Wet</i>	11.9	3.9	3.0	38.0	6.3	6.1	69.1
<i>Total</i>	14.1	4.7	3.6	51.7	11.5	9.6	95.3
<i>Flux</i>	121	157	197	246	562	411	229

Table 4.4. Annual dry, wet, and total depositions (ktonnes year⁻¹) and total deposition fluxes (mg m⁻² year⁻¹) of total nitrogen to the Baltic Sea sub-basins in 2003.

Deposition	GUB	GUF	GUR	BAP	BES	KAT	Baltic Sea basin
<i>Dry</i>	9.3	3.9	3.0	39.5	8.4	6.8	70.9
<i>Wet</i>	25.5	8.6	6.3	82.1	11.8	12.2	146.5
<i>Total</i>	34.8	12.4	9.2	121.6	20.3	19.0	217.4
<i>Flux</i>	298	414	499	578	987	817	522

Table 4.5. Annual dry, wet, and total depositions (ktonnes year⁻¹) and total deposition fluxes (mg m⁻² year⁻¹) of total nitrogen to the Baltic Sea catchments in 2003.

Deposition	GUB	GUF	GUR	BAP	BES	KAT	Baltic Sea catchment
<i>Dry</i>	52.5	66.6	33.7	268.9	21.4	36.4	479.5
<i>Wet</i>	105.7	132.2	63.8	396.1	28.5	51.6	777.9
<i>Total</i>	158.2	198.8	97.5	665.1	49.9	88.0	1257.4
<i>Flux</i>	261	442	621	871	1070	812	600

The highest values of the deposition fluxes for kinds of nitrogen deposition can be noticed for the Belt Sea sub-basin and catchment. The lowest values of nitrogen deposition fluxes were calculated for the Gulf of Bothnia sub-basin and catchment. The 2003 nitrogen deposition fluxes calculated for the BES sub-basin and catchment are 2-3 times higher than the deposition fluxes calculated for the GUB sub-basin and catchment.

Comparison of total nitrogen depositions to sub-basins of the Baltic Sea in 2002 and 2003 is shown in Figure 4.12.

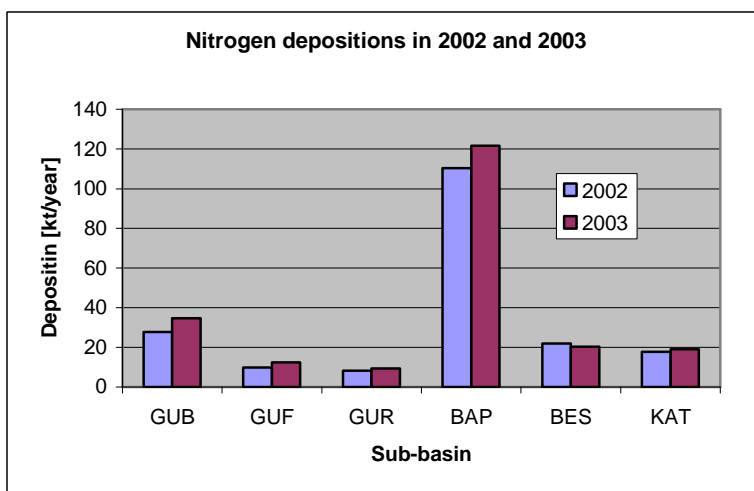


Figure 4.12. Comparison of total nitrogen (oxidized + reduced) depositions to sub-basins of the Baltic Sea in 2002 and in 2003. Units: ktonnes N yr⁻¹.

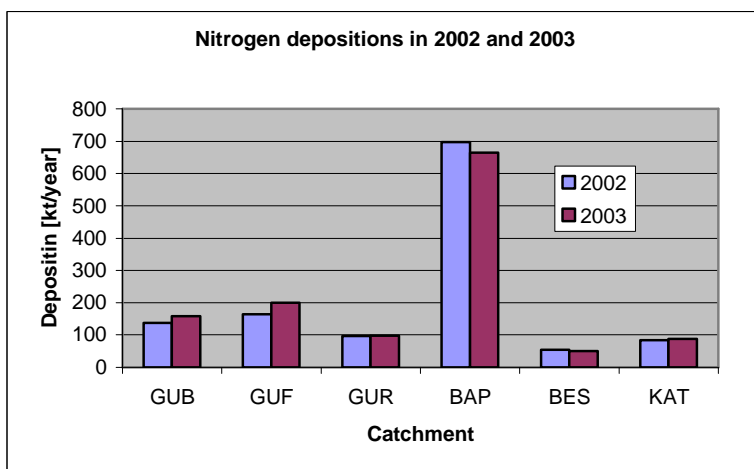
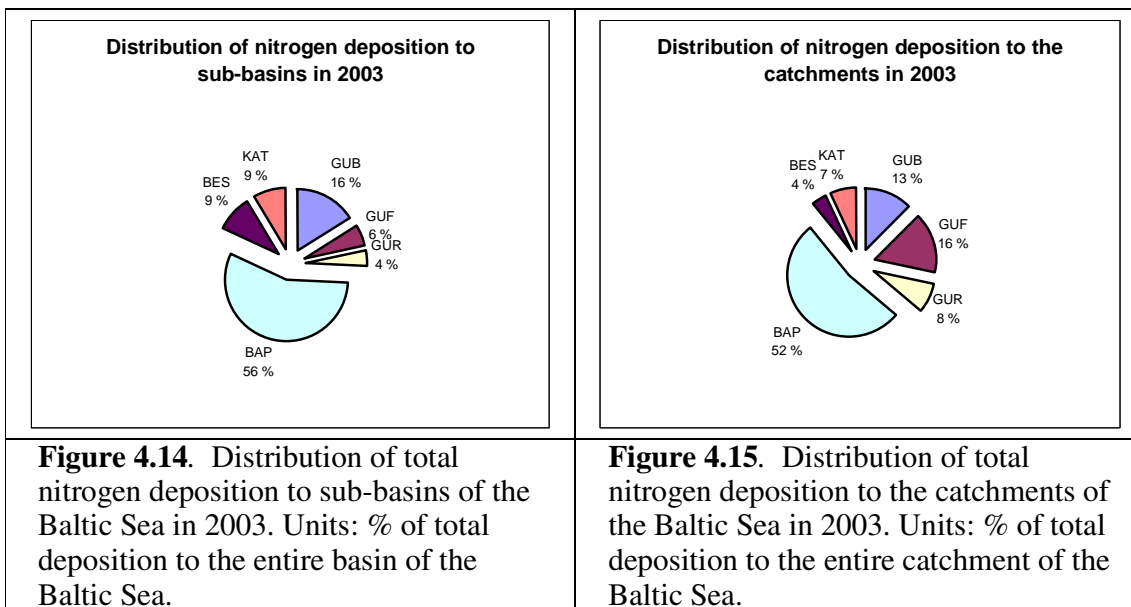


Figure 4.13. Comparison of total nitrogen (oxidized + reduced) depositions to the catchments of the Baltic Sea in 2002 and in 2003. Units: ktonnes N yr⁻¹.

Depositions to GUB, GUF, GUR, BAP and KAT sub-basins are respectively 25%, 25%, 13%, 10% and 7% higher in 2003 than in 2002. Deposition to the Belt Sea sub-basin is 8% lower in 2003 than in 2002. Total nitrogen deposition to the entire basin of the Baltic Sea is 11% higher in 2003 than in 2002.

Comparison of total nitrogen depositions to the catchments of the Baltic Sea in 2002 and 2003 is shown in Figure 4.13. Depositions to GUB, GUF, GUR and KAT catchments are respectively 16%, 22%, 1% and 5% higher in 2003 than in 2002. Depositions to the Baltic Proper and Belt Sea catchments are respectively 5% and 8% lower in 2003 than in 2002. Total nitrogen deposition to the entire basin of the Baltic Sea is 11% higher in 2003 than in 2002 and total nitrogen deposition to the entire catchment of the Baltic Sea is only 2% higher in 2003 than in 2002.

Distributions of nitrogen depositions to sub-basins and catchments of the Baltic Sea in 2003 are shown in Figures 4.14 and 4.15, respectively.



The largest part (56%) of nitrogen was deposited to the Baltic Proper sub-basin in 2003. The next receiver on the list was Gulf of Bothnia (16%). The lowest amount of nitrogen (4%) was deposited to the Gulf of Riga sub-basin.

Also in the case of catchments, the largest part (52%) of nitrogen was deposited to the Baltic Proper sub-basin in 2003, with the Gulf of Finland (16%) being number two on the list. The lowest amount of nitrogen (4%) was deposited to the Belt Sea catchment in 2003.

4.3 Monthly depositions of nitrogen

Monthly 2003 depositions of oxidized, reduced and total nitrogen to the entire Baltic Sea basin and the Baltic Sea catchment are shown in Figures 4.16 and 4.17, respectively.

Deposition patterns for the Baltic Sea basin and Baltic Sea catchment are similar. Characteristic are local minima for all types of deposition in February and March, and local maxima of the depositions in May and November. Deposition of oxidized nitrogen to the entire Baltic Sea basin is larger than the deposition of reduced nitrogen for all months except for April and September, when the deposition of reduced nitrogen is slightly larger or on the same level as the deposition of oxidized nitrogen.

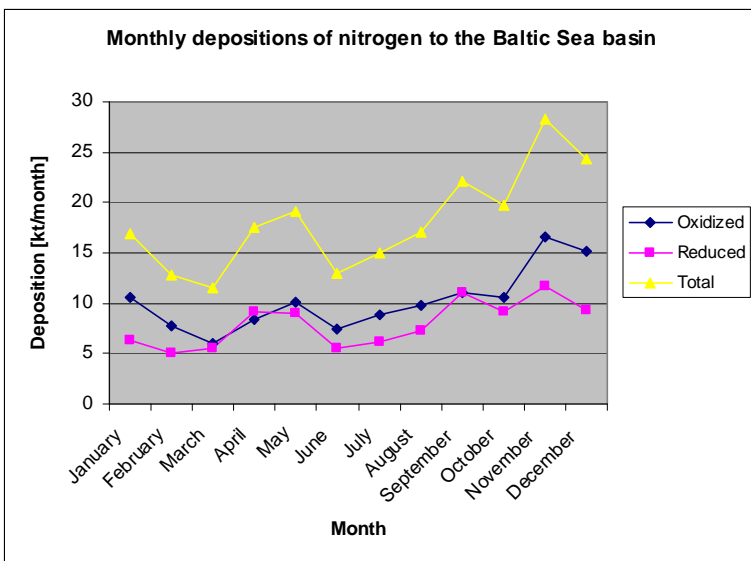


Figure 4.16. Monthly depositions of oxidized, reduced and total (oxidized +reduced) nitrogen to the entire Baltic Sea basin in 2003. Units: ktonnes N month⁻¹.

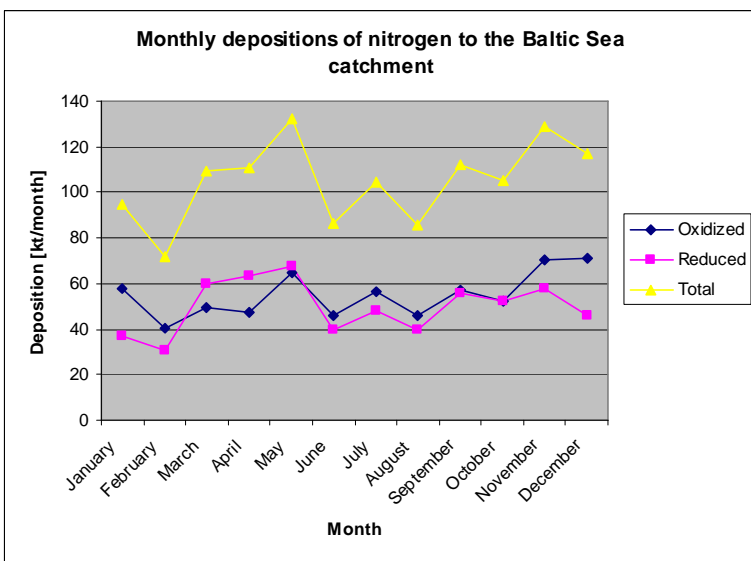


Figure 4.17. Monthly depositions of oxidized, reduced and total (oxidized +reduced) nitrogen to the entire Baltic Sea catchment in 2003. Units: ktonnes N month⁻¹.

For the Baltic Sea catchment, deposition of reduced nitrogen is larger than the deposition of oxidized nitrogen in March, April and May when intensive agricultural activities take place over the land, and is on the same level in September and October. Absolute maximum of monthly oxidized, reduced and total nitrogen deposition to the Baltic Sea basin with 17, 12 and 28 kt N, respectively, was calculated for November 2003. Absolute maximum of monthly oxidized, reduced and total nitrogen deposition to the Baltic Sea catchment was calculated for May (65 kt N of reduced nitrogen deposition and 132 kt N of total nitrogen deposition) and December (71 kt N of reduced deposition).

Comparisons of monthly depositions of total nitrogen in 2002 and 2003 to the entire Baltic Sea basin and to the entire Baltic Sea catchment are shown in Figures 4.18 and 4.19, respectively.

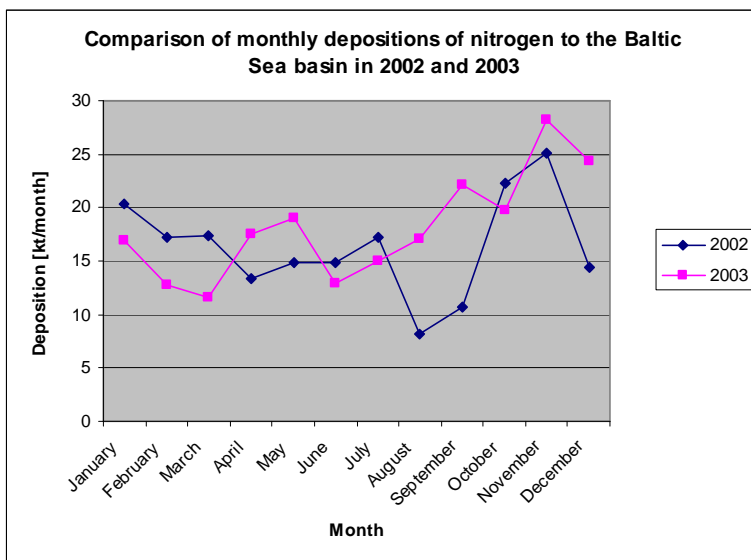


Figure 4.18. Comparison of monthly depositions of total (oxidized +reduced) nitrogen to the entire Baltic Sea basin in 2002 and 2003. Units: ktonnes N month⁻¹.

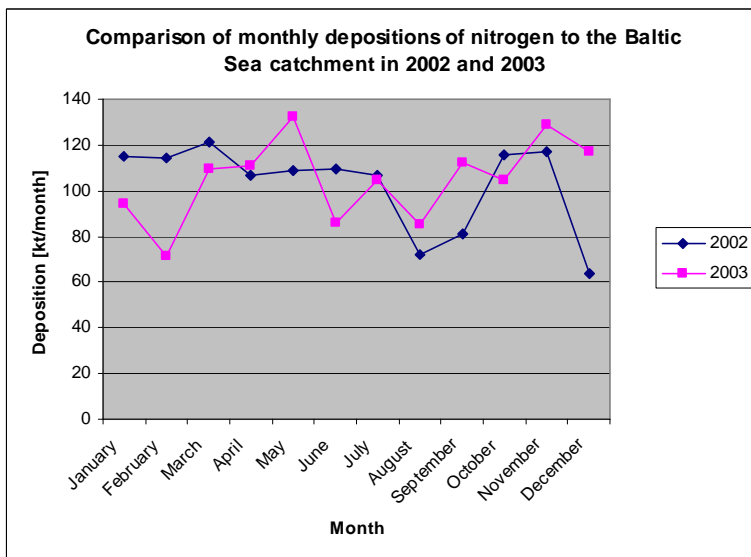


Figure 4.19. Monthly depositions of and total (oxidized +reduced) nitrogen to the entire Baltic Sea catchment in 2002 and 2003. Units: ktonnes N month⁻¹.

Monthly deposition patterns of total nitrogen to the Baltic Sea basin in 2002 and 2003 are similar with more pronounced differences in August, September and December, when 2002 depositions are significantly lower than 2003 depositions.

Also monthly deposition patterns of total nitrogen to the Baltic Sea catchment in 2002 and 2003 are similar. However in this case, the largest differences can be noticed in February and December. In February 2003 depositions are significantly lower than 2002 depositions and in December it is quite opposite with 2002 depositions being significantly lower than 2003 depositions.

4.4 Source allocation of nitrogen deposition

Not only local emission sources of nitrogen (HELCOM Parties, Ship traffic) but also distant emission sources (e.g. UK and France) contribute to nitrogen deposition into the Baltic Sea. Comparison of contributions of nitrogen emissions from the HELCOM Parties to oxidized and reduced nitrogen deposition into the Baltic Sea Basin in the years 1997 and 2000 was given in the previous report (Bartnicki *et al.* 2003).

In the present report we present the source allocation budget for the year 2003. Ten countries (sources) with highest contributions of nitrogen emissions to annual deposition of oxidized, reduced and total nitrogen into the Baltic Sea basin in the year 2003 are shown in Figure 4.20.

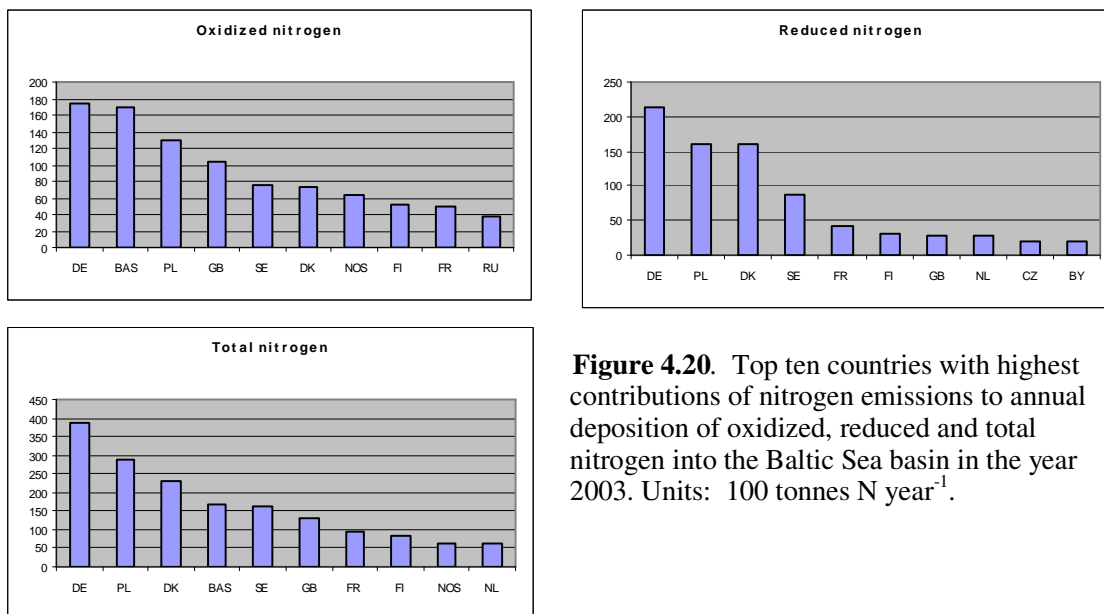


Figure 4.20. Top ten countries with highest contributions of nitrogen emissions to annual deposition of oxidized, reduced and total nitrogen into the Baltic Sea basin in the year 2003. Units: 100 tonnes N year⁻¹.

For oxidized, reduced and total nitrogen deposition, Germany is definitely the largest contributor in 2003. In case of oxidized nitrogen deposition, contribution of emissions

from the international ship traffic on the Baltic Sea is the second largest and it is only 3% lower than the German contribution. Polish sources are next (third position) on the list. Contribution of distant sources, like UK, and French emissions, is also significant. It is interesting to notice that the contribution of emissions from the international ship traffic over the North Sea is also large – number seven on the list.

In case of reduced nitrogen deposition, contribution of emissions from Germany dominates, followed by relatively large contributions of Poland, Denmark and slightly lower from Sweden. However, a distant country, such as France is number five on the list. Two other sources outside HELCOM Parties: United Kingdom and Netherlands are also among ten major contributors to the deposition.

Concerning total (oxidized + reduced) nitrogen deposition to the Baltic Sea in 2003, Germany, Poland and Denmark are three major contributors. Nitrogen emissions from the ship traffic on the Baltic Sea are the next most important contributor to nitrogen deposition. Four distant sources from outside the HELCOM Parties can be found among ten major contributors: United Kingdom, ship emissions from the North Sea, France and Netherlands.

Complete source-receptor matrices for oxidized, reduced and total (oxidized + reduced) nitrogen deposition to sub-basins of the Baltic Sea in the year 2003 are presented in Appendix C, in Tables C1, C2 and C3, respectively. Annual nitrogen emissions from all EMEP Contracting Parties (including HELCOM Parties and emissions from the international ship traffic on the European seas) are the emission sources in the first column of the source- matrices. Six sub-basins of the Baltic Sea and the entire Baltic Sea basin are the receptors listed in the first row of the source-receptor matrices.

Source-receptor matrices for oxidized, reduced and total (oxidized + reduced) nitrogen deposition to the catchments of the Baltic Sea in the year 2003 are presented in Appendix C, in Tables C4, C5 and C6, respectively.

Comparison of 2000 (Bartnicki et al., 2004) and 2003 source-receptor matrices indicates that four major contributors to oxidized nitrogen deposition (Germany, Baltic Sea, Poland, United Kingdom), as well as four major contributors to reduced nitrogen deposition (Germany, Baltic Sea, Poland, United Kingdom) are the same in 2000 and 2003. Small changes can be observed for the remaining contributors. Sweden, Denmark and Finland, contribute more to oxidized deposition in 2003 than in 2000. Also, France, Finland and the United Kingdom contribute more to reduced nitrogen deposition in 2003 than in 2000.

First three most important contributors to the deposition of total (oxidized + reduced) nitrogen to sub-basins and catchments of the Baltic Sea are shown in Tables 4.6 and 4.7, respectively.

Table 4.6. Three main contributors to annual total (oxidized + reduced) nitrogen deposition to the sub-basins of the Baltic Sea in the year 2003. Units: kt N yr⁻¹ region⁻¹.

GUB	GUF	GUR	BAP	BES	KAT
SE – 4.10	RU – 1.43	PL – 1.02	DE – 22.46	DE – 6.94	DK – 5.83
DE – 4.05	FI – 1.39	DE – 1.01	PL – 21.37	DK – 5.34	DE – 3.20
PL – 3.90	BAS – 1.03	BAS – 0.87	BAS – 10.45	GB – 1.73	GB – 2.04

Table 4.7. Three main contributors to annual total (oxidized + reduced) nitrogen deposition to the catchments of the Baltic Sea in the year 2003. Units: kt N yr⁻¹ region⁻¹.

GUB	GUF	GUR	BAP	BES	KAT
FI – 22.5	RU – 45.2	BY – 12.0	PL – 218	DE – 18.0	DK – 19.6
SE – 17.9	FI – 20.7	PL – 10.8	DE – 102	DK – 11.7	DE – 12.5
DE – 15.7	DE – 14.8	RU – 9.6	CZ – 31	GB – 4.2	GB – 10.3

Germany, Poland, Denmark, Russian Federation, Sweden, the United Kingdom and emissions from the Baltic Sea ship traffic are the main contributors to total nitrogen deposition to different sub-basins of the Baltic Sea. Finland, Russian Federation, Belarus, Poland, Germany, Denmark, Sweden, Czech Republic and the United Kingdom are the main contributors to total nitrogen deposition to different catchments of the Baltic Sea.

Some changes on the list of contributors to each sub-basin and catchment can be noticed in the year 2003 compared to 2000. However the major contributors to nitrogen deposition in these two years remain the same.

4.5 Comparison of model results with measurements

The EMEP Unified Eulerian model system has undergone a major overhaul the last years, where the previous EMEP models (Lagrangian as well as Eulerian) have been merged and re-written in order to produce the Unified EMEP Eulerian model. The model has been carefully documented in EMEP Status Report 1/2003, Part I and verified against measurement data at EMEP stations for ten different years (1980, 1985, 1990, 1995-2001) in EMEP Status Report 1/2003. The model code has been revised (EMEP Status report 1/2004) since then, but the changes are small and affect the result for the nitrogen species to a small extent. Verification of the model results for 2003 against measurements for all EMEP stations has been presented in EMEP status report 1/2005. Most of the HELCOM stations are also EMEP stations, thus the focus here is on a subset of what is already presented.

The agreement between predicted by the model and observed air and precipitation data

heavily depends upon an adequate description of emissions. This includes both reasonable estimates of national totals, gridded (source sector) data and temporal distribution of emissions. The emissions are undergoing a continuous process of review and revision. Last year for the first time the general annual review of emission inventory quality indicators (timeliness, completeness, internal consistency) was extended to include a series of more detailed comparability analysis. In addition, the spatial distribution of the emissions used as input to the Unified EMEP model has been thoroughly revised and a new methodology for allocating emissions by sector has been proposed and tested. These changes were already introduced last year, and the methodology used for gridding of the emissions is the same this year.

In this section we will concentrate on the model performance for nitrogen compounds at the HELCOM sites. Note that the agreement between model results and observations depends not only on the model performance and the adequacy of emissions, but also on the quality and representativeness of the measurement sites. Thus, the following discussion on model *underestimation* and *overestimation* simply imply that the calculated values are lower or higher than the observations, and does not refer to model deficiency only.

4.5.1 Air concentrations

Measurements of particulate ammonium and nitrate are available only from four sites, LV10, LV16, PL04, RU16 (Last year: DE09, DK05, DK08 and DK20). Therefore, it is difficult to conclude anything on the model performance for these compounds based on the HELCOM measurements. However, observations for the sum of ammonia plus ammonium and total nitrate (nitric acid plus particulate nitrate) have been reported by a 10 HELCOM sites this year. In Figure 4.20 we present monthly time series for model versus observations for sum of ammonia and ammonium. The overall agreement between measurement and model is good, and it is especially encouraging that the model manages to reproduce the seasonal cycle. The model shows, however, a tendency to overestimate winter concentrations and underestimate summer concentrations. In (Fagerli et al., 2003) it was suggested that the overestimation in winter is caused by an overestimation of ammonium aerosol. The underestimation of summer concentrations compared to measurements is probably due to problems in the modeling of the spatially variable ammonia gas in combination with influence of local sources on measurements.

In Figure 4.21 we present monthly time-series for the sum of nitric acid and nitrate in air for 10 HELCOM stations for 2003. The observed seasonal variation of total nitrate in air is well reproduced by the model. However, the model predicts somewhat higher nitrate concentrations in air than measurements, especially in winter. This may be caused by too high conversion of nitric acid to nitrate in the cold periods. Another possible explanation is an overestimation of the conversion of NO_2 to HNO_3 .

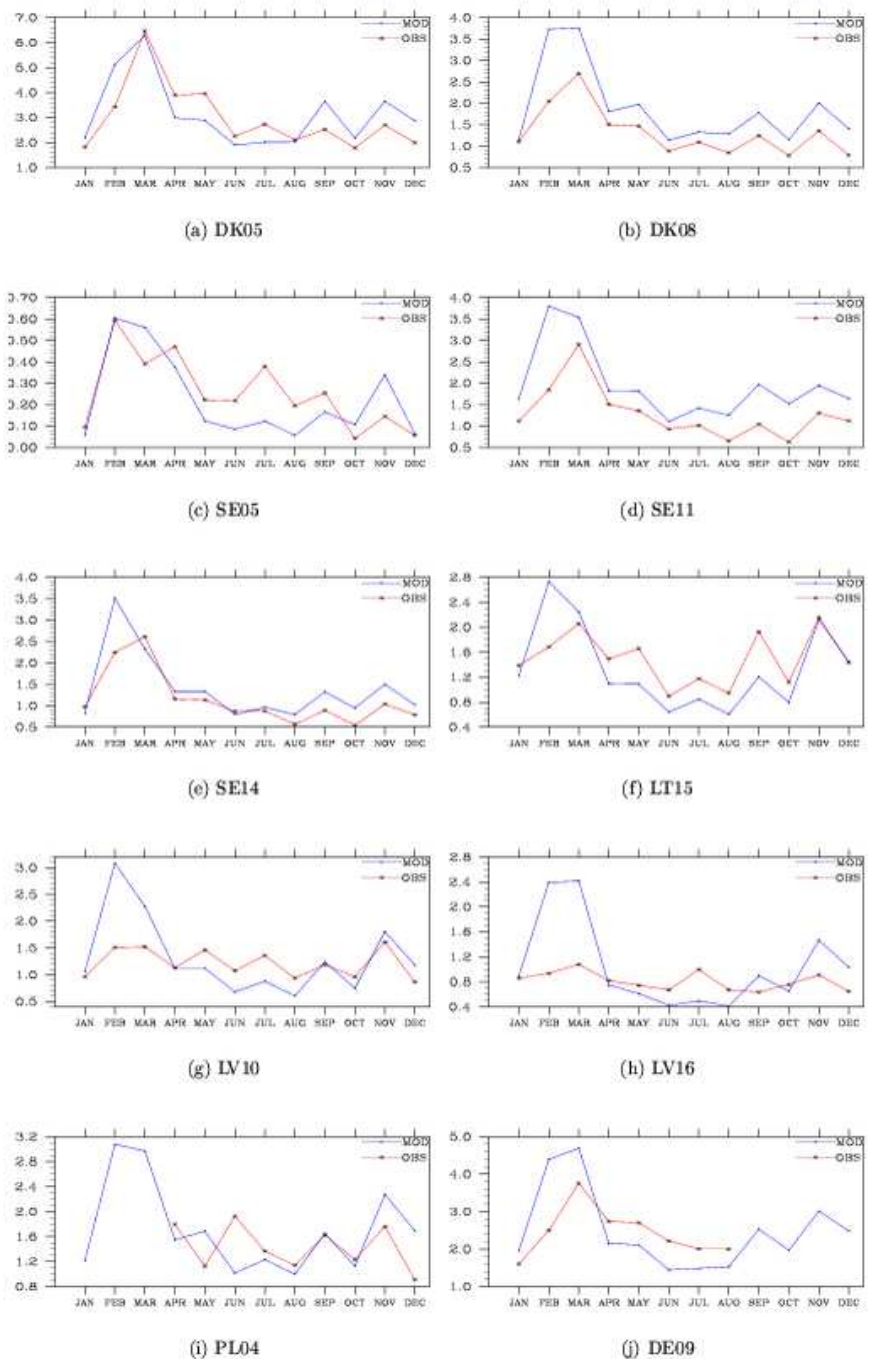
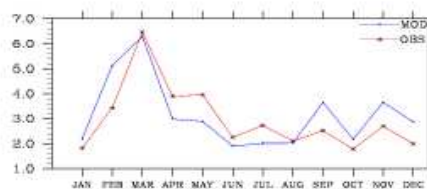


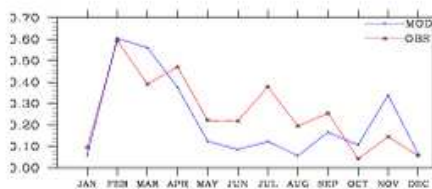
Figure 4.20. Monthly time-series for modelled versus measured concentrations of ammonia plus ammonium in air in 2003. Units: mg N m^{-3} .



(a) DK05



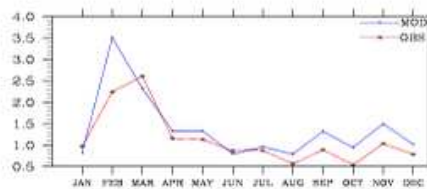
(b) DK08



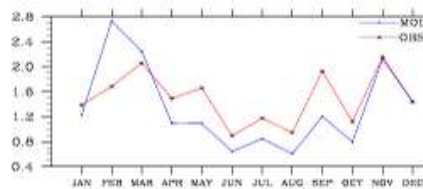
(c) SE05



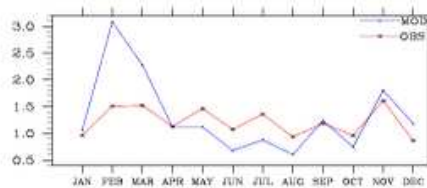
(d) SE11



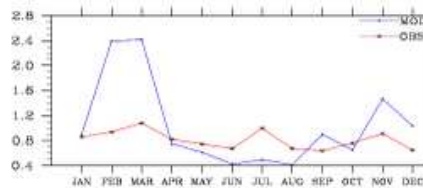
(e) SE14



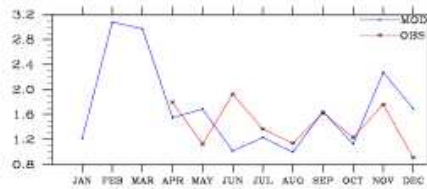
(f) LT15



(g) LV10



(h) LV16



(i) PL04



(j) DE09

Figure 4.20. Monthly time-series for modelled versus measured concentrations of ammonia plus ammonium in air in 2003. Units: mg N m^{-3} .

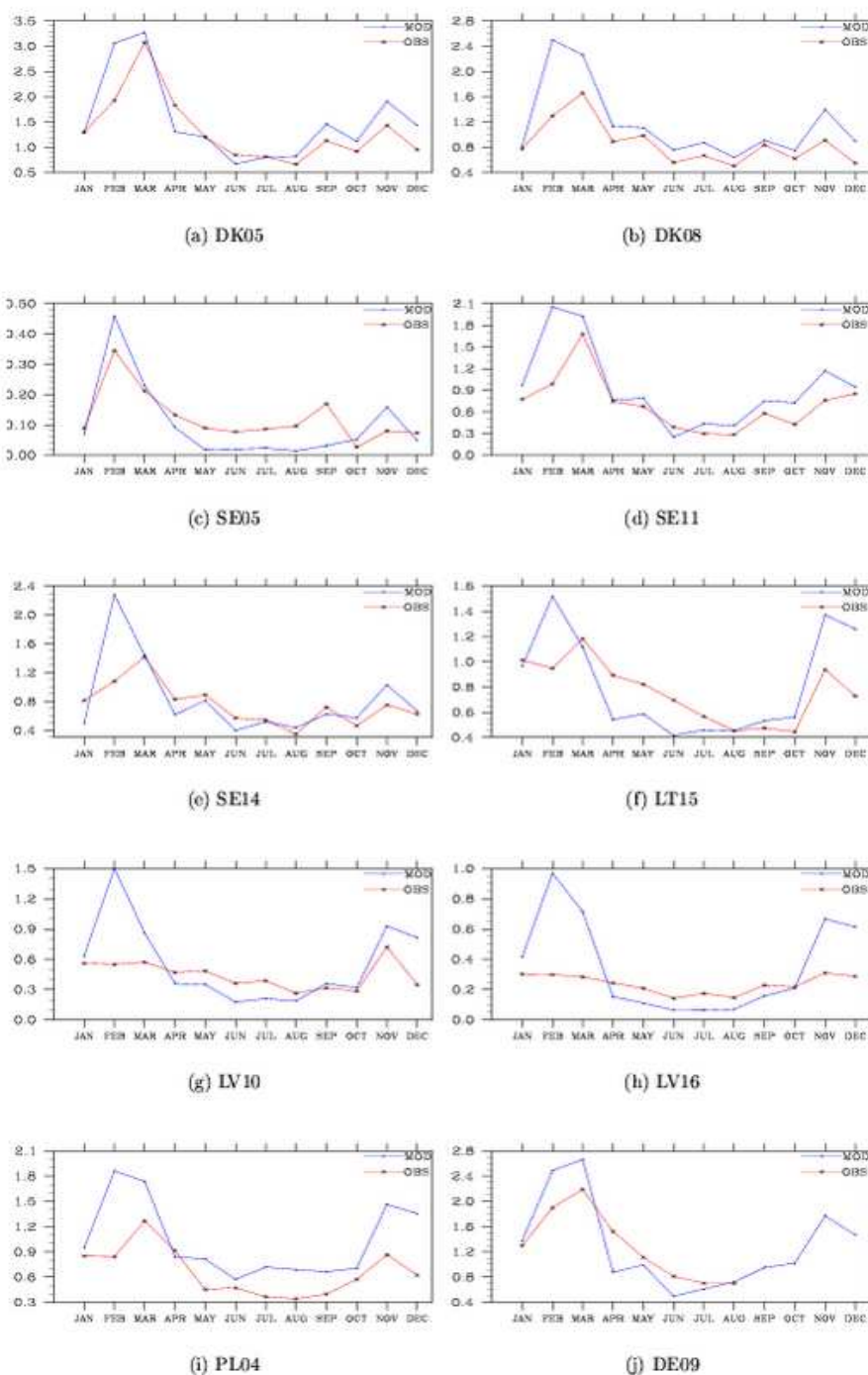


Figure 4.21. Monthly time-series for modelled versus measured concentrations of nitric acid plus ammonium nitrate in air in 2003. Units: $\mu\text{g N m}^{-3}$.

4.5.2 Concentrations in precipitation

The correlation between model and measurements for concentrations in precipitation and wet depositions depends to a large extent on the modeled precipitation field. However, the precipitation field pattern is very patchy (e.g. influenced by local topographic effects), and the regional scale EMEP model is unable to resolve this sub grid scale distribution. A typical problem arises with small scale showers. In reality precipitation is high in a small area of a given grid, but a large fraction of the grid should remain dry. Within the model, however, this precipitation is averaged out to cover the whole grid at a lower intensity. Thus, even though average precipitation amounts may be simulated well, the model experiences precipitation more often, but in lower amounts, than occur in reality.

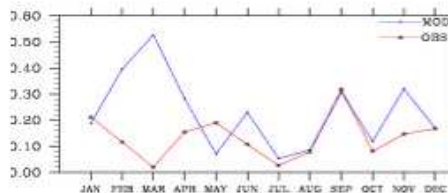
For these reasons, it is clear that the comparisons between model and measurements for components in precipitation are expected to be worse than those for air concentrations.

In Figures 4.22 and 4.23 we compare modeled and measured monthly concentrations of oxidized and reduced nitrogen in precipitation. For the majority of the stations, the modeled and measured concentrations agree well. However, a more thorough analysis of results at all EMEP stations indicates that concentrations of ammonium and nitrate in precipitation are somewhat underestimated. Further work is needed in order to fully understand the reason for the discrepancy between modeled and measured nitrate and ammonium concentrations in precipitation.

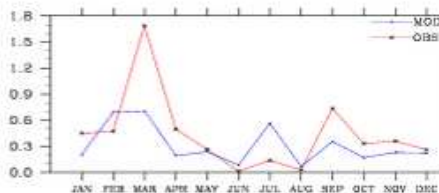
4.5.3 Concluding remarks

In general, the comparison between model and measurements for concentrations of nitrogen compounds is good and comparable to the model performance for the EMEP sites. Thus, the model provides a reliable tool in order to assess the nitrogen supply to the Baltic Sea. Moreover, the results from 2003 are quantitatively the same as in 2002.

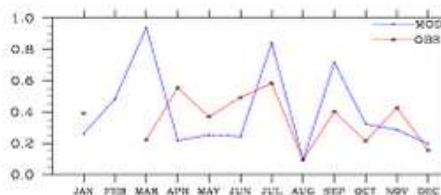
It should be noted, however, that in order to make a proper evaluation of model performance, monthly measurements are not satisfactory. For example, it happens that measurements are contaminated or that a measurement site is closed down for a day or two during a month. When comparing the model and the measurement data, the comparison should be done only for days when both modeled and measured data are available. In addition, daily data is needed in order to examine e.g. how the model performs during specific meteorological situations. Thus, to a large extent we rely on the evaluation of the Unified EMEP model against daily measurements from the total EMEP network when drawing conclusions on the model performance for the HELCOM sites.



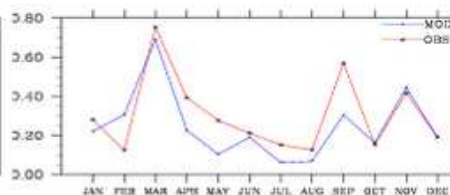
(a) EE09



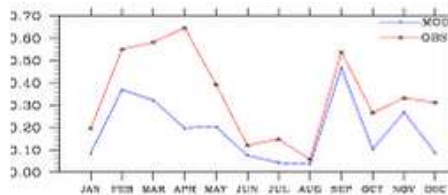
(b) EE11



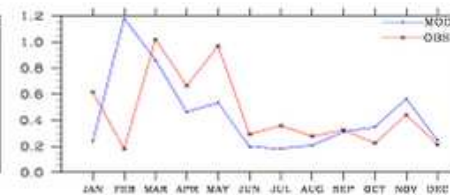
(c) FI09



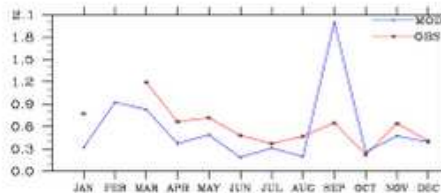
(d) FI17



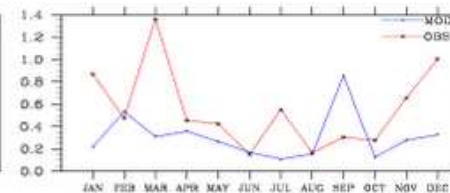
(e) FI53



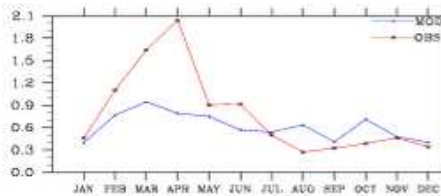
(f) LT15



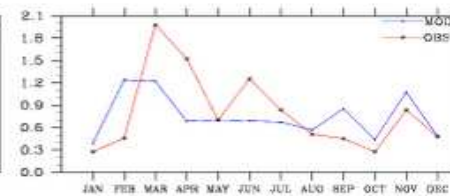
(g) IV 10



(h) LV16



(i) DE09



(j) DK05

Figure 4.22. Monthly time-series for modelled versus measured concentrations of ammonium in precipitation in 2003. Units: $\mu\text{g N l}^{-1}$.

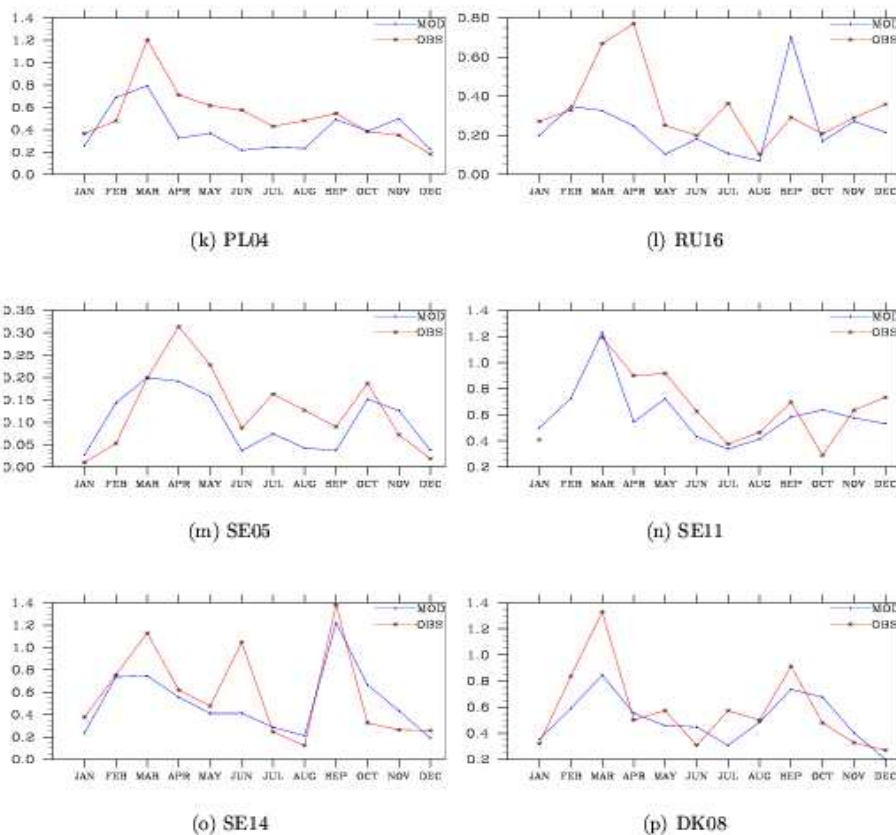
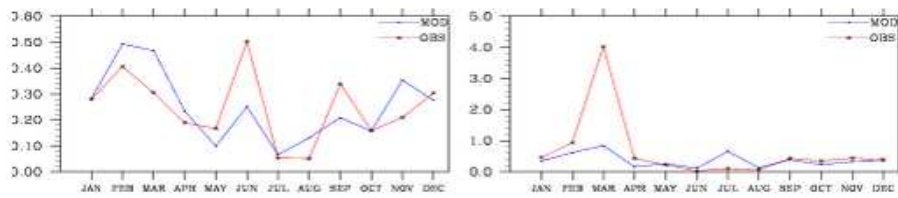
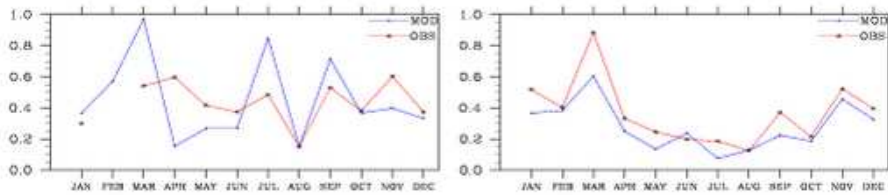


Figure 4.22 (cont.). Monthly time-series for modelled versus measured concentrations of ammonium in precipitation in 2003. Units: $\mu\text{g N l}^{-1}$.



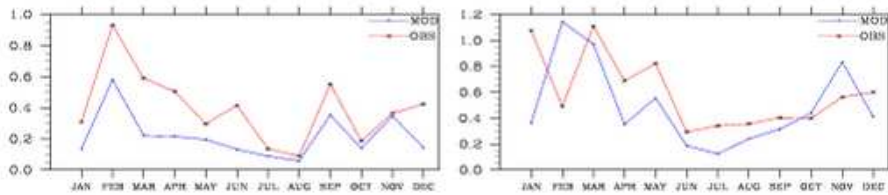
(a) EE09

(b) EE11



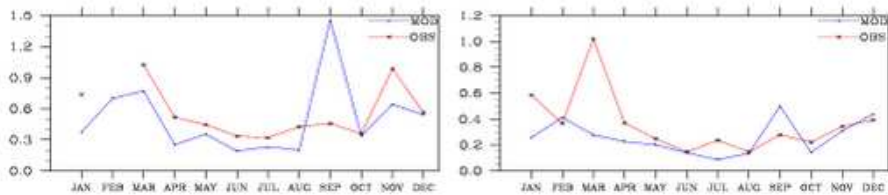
(c) FI09

(d) FI17



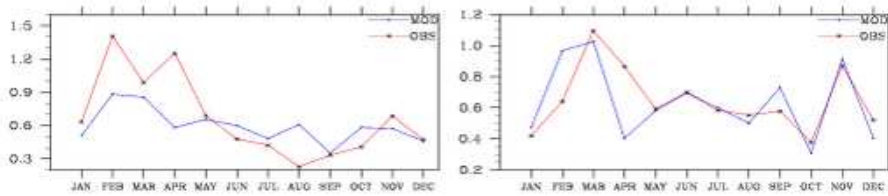
(e) FI53

(f) LT15



(g) IV10

(h) LV16



(i) DE09

(j) DK05

Figure 4.23. Monthly time-series for modelled versus measured concentrations of oxidized nitrogen in precipitation in 2003. Units: $\mu\text{g N l}^{-1}$.

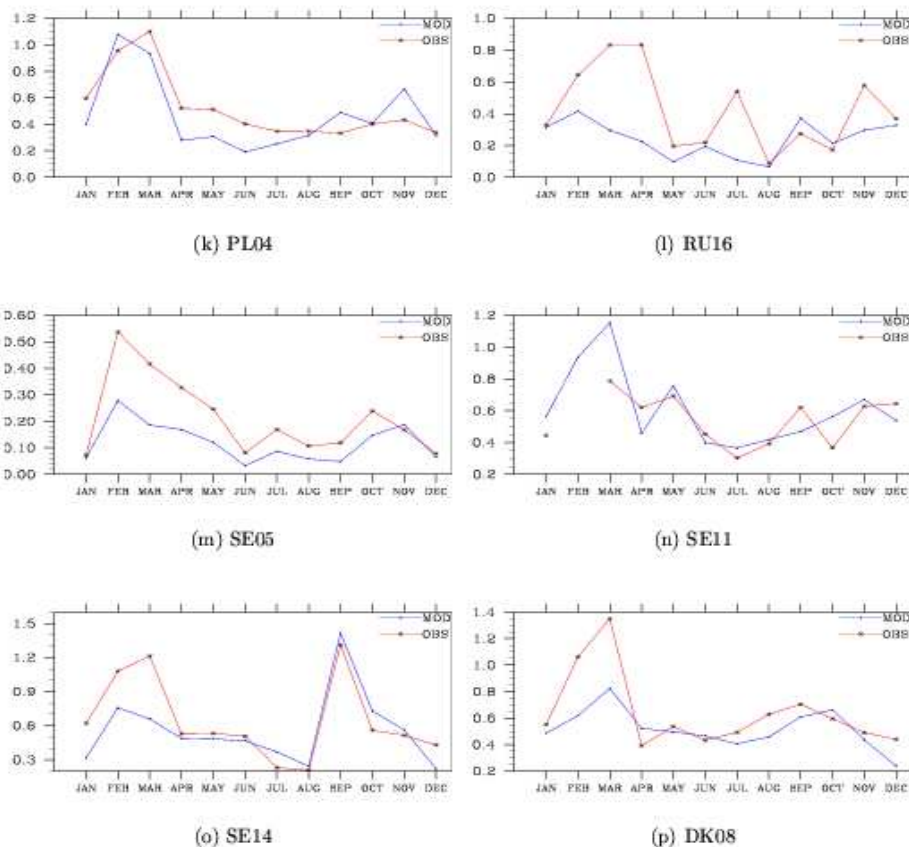


Figure 4.23 (cont.). Monthly time-series for modelled versus measured concentrations of oxidized nitrogen in precipitation in 2003. Units: $\mu\text{g N l}^{-1}$.