Eutrophication Series

Atmospheric Nitrogen in the OSPAR Convention Area and Agreed International Reduction Measures

OSPAR Commission
2005

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l'Espagne.

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Executive Summary

Shipping is the largest single emission source for NO_2 in the OSPAR Convention area. This is the conclusion to which the Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) comes in its report, commissioned by the German Federal Environment Agency, on "Atmospheric Nitrogen in the OSPAR Convention Area for the period 1990 – 2001". The essential parts of that report are included in chapter 2 of the present study.

By identifying the main sources and contributors to airborne emissions of nitrogen, and their deposition to OSPAR Convention waters, the EMEP report forms an important part of the OSPAR assessment of how the effectiveness of agreed international (reduction) measures can contribute to the objective of the OSPAR Eutrophication Strategy, by 2010, to achieve and maintain a healthy marine environment where eutrophication does not occur.

The present study highlights that, so far, airborne inputs of nitrogen to the OSPAR Convention waters have not sufficiently been taken into account in the assessment of the eutrophication status of OSPAR maritime area. Although the data on emissions from shipping available for the EMEP report was limited (mainly from 1990), they at least indicate that nitrogen emissions, and their deposition, to OSPAR Convention waters appear to be of a non-negligible magnitude and should be taken into account in future eutrophication assessments under the OSPAR Common Procedure. This would, however, require improving the emission data from the shipping sector which are far from being satisfactory. For deposition data, EMEP has adapted its modelling tool to OSPAR needs and therefore can make available high quality data for assessment.

The present study outlines activities in the European Union and other international forums relating to nitrogen emissions with relevance for the OSPAR Eutrophication Strategy. Whereas a number of regulatory measures are in place to support the reduction of nitrogen emissions, one recommendation is that OSPAR should seek to improve data collection, also through co-operation with other forums, in particular EMEP and the European Union, for the preparation of a comprehensive, integrated assessment to identify sources, sectors, pathways, inputs, concentrations and effects of nitrogen releases to the OSPAR Convention waters.

Récapitulatif

Le Programme coopératif de surveillance continue et d'évaluation de la transmission des polluants atmosphériques à longue distance en Europe (EMEP) parvient, dans son rapport, à la conclusion que la navigation est la plus importante source d'émission de NO_2 dans la zone de la Convention OSPAR. Il s'agit d'un rapport sur «l'azote atmosphérique dans la zone de la Convention OSPAR entre 1990 et 2001», mandaté par l'Agence fédérale allemande pour l'environnement, et dont les points principaux sont repris dans le chapitre deux de la présente étude.

Le rapport de l'EMEP détermine les principales sources et contributeurs d'émissions aéroportées et leurs retombées dans les eaux de la Convention OSPAR. Il constitue donc une partie importante de l'évaluation d'OSPAR sur la manière dont l'efficacité des mesures (de réduction) internationales convenues contribue à l'objectif de la stratégie sur l'eutrophisation d'OSPAR, à savoir parvenir d'ici 2010 à une milieu marin sain exempt d'eutrophisation.

La présente étude met en évidence que, jusqu'à présent, on ne tient pas assez compte des apports aéroportés d'azote dans les eaux de la Convention OSPAR lors de l'évaluation de l'état d'eutrophisation de la zone maritime OSPAR. Bien que les données sur les émissions provenant de la navigation, utilisées dans le rapport de l'EMEP, soient limitées (portant essentiellement sur 1990), elles indiquent tout au moins que les émissions d'azote et leurs retombées dans les eaux de la Convention OSPAR semblent être d'une importance non négligeable et qu'il conviendra d'en tenir compte dans les évaluations futures de l'eutrophisation dans le cadre de la Procédure commune d'OSPAR. Il sera cependant nécessaire d'améliorer les données sur les émissions provenant de la navigation qui sont loin d'être satisfaisantes. L'EMEP a adapté son outil de modélisation aux besoins d'OSPAR, pour les données sur les retombées. Il est donc en mesure de fournir des données de très bonne qualité pour l'évaluation.

La présente étude définit les activités de l'Union européenne et d'autres instances internationales relatives aux émissions d'azote qui sont pertinentes à la Stratégie sur l'eutrophisation d'OSPAR. Bien qu'un certain nombre de mesures réglementaires soient en place afin de permettre la réduction des émissions d'azote, il est recommandé à OSPAR de s'efforcer d'améliorer le recueil des données, également en coopération avec d'autres instances, en particulier l'EMEP et l'Union européenne, afin de préparer une évaluation exhaustive et intégrée pour déterminer les sources, secteurs, voies, apports, teneurs et effets des rejets d'azote dans les eaux de la Convention OSPAR.

Acknowledgements

The part of the report elaborated by EMEP (mainly Chapter 2 including figures and related tables) has been initiated, supported and financed by the German Federal Environmental Agency (UBA) in the framework of the Oslo-Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention). The authors are indebted to the scientific team at MSC-W for providing the results included in this report and especially to Heiko Klein for his help with the Internet related tasks, Vigdis Vestreng for the emission data and Per Helmer Skaali for his help with many technical matters. We are grateful to Kevin Barrett, who has provided measurement data for OSPAR coastal monitoring stations, to Dornford Rugg from OSPAR Secretariat for definitions of the main OSPAR Regions and to Heike Herata and Uli Claussen from UBA for their cooperation and help concerning this report.

Chapter 3 on the agreed international reduction measures for nitrogen emissions has been elaborated by the German Federal Environmental Agency (thanks to all colleagues involved) assisted by Jeannette Plokker from RIZA/NL.

Summary

A gap in knowledge has been recognised with regard to the role of atmospheric emissions and deposition of nitrogen in the OSPAR maritime area. It is the objective of the 2003 OSPAR Eutrophication Strategy (reference number: 2003-21) to achieve, by the year 2010, a healthy marine environment in which (anthropogenic) eutrophication does no longer occur. To this end, Contracting Parties are committed to implement any international or national measures, as adopted by them jointly or individually, for the reduction of nutrients in discharges and emissions.

To this end, the 2003 OSPAR Strategy for a Joint Assessment and Monitoring Programme (JAMP, reference number: 2003-22), requires an assessment of how the effectiveness of agreed international (reduction) measures can contribute to achieving the 2010 objective of the OSPAR Eutrophication Strategy.

To support this assessment, work on a report on atmospheric emissions and deposition of nitrogen in the OSPAR Convention area and agreed international reduction measures was launched in 2002. One main part of the report was prepared by OSPAR in cooperation with the Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP). EMEP authored the report "Atmospheric Nitrogen in the OSPAR Convention Area for the period 1990 – 2001" (OSPAR publication no. 217/2004). An extract of this EMEP report is included as chapter 2 of the present overview report. The whole EMEP report is available on the EMEP website (www.emep.int) and the OSPAR website (www.ospar.org).

The extracts of the EMEP report presented here comprise the results of estimates of atmospheric emissions of nitrogen as well as calculations of their deposition to the OSPAR Convention waters for the period 1990 – 2001, including information on:

- Annual emissions of nitrogen oxides and ammonia from OSPAR Contracting Parties and selected large outside contributors to nitrogen deposition to the OSPAR maritime area;
- Modelled annual deposition of nitrogen to the main OSPAR regions with an emphasis on the Greater North Sea;
- Comparison of model results and measurements from coastal monitoring stations within OSPAR;
- Source-receptor matrices (countries to regions) for the same area, and;
- Contributions of selected emission sectors to nitrogen deposition in the Convention area.

Nitrogen Emissions

Emission inventories from the countries participating in EMEP (including OSPAR Contracting Parties) and three selected countries (Italy, Poland and the Russian Federation) with the largest contribution to nitrogen deposition to the OSPAR Convention area are presented for the period 1990 – 2001. For most OSPAR Contracting Parties, a reduction of nitrogen oxides emissions has been reported for this period. Amongst these countries, the United Kingdom, Germany and France were the largest emitters of NO_x. Annual emissions of nitrogen oxides decreased by 30 % from 1990 to 2001 for all countries considered. During the same period a decrease of ammonia emissions in the order of 20 % was observed.

International ship traffic on the OSPAR Convention waters is the largest single source of NO_2 emissions in the area of interest. Unfortunately, the latest official data on these emissions available to EMEP are for 1990 only. It is very important to update ship emissions for further calculations of the related deposition with the EMEP model.

A ship emissions quantification study was conducted by Entec UK Limited on behalf of the European Commission in 2002 based on ship movement data for the year 2000. The resulting data were shared with EMEP. However, there are ongoing discussions between EMEP and Entec about methodological aspects. The results of the study suggest that ship NO_x emissions increased by more than 40 % from 1990 to 2000, and that by 2020 ships will emit more NO_x than all EU land-based sources combined. This emission inventory is currently being refined in the context of a new study of the European Community (EC), which also considers the cost-effectiveness of various NO_x abatement technologies for shipping. Data of this EC study are not included in the present overview report because of the above-mentioned ongoing discussions on methodological aspects.

Nitrogen Deposition

The annual nitrogen deposition in the entire OSPAR Convention maritime area (Figure 12) was calculated for the years 1990, 1995, 1996, 1997, 1998, 1999, 2000 and 2001. Nitrogen deposition reached a clear

maximum in the year 1996 and was then decreasing until 1999. From 1999 to 2001, deposition of oxidized and total nitrogen was slightly increasing, while deposition of reduced nitrogen was slightly going down.

For both oxidized and reduced nitrogen, a clear gradient of the modelled deposition towards the open sea can be observed with maxima of deposition in the OSPAR Region II (Greater North Sea) for the years 1990 and 2001 (Figures 6-9).

The modelled deposition of oxidized nitrogen (maximum 610 mg N m^{-2} in 2001) was higher than the modelled deposition of reduced nitrogen (maximum 530 mg N m^{-2} in 2001). From this observation EMEP concludes that nitrogen emitted from mobile sources (shipping included) contributed more to deposition than nitrogen emitted mainly from sources related to agriculture (Figures 7 and 10).

The annual modelled deposition of reduced nitrogen in 2001 was slightly higher than in 1990 in OSPAR Region II (Greater North Sea) (1 %) and in OSPAR Region III (Celtic Seas) (6 %). In the three remaining OSPAR regions it was lower by 30 %, 11 % and 15 % for Arctic Waters (OSPAR Region I), the Bay of Biscay (OSPAR Region IV) and the Wider Atlantic (OSPAR Region V), respectively (Table 4).

The annual modelled deposition of oxidized nitrogen in all sub-regions of the Greater North Sea, except sub-regions 2 and 4, were lower in 2001 than in 1990 by 2 % to 30 %. Deposition of oxidized nitrogen in sub-regions 6 and 13 remained at the same level in 2001 and in 1990 (Table 6 and Figure 22).

For 8 of the 13 sub-regions of the Greater North Sea, the annual modelled deposition of reduced nitrogen in 2001 was higher than in 1990. For some of the sub-regions, the deposition increase is significant, amounting, for example, to 30 % and 22 % for sub-regions 2 and 9, respectively. A decrease in nitrogen deposition in 2001 compared to 1990 of 22% and 20% can be observed for sub-regions 9 and 12 of the Greater North Sea, respectively (Table 7 and Figure 23).

Comparison of Deposition Measurements with Modelling Results

A comparison of computed and measured nitrogen deposition at the OSPAR coastal monitoring stations for 1990, 1995, 1996, 1997, 1998, 1999, and 2000 is described in the present report. Measured and computed wet annual deposition of oxidized, reduced and total nitrogen were compared for the years 1990, 1995, 1996, 1997, 1998, 1999, 2000 and 2001 for the stations located in the main OSPAR regions and in the sub-regions of OSPAR Region II (Greater North Sea). For the majority of the stations, the modelled and measured concentrations concur well.

Source-receptor Interrelations

Emission sources located in the United Kingdom are the main contributors to modelled oxidized nitrogen deposition in OSPAR Regions I (Arctic Waters), II (Greater North Sea) and III (Celtic Seas) with 47, 103 and 20 kt N a^{-1}, respectively. For OSPAR Regions IV (Bay of Biscay) and V (Wider Atlantic), international ship traffic on the Atlantic Ocean is the main source, contributing 34 and 96 kt N a^{-1}, respectively, to reduced nitrogen deposition (Table 9 and Figure 32).

Emission sources located in France were the largest contributors to modelled reduced nitrogen deposition in Regions II (Greater North Sea), IV (Bay of Biscay) and V (Wider Atlantic) with 60, 26 and 21 kt N a^{-1}, respectively. The United Kingdom and Germany were the largest contributors to reduced nitrogen deposition in OSPAR Region I (Arctic Waters) with 12 kt N a^{-1}, whereas Ireland was the largest contributor to OSPAR Region III (Celtic Seas) with 22 kt N a^{-1} (Table 10 and Figure 33).

The most important contributor to modelled total nitrogen deposition in OSPAR Regions I (Arctic Waters), II (Greater North Sea) and III (Celtic Seas) was the United Kingdom with 58, 158 and 40 kt N a^{-1}, respectively, whereas the main contributor to deposition in Regions IV (Bay of Biscay) and V (Wider Atlantic) was international ship traffic on the Atlantic Ocean with 96 and 169 kt N a^{-1}, respectively (Table 11 and Figure 34).

Contribution of Selected Sectors to Nitrogen Deposition

Both for OSPAR Region II (Greater North Sea) and its sub-regions, two sectors were the major contributors to modelled oxidized nitrogen deposition: road transport, and other mobile sources and machinery. The latter includes international ship traffic on all European Seas (including OSPAR Convention waters; Tables 12 and 21, and Figures 38 and 44).

Concerning modelled reduced nitrogen deposition in all regions and sub-regions of the OSPAR Convention area, agriculture was the largest contributor to the deposition (Tables 13 and 25, and Figures 36 and 48).

Estimation of the Overall Nitrogen Input to the Greater North Sea

The recent EMEP report can also be used to compare figures on direct and riverine nitrogen inputs with atmospheric nitrogen inputs. For the Greater North Sea, Table 1 presents results for selected years from 1990 to 2001. In this period, riverine and direct nitrogen inputs varied from 700,000 to 1,100,000 t Total N/y (based on data submitted by Contracting Parties under the OSPAR Comprehensive Study on Riverine Inputs and Direct Discharges (RID), reference number: 1998-5). For the same period, airborne nitrogen input amounted to 470,000 – 560,000 t Total N/y (EMEP, see also tables 5-8). The portion of atmospheric nitrogen inputs in the total nitrogen input varied from 29 to 43 %. These results clearly show that atmospheric nitrogen input cannot be neglected for large parts of the OSPAR maritime area, in particular the Greater North Sea, and should therefore be included in future assessments of nitrogen inputs to, and the eutrophication status of, the OSPAR Convention area.

Table 0: Riverine, direct and atmospheric nitrogen input to the Greater North Sea [kt N/y]

Year	Direct	Riverine	Riverine and Direct	Atmospheric	Total	Portion of atmospheric N
1990	85	720	805	524	1,329	39 %
1995	63	1,100	1,163	483	1,646	29 %
1996	57	687	744	562	1,306	43 %
1997	58	659	717	513	1,230	42 %
1998	55	894	949	523	1,472	36 %
1999	55	893	948	469	1,417	33 %
2000	61	875	936	550	1,486	37 %
2001	59	889	948	486	1,434	34 %

Recommendations

The following main recommendations can be derived from this overview report including:

- EMEP data on atmospheric nitrogen (emissions and deposition) should be used by OSPAR to a much larger extent;
- EMEP developed for this overview report an OSPAR adapted grid which provides an appropriate spatial resolution and data quality to answer OSPAR requests on nitrogen deposition data on an overall as well as on a regional basis which should therefore be used for future assessments, for example, of the eutrophication status;
- future OSPAR assessments would be facilitated by a coordinated reporting on atmospheric nitrogen at the same time as reporting, for example, on PARCOM Recommendation 88/2. In this context the use of the results of EMEP and the European Pollutant Emissions Register (EPER) and regular reporting under relevant EC Directives (e.g. Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants (NECs Directive)) and international conventions (e.g. UNECE Convention on Long-rage Transboundary Air Pollution (LRTAP), United Nations Framework Convention on Climate Change (UNFCCC)) is recommended when assessing the effectiveness of measures to combat eutrophication. Any improvement of data on nitrogen emissions from shipping should be addressed as well.

In summary this overview document can be used for:

- the OSPAR Eutrophication Strategy with regard to the obligatory assessment of all measures to achieve the overall 2010 objective of the Strategy;
- applications of the “Comprehensive Procedure” of the OSPAR Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area (reference number: 2005-3);
- integrated assessments under the OSPAR JAMP (on emissions, inputs, concentrations and effects in the maritime area), and;
- preparation of future Quality Status Reports in 2010 and thereafter.

In order to facilitate regular reporting on nitrogen emissions and deposition in the OSPAR area and the subsequent inclusion of the submitted data in relevant assessments, the OSPAR Eutrophication Committee (EUC) is invited to propose and/or establish arrangements for further co-operation with EMEP and the European Community.

1. Introduction

OSPAR as the regional Convention for the Protection of the Marine Environment of the North-East Atlantic has, *inter alia*, set up a Strategy to combat eutrophication with the objective by 2010 to achieve and maintain a healthy marine environment where (anthropogenic) eutrophication does not occur. One major part of the process to implement the OSPAR Eutrophication Strategy is the assessment of the role of nutrient emissions, discharges, losses and inputs (like riverine, direct or atmospheric) into the OSPAR maritime area. In the light of that information, actions and measures to reduce nutrient inputs should be formulated.

The OSPAR Eutrophication Strategy will be implemented in line with the development of an ecosystem approach including, *inter alia*:

- the assessment of the eutrophication status of the OSPAR maritime area in accordance with the "Comprehensive Procedure" of the Common Procedure (reference number: 2005-3);
- the identification and quantification of the various sources of nutrients (e.g. by sector, sub-catchment, catchment, region, nation and/or other relevant subdivision);
- the development of measures to combat eutrophication in order to achieve the Ecological Quality Objectives set by OSPAR, and;
- the establishment of the direct and indirect links between the various sources of nutrients and any eutrophication problems, and, hence, the significance of those sources.

Within the implementation process of the OSPAR Eutrophication Strategy an outline for a report on atmospheric emissions and deposition of nitrogen to the OSPAR Convention area and agreed international reduction measures has been prepared in 2002. The report has been finalised since then and is intended to form one main building block of the further assessment of how the effectiveness of agreed international measures can contribute to achieving the 2010 objective of the Eutrophication Strategy. It could also provide a basis for deciding whether there is a need for any additional action or measures to reach this goal.

One main part of the present report was prepared by OSPAR through cooperation with EMEP, initiated, supported and financed by the German Federal Environmental Agency. Chapter 2 of the present overview report contains major parts of the EMEP report on "Atmospheric Nitrogen in the OSPAR Convention Area for the period 1990 – 2001" (Bartnicki *et al.*, 2004). This information is complemented in Chapter 3 by a comprehensive overview of agreed international measures to reduce nitrogen emissions, prepared with the assistance of the Netherlands and the European Community.

Chapter 2 on atmospheric nitrogen inputs to the OSPAR Convention area presents the EMEP results of estimates of atmospheric emissions of nitrogen as well as calculations of their deposition to the OSPAR Convention waters in the period 1990 – 2001. This includes information on:

- annual emissions of nitrogen oxides (NO_2) and ammonia (NH_3) from OSPAR Contracting Parties and the three largest outside contributors to nitrogen deposition to OSPAR Convention waters in the period 1990 – 2001;
- modelled annual deposition of nitrogen oxides (NO_2) and ammonia (NH_3) in the five main OSPAR regions and the 13 sub-regions of the Greater North Sea for the years 1990, 1995, 1996, 1997, 1998, 1999, 2000 and 2001;
- comparison of model results and measurements currently available from the OSPAR coastal monitoring stations, for wet deposition of nitrogen in the years 1990, 1995, 1996, 1997, 1998, 1999 and 2000;
- source-receptor matrices (countries to regions) for the main OSPAR regions and all sub-regions of OSPAR Region II (Greater North Sea) for the year 2000;
- contributions of individual emission sectors to nitrogen deposition to the main OSPAR regions and all sub-regions of OSPAR Region II (Greater North Sea) for the year 2000, and;
- comments on uncertainties of computed results.

The results are based on model estimates and monitoring results. Chapter 2 includes data on emissions and computed nitrogen deposition in the five main OSPAR Regions I – V (Arctic Waters, Greater North Sea, Celtic Seas, Bay of Biscay, and Wider Atlantic) according to the Quality Status Report 2000. For assessment purposes, Region II (the Greater North Sea) is further divided into 13 sub-regions according to the ICES boxes. In addition, the results of source-receptor computations are included, with contributions of nitrogen emissions by 15 OSPAR Contracting Parties and three additional selected countries to nitrogen deposition to the five main OSPAR regions and 13 sub-regions of OSPAR Region II. The contribution of 10 emission sectors to nitrogen deposition to the OSPAR main regions and the sub-regions of OSPAR Region II (Greater North Sea) are also presented and analysed in Chapter 2. All specific results (maps, tables, ascii files with data) of this chapter as well as the whole report are available on the EMEP web site www.emep.int/index_facts.html.

The role of atmospheric deposition of nitrogen with regard to the total fluxes to the North Sea and North-East Atlantic, as well as discussion of related chemical and biological processes has been subject of many scientific publications (e.g. Rendell *et al.,* 1993; Peierls and Paerl, 1977; Shultz *et al.,* 1999 and Klein, L. M., 2002). However, most of the studies relating to atmospheric supply of nitrogen to the OSPAR Convention waters were based on measurements and limited to rather small coastal (or mainly coastal) regions, not covering the entire area of interest.

For all nitrogen computations presented in this report, the EMEP Unified Eulerian model system was used. This system underwent a major overhaul in the last two years when the previous EMEP models (Lagrangian as well as Eulerian) were merged and re-written to produce the Unified EMEP Eulerian model. The model is documented in detail in the EMEP Status Report 1/2003, Part I (Simpson *et. al.,* 2003). In Part II of the EMEP Status Report 1/2003 (Fagerli *et al*., 2003), the new unified model was tested against measured data from EMEP stations for nine different years (1980, 1985, 1990, 1995, 1996, 1997, 1998, 1999 and 2000). A short description of the main EMEP model features is given in chapter 2.1.

Similar computations as for the OSPAR Convention waters had already been performed for the Baltic Sea in the frame of a cooperation between the Helsinki Commission and EMEP (Bartnicki *et al.,* 2002, 2003). As proposed by Germany at EUC 2002, the results of the computations for the OSPAR Convention waters are presented here in a similar way as it has been done for HELCOM to possibly facilitate comparative considerations in future (e.g. under the EU Marine Strategy or the implementation of the EC Water Framework Directive).

Chapter 3 is an overview of agreed international measures to reduce nitrogen emissions. It comprises information on:

- monitoring of transboundary air pollution under EMEP (Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe);
- national emission ceilings/ambient air quality (e.g. UNECE LRTAP, EC NECs Directive, Ambient Air Directive);
- other relevant developments within Europe on emissions to air (e.g. EC Directives for large combustion plants, incineration of waste, large industrial installations, BREFs, emissions from shipping, Clean Air for Europe and agriculture).

2. Atmospheric Nitrogen in the OSPAR Convention Area[1]

2.1 Short Description of the Unified EMEP Model

The Unified EMEP model is an Eulerian model that has been developed at EMEP/MSC-W (EMEP Meteorological Synthesizing Centre – West) for simulating atmospheric transport and deposition of acidifying and euthrophying compounds as well as photo-oxidants in Europe. The latest model version is documented in EMEP Status Report I, Part I (Simpson *et. al.,* 2003). Here, only a short description of the basic features of the model is given. Model details and its applications can be also found on the EMEP web site www.emep.int.

The model domain covers Europe and the Atlantic Ocean (Figure 1). The model grid (of the size 170 ×133) has a horizontal resolution of 50 km at 60^{o} N, which is consistent with the resolution of emission data reported to CLRTAP (Vestreng, 2003). In the vertical, the model has 20 sigma layers reaching up to 100

[1] This chapter is extracted from Jerzy Bartnicki/Hilde Fagerli, Atmospheric Nitrogen in the OSPAR Convention Area in the Period 1990-2001, Summary Report for the German Federal Environmental Agency, EMEP, Technical Report MSC-W 4/2004, Oslo 2004, ISSN 0804-2446.

hPa. Approximately 10 of these layers are placed below 2 km to obtain high resolution of the boundary layer which is of special importance to the long-range transport of air pollution.

The Unified Model uses 3-hourly resolution meteorological data from the PARLAM-PS model, a dedicated version of the HIRLAM (High Resolution Limited Area Model) Numerical Weather Prediction model.

The emissions consist of gridded national annual emissions of sulphur dioxide, nitrogen oxides, ammonia, non-methane volatile organic compounds (VOC) and carbon monoxide. They are available in each of the 50 × 50 km^2 model grid. These emissions are distributed temporally according to monthly and daily factors derived from data provided by the University of Stuttgart (IER).

Concentrations of 71 species are computed in the latest version of the Unified EMEP model (56 are advected, 15 are short-lived and not advected). The sulphur and nitrogen chemistry is coupled to the photo-chemistry, which allows a more sophisticated description of e.g. the oxidation of sulphur dioxide to sulphate.

Dry deposition is calculated using the resistance analogy and is a function of the pollutant type, meteorological conditions and surface properties. Parameterization of wet deposition processes includes both in-cloud and sub-cloud scavenging of gases and particles using scavenging coefficients.

2.2 Definitions of the OSPAR Regions and Sub-regions in the EMEP Grid System

Annual deposition of nitrogen has been calculated for the five main regions of the OSPAR Convention waters and for the 13 sub-regions of OSPAR Region II (Greater North Sea).

OSPAR Convention waters are divided into five main regions (see also Figure 2):

Region I: Arctic Waters
Region II: Greater North Sea
Region III: Celtic Seas
Region IV: Bay of Biscay
Region V: Wider Atlantic

Definitions of the OSPAR border lines for the five main regions are available on the OSPAR web site as descriptive geographical co-ordinates. Definitions of 13 sub-regions of OSPAR Region II (Greater North Sea), were provided to EMEP by the German Federal Environmental Agency, also in the form of geographical co-ordinates in accordance with the sub-regions used by OSPAR within the OSPAR Quality Status Reports.

The sub-regions of the main OSPAR Region II (Greater North Sea) are related to the ICES Boxes in the following way (see also Figure 3):

Sub-region 1: ICES Box 1
Sub-region 2: ICES Box 2a
Sub-region 3: ICES Box 2b
Sub-region 4: ICES Box 3a
Sub-region 5: ICES Box 3b
Sub-region 6: ICES Box 4
Sub-region 7: ICES Box 5a
Sub-region 8: ICES Box 5b
Sub-region 9: ICES Box 6
Sub-region 10: ICES Box 7a
Sub-region 11: ICES Box 7b
Sub-region 12: ICES Box 8
Sub-region 13: ICES Box 9

In order to calculate nitrogen deposition in the OSPAR regions, the borders of the main OSPAR regions and sub-regions had to be converted into the EMEP grid system, which is shown in Figure 1. In the first stage of this conversion, descriptive geographical coordinates were transformed into the sets of discrete geographical coordinates describing each main region or sub-region. A major problem in this stage was the lack of a data set with geographical coordinates defining the western border of Region III (Wider Atlantic) (see Figure 2). These coordinates were finally read manually from the map.

In a second, more difficult and time consuming stage, borders of the regions in the EMEP grid system were used to calculate the percentage of the considered OSPAR region or sub-region that was included in each EMEP grid square. In this way, a separate percentage file was created for each region and sub-region.

A map with the borders of the main OSPAR regions in the EMEP grid system is shown in Figure 2, and a map with the borders of the sub-regions (ICES Boxes) of OSPAR Region II (Greater North Sea), is shown in Figure 3.

The border of the main OSPAR Region V (Wider Atlantic) goes slightly outside the EMEP model grid system resulting in the underestimation of computed nitrogen deposition in this region. The underestimation is small, approximately less than 0.1 %, because of the small number of missing grids and small values of deposition in the missing grids, which are located far away from the significant sources of nitrogen emission.

An additional reason for the underestimation of nitrogen deposition in the Wider Atlantic Region is the formulation of boundary conditions in the EMEP model. According to this formulation, the values of the deposition in the lowest row in the EMEP grid system are always equal to zero. Also in this case underestimation is practically insignificant, below 0.1 % of the total deposition value in this region.

These two problems could be solved by the extension of the EMEP model domain to the south. Such a solution is not possible at present, but the extension of the model domain is included in the future plans of EMEP.

2.3 Atmospheric Nitrogen Emissions

In the deposition calculations, official figures on national emissions reported to EMEP were used (Vestreng, 2003). Emission inventories from EMEP Participating Parties, which include OSPAR Contracting Parties and the three selected countries (Italy, Poland and the Russian Federation) with the largest deposition of nitrogen to the OSPAR Convention waters from outside the OSPAR Convention area, are presented in this report for the period 1990 – 2001. There are two kinds of nitrogen emissions used as input files to the EMEP model calculations: nitrogen oxides emissions as NO_2 and ammonia emissions as NH_3, both in nitrogen units.

According to the results of source-receptor calculations performed with the EMEP Unified Model for the year 2000, the three largest contributors to nitrogen deposition to OSPAR Convention waters from countries other than OSPAR Contracting Parties were Italy, Poland and the Russian Federation.

An additional and very important source of atmospheric NO_x emissions in the OSPAR Convention area is the international ship traffic. Official data for 1990 give 1,266 kt NO_x (as NO_2) annual emissions from the international ship traffic on the North-East Atlantic and 648 kt NO_x (as NO_2) from the international ship traffic on the North Sea. This is the largest source of NO_x emissions in the OSPAR area of interest. Official information about this source is rather old and exists only for 1990. It is important to update the ship traffic emission data for more recent years as soon as possible.

A ship emissions quantification study was conducted by Entec UK Limited on behalf of the European Commission in 2002 based on ship movement data for the year 2000. The resulting data were shared with EMEP. However, there are ongoing discussions between EMEP and Entec about methodological aspects. The results of the study suggest that ship NO_x emissions increased by more than 40 % from 1990 to 2000, and that by 2020 ships will emit more NO_x than all EU land-based sources combined. This emission inventory is currently being refined in the context of a new study of the European Community (EC), which also considers the cost-effectiveness of various NO_x abatement technologies for shipping. Data of this EC study are not included in the present overview report because of the above-mentioned ongoing discussions on methodological aspects.

A map with time series of nitrogen oxides (NO_x) emissions from OSPAR Contracting Parties, and additionally from Italy, Poland and the Russian Federation, is shown in Figure 4 for the period 1990 - 2001. A similar map for ammonia (NH_3) emissions is shown in Figure 5. The same data are available as numbers in Tables 1 and 2, for nitrogen oxides (NO_2) and ammonia (NH_3) emissions, respectively. All emissions data, both for nitrogen oxides and ammonia, are presented in nitrogen units in Tables 1 and in Figures 4 and 5.

For most of the OSPAR Contracting Parties, a reduction of nitrogen oxides emissions (NO_2) has been reported for the period 1990 – 2001 (Figure 4 and Table 1). Only in four of the 18 countries relevant for OSPAR – Portugal, Spain, Iceland and Ireland – annual emissions of nitrogen oxides were reported to be higher in 2001 than in 1990 by 35 %, 8 %, 8 % and 6 %, respectively. Moreover, in two of these countries (Iceland and Ireland) emissions in both years were low (9 and 38 kt N a^{-1}, respectively) compared to the rest of the countries. The United Kingdom, Germany and France were the largest emitters of nitrogen oxides among OSPAR Contracting Parties. In these three countries, emissions were significantly lower in 2001 than in 1990 by 39 %, 42 % and 26 %, respectively. The three largest contributors to nitrogen deposition to the OSPAR Convention waters from outside the OSPAR Convention area were Poland, Italy and the part of the Russian Federation included in the EMEP area. In these three countries, emissions in 2001 were reported to be lower than in 1990 by 37 %, 35 % and 29 %, respectively.

Annual emissions of nitrogen oxides, as a sum of emissions from all OSPAR Contracting Parties and selected additional three countries outside OSPAR, were 29 % lower in 2001 than the annual emissions in the year 1990. Taking into account the uncertainties regarding the reporting of emission data, there seems to be evidence for nitrogen oxides emissions going down in the OSPAR Convention area.

Ammonia (NH_3) emissions for the period 1990 – 2001 are shown in Figure 5 and Table 2. Also annual emissions of ammonia (NH_3) were lower in 2001 than in 1990 for most of the OSPAR Contracting Parties and all selected three countries outside OSPAR. In 15 of the 18 countries relevant for OSPAR, annual emissions were lower in 2001 than in 1990. In the Russian Federation, Poland and in the Netherlands, this emission reduction was sometimes significant (45 %, 39 % and 36 %, respectively).

In the Russian Federation, Poland and Germany ammonia (NH_3) emissions decreased in the beginning of the period investigated (approximately until 1994). From 1994 to 2001 emissions remained at the same level in almost all countries except Spain, where emissions were slightly rising from 1994 to 2001.

In the period 1990 – 2001, the rate of ammonia (NH_3) emission reduction was slightly lower than the rate of nitrogen oxides (NO_2) emission reduction. Annual emissions of ammonia, as a sum of emissions from all OSPAR Contracting Parties and the three selected countries outside OSPAR were 20 % lower in 2001 than the annual emissions in the year 1990.

Annual emissions of nitrogen oxides (NO_2), as a sum of emissions from all OSPAR Contracting Parties and the three selected countries outside OSPAR, were 13 % higher than the corresponding annual emissions of ammonia (NH_3) in the year 2001, in terms of nitrogen emitted.

2.4 Atmospheric Nitrogen Deposition to the OSPAR Convention Waters

Atmospheric deposition of oxidized nitrogen and reduced nitrogen were calculated for eight years: 1990, 1995, 1996, 1997, 1998, 1999, 2000 and 2001. Oxidized nitrogen deposition calculated in nitrogen units consists of the sum of peroxyacetyl nitrate (PAN), NO_2, HNO_3 and aerosol nitrate (ammonium nitrate + coarse nitrate) deposition. Deposition of reduced nitrogen includes deposition of NH_3 and aerosol ammonium (ammonium sulphate + ammonium nitrate).

Maps of modelled annual deposition of oxidized nitrogen in the five main OSPAR regions in 1990 and 2001 are shown in Figures 6 and 7, respectively. Maps of annual deposition of reduced nitrogen in 1990 and 2001 are shown in Figures 8 and 9, respectively. Numerical values of the deposition in the five main OSPAR regions for all nine years are included in Tables 3 and 4 for oxidized and reduced nitrogen, respectively.

For oxidized nitrogen, the annual deposition in all main OSPAR regions was lower in 2001 than in 1990 by 25 %, 15 %, 17 %, 12 % and 5 % for Arctic Waters, Greater North Sea, Bay of Biscay and Wider Atlantic, respectively. Thus, the declining pattern of nitrogen oxides (NO_2) emissions is followed by the deposition pattern for the same period.

In case of reduced nitrogen, the annual deposition in 2001 was slightly higher than in 1990 in the main OSPAR Region II (Greater North Sea) (0.7 %) and in the main OSPAR Region III (Celtic Seas) (6 %). In the three remaining main OSPAR regions it was lower by 30 %, 11 % and 15 % for Arctic Waters, Bay of Biscay and Wider Atlantic, respectively. The figures clearly show that there was a large inter-annual variability of deposition, probably caused by different meteorological conditions in different years. The year-to-year variations were large and had the same magnitude as the change in deposition in the period from 1990 to 2001. This illustrates that in order to detect trends caused by changes in emissions, many years of observational data are necessary. Moreover, model calculations can be a helpful tool to assess whether observed changes are related to changes in the meteorological conditions or to emission changes. For instance, in the Wider Atlantic deposition of nitrogen peaked in 1996/1997, whilst the relevant reported emissions exhibit no such peak. Both observations and model results at the Portuguese Atlantic coast point towards high wet deposition of nitrogen in these years. Thus, it is likely that the peaks of nitrogen deposition to the Wider Atlantic in the mid-1990s were caused by specific meteorological conditions.

For both oxidized and reduced nitrogen, a clear gradient of deposition towards the open sea can be observed with maxima of deposition in OSPAR Region II (Greater North Sea). The deposition of oxidized nitrogen (maximum 630 mg N m^{-2} in 2001) was higher than the deposition of reduced nitrogen (maximum 537 mg N m^{-2} in 2001). This means that the nitrogen emitted from mobile sources contributed more to the deposition than the nitrogen emitted mainly from sources related to agriculture.

The total annual nitrogen deposition in the main OSPAR regions is shown in Figures 10 and 11, for the years 1990 and 2001, respectively. Numerical values of total (oxidized + reduced) nitrogen deposition for all seven years are given in Table 5. Also in this case a clear gradient of the deposition towards the open sea is confirmed especially by figures 10 and 11 with a maximum of deposition in OSPAR Region II (Greater North

Sea). Compared to 1990, annual deposition of total nitrogen in 2001 was higher only in the main OSPAR Region II (Greater North Sea).

The annual nitrogen deposition in the entire OSPAR maritime area is shown in Figure 12 for the years 1990, 1995, 1996, 1997, 1998, 1999, 2000 and 2001. Deposition of oxidized and total (oxidized + reduced) nitrogen was going down from 1990 to 1995, whereas deposition of reduced nitrogen was slightly higher in 1995 than in 1990. There is a clear maximum for all three types of nitrogen deposition in the year 1996 and then decreasing until 1999. From 1999 to 2001, deposition of oxidized and total nitrogen was going slightly up, but deposition of reduced nitrogen was going slightly down.

Maps of modelled annual deposition of oxidized nitrogen in the sub-regions of OSPAR Region II (Greater North Sea) in 1990 and 2001 are shown in Figures 13 and 14, respectively. Maps of modelled annual deposition of reduced nitrogen in 1990 and 2001 are shown in Figures 15 and 16, respectively. Numerical values of the modelled deposition in 13 sub-regions of the Greater North Sea for all seven years are given in Tables 6 and 7 for oxidized and reduced nitrogen, respectively.

For oxidized nitrogen, annual deposition in all sub-regions of the Greater North Sea (Table 6) except sub-regions 2 and 4 was lower in 2001 than in 1990 by 2 % to 30 %. Deposition of oxidized nitrogen in sub-regions 6 and 13 remained on the same level in 2001 as in 1990. Maxima (over 600 mg N m^{-2}) of the deposition were observed close to the Norwegian and Swedish coasts in sub-region 12 and a minimum (below 150 mg N m^{-2}) in sub-region 2. The largest deposition reduction of 30 % was calculated for sub-region 7, from 10.5 kt N a^{-1} in 1990 to 7.4 kt N a^{-1} in 2001. The highest increase of deposition by 6 % was calculated for sub-region 2, from 10.3 kt N a^{-1} in 1990 to 11 kt N a^{-1} in 2001.

In 8 of the 13 sub-regions of the Greater North Sea annual deposition of reduced nitrogen in 2001 was higher than in 1990 (Table 7). For some of the sub-regions, the deposition increase was significant, e.g. 30 % and 22 % for sub-regions 2 and 9, respectively. Maxima (over 1,000 mg N m^{-2}) of deposition was observed close to the German, Belgian and French coasts and a minimum (below 150 mg N m^{-2}) again in sub-region 2. Lower deposition in 2001 than in 1990 was observed especially in sub-regions 9 and 12 of the Greater North Sea with 22 % and 20 % reduction, respectively. The largest deposition reduction by 22 % was calculated for sub-region 9, from 20 kt N a^{-1} in 1990 to 15.7 kt N a^{-1} in 2001. The highest increase in deposition by 30 % was calculated for sub-region 2, from 4.2 kt N a^{-1} in 1990 to 5.5 kt N a^{-1} in 2001.

The total modelled annual nitrogen (oxidized + reduced nitrogen) deposition in the sub-regions of the Greater North Sea is shown in Figures 17 and 18, for the years 1990 and 2001, respectively. Numerical values of the modelled total (oxidized + reduced) nitrogen deposition for all eight years are given in Table 8. Compared to 1990, annual deposition of total nitrogen in 2001 was higher in 5 of the 13 sub-regions of the Greater North Sea and especially at the east-south border of the Greater North Sea with a maximum over 1000 mg N m^{-2}. The largest deposition reduction by 27 % was calculated for sub-region 9, from 63 kt N a^{-1} in 1990 to 46.3 kt N a^{-1} in 2001. The highest increase in deposition by 13 % was calculated for sub-region 2, from 14.5 kt N a^{-1} in 1990 to 16.4 kt N a^{-1} in 2001.

Maps with time series of modelled oxidized, reduced and total nitrogen deposition in the five main OSPAR regions are shown for the years 1990, 1995, 1996, 1997, 1998, 1999, 2000 and 2001 in Figures 19, 20 and 21, respectively. For all types of deposition and for all components a maximum in the four main OSPAR regions (Arctic Waters, Celtic Seas, Bay of Biscay, and Wider Atlantic) occurred in 1996. In the Greater North Sea region a maximum of reduced and total deposition occurred in 2000.

Maps with time series of modelled oxidized, reduced and total nitrogen deposition in the 13 sub-regions of the main OSPAR Region II (Greater North Sea) are shown for the years 1990, 1995, 1996, 1997, 1998, 1999, 2000 and 2001 in Figures 22, 23 and 24, respectively. Deposition values of oxidized nitrogen in 2001 were lower than 1990 deposition in all sub-regions. Deposition of reduced nitrogen was higher in 2001 than in 1990 in many sub-regions, and no clear trend is visible in the deposition pattern. The same applies to the deposition of total nitrogen.

2.5 Comparison of Computed Versus Measured Deposition at OSPAR Coastal Monitoring Stations

Within the framework of the OSPAR Working Group on Inputs to the Marine Environment (INPUT) every year a report of the Comprehensive Atmospheric Monitoring Programme (CAMP) – Pollutant Deposits and Air Quality at Coastal Stations – is prepared and published. For this purpose, all Contracting Parties measure and submit data from their coastal monitoring stations of observed input of atmospheric pollutants to the OSPAR maritime area, and of the concentrations of pollutants in the ambient air of the OSPAR region. These data were used for the comparison of modelled and computed annual atmospheric deposition. Maps with modelled versus measured annual deposition of oxidized, reduced and total (oxidized and reduced) nitrogen for the years 1990, 1995, 1996, 1997, 1998, 1999 and 2000 at the stations located in the main OSPAR regions are shown in Figures 25, 26 and 27, respectively. Similar maps with measured versus calculated deposition of oxidized, reduced and total nitrogen, for the stations located in OSPAR Region II (Greater North Sea), are shown in Figures 28, 29 and 30, respectively.

The agreement between model results and observations depends not only on the “model performance” and the adequacy of emissions employed, but also on the quality and representativeness of the measurement sites. It is worth mentioning here that, for some stations, double sets of measurement data (e.g. obtained with different methods) were reported. In some cases, these data sets differed by as much as 20 - 30 %. This indicates that there is a substantial uncertainty in the measurements. Thus, the following discussion on model *underestimation* and *overestimation* simply implies that the calculated values are lower or higher than the observations and does not refer to model deficiency only.

For the majority of the stations considered, modelled and measured concentrations matched well. In general, modelled wet deposition for stations situated in the sub-regions were in better agreement with observations than stations located in the main regions. For instance, wet deposition of both oxidized and reduced nitrogen for the Portuguese station PT0010R, situated at the Azores, was substantially underestimated by the model. The observed values were relatively high for a background station, presumably due to the observations being influenced by local sources.

Both, this station and the Norwegian station at Spitzbergen, NO0059R, are situated close to the boundary of the model domain. Therefore, the model results are sensitive to the choice of boundary conditions in the model. Consequently, the results for these stations are expected to be worse than for other stations.

Observed wet deposition for sites situated in the sub-regions of the Greater North Sea matches very well modelled wet deposition. It is especially encouraging that the model manages to reproduce the monitored year-to-year variations.

In general, wet deposition of ammonium and nitrate is somewhat underestimated. It is well known that dry deposition of NH_3 to open bulk collectors can account for a substantial part of the measured wet deposition. Thus, the apparent underprediction of wet deposition may partly be caused by the bias in measured wet deposition.

2.6 Source-receptor Matrices for the Five Main OSPAR Regions and 13 Sub-regions of OSPAR Region II (Greater North Sea)

Each year, all EMEP countries have the obligation to report their national emissions according to the guidelines set out by the Steering Body of EMEP. Concerning nitrogen, countries should report: national totals, sector emissions, gridded data in the EMEP 50 × 50 km system, emissions for large point sources and projection data. In this section, contributions of nitrogen emissions in 2000 from the OSPAR Contracting Parties and other selected sources to the deposition to the five main regions of the OSPAR Convention waters and the 13 sub-regions of Region II (Greater North Sea) are presented and discussed. Other sources include three emitter countries from outside the OSPAR Convention area (Italy, Poland and the Russian Federation) with highest deposition to OSPAR Convention waters. They also include emissions from international ship traffic on the North Sea and the Atlantic Ocean, but unfortunately data on ship emissions used here are comparably old and are only available for the year 1990. Although there is a recent study conducted by Entec UK Limited for the European Commission, it was decided not to use the study’s data for this report because of the above-described ongoing discussions between EMEP on the one side, and the EC and ENTEC on the other side, on methodological aspects of the study concerned.

The complete list with the names and codes of the sources taken into account in the source allocation budgets calculations is given below.

Code	Source name
BE	Belgium
DK	Denmark
FI	Finland
FR	France
DE	Germany
IS	Iceland
IE	Ireland
NL	Netherlands
NO	Norway
PT	Portugal

ES	Spain
SE	Sweden
GB	United Kingdom
IT	Italy
PL	Poland
RU	Russian Federation
NOS	North Sea (international ship traffic, only 1990 data)
ATL	Atlantic Ocean (international ship traffic, only 1990 data)

Contributions of emitter countries (13 OSPAR Contracting Parties plus three of the largest contributors outside the OSPAR Convention area, plus ship traffic on the North Sea and on the Atlantic Ocean) to annual oxidized, reduced and total nitrogen deposition to OSPAR Convention waters in the year 2000 are shown in Figure 31.

Nitrogen emissions – in the sequence of their magnitude – from the United Kingdom, ship traffic on the Atlantic Ocean, ship traffic on the North Sea, from France, Germany and from Spain were the main sources for atmospheric deposition of oxidized nitrogen contributing to the annual total with 20 %, 16 %, 7 %, 7 %, 6 % and 6 %, respectively. Emissions from the international ship traffic on the North Sea and Atlantic Ocean together were the largest (23 %) contributors to oxidized nitrogen deposition in the entire OSPAR area.

Annual nitrogen emissions from France, the United Kingdom, Germany, Ireland and Spain were the most important sources for reduced nitrogen deposition to OSPAR Convention waters with a contribution of 24 %, 20 %, 11 %, 8 % and 8 %, respectively.

Main sources of nitrogen emissions responsible for total (oxidized and reduced) nitrogen deposition in the entire OSPAR area were, in the sequence of their magnitude: the United Kingdom, France, ship traffic on the Atlantic Ocean, Germany and Spain with 20 %, 13 %, 11 %, 8 % and 7 %, respectively. It is important to notice that emissions from ship traffic on the Atlantic Ocean and the North Sea together were the second largest contributor to the total deposition of nitrogen to OSPAR Convention waters.

Boundary and intial conditions applied for each EMEP model run can also be considered as an additional emission source contributing to nitrogen deposition to all OSPAR Convention waters. This contribution is relatively high for oxidized and total nitrogen, i.e. 13 % and 10 % respectively. Contribution of intial and boundary conditions to reduced nitrogen deposition is lower (4 %).

Concerning the main OSPAR regions, the largest contribution of initial and boundary conditions to oxidized nitrogen deposition was observed for OSPAR Regions V (Wider Atlantic) and I (Arctic Waters) with 34 % and 9 %, respectively. The largest contribution (17 %) of initial and boundary conditions to reduced nitrogen deposition occured in OSPAR Region I (Arctic Waters).

Contributions of the selected emission sources of oxidized, reduced and total nitrogen to the deposition in each of the five main OSPAR regions in 2000 are shown in Figures 32, 33 and 34, respectively. Corresponding numerical values are given in Tables 9, 10 and 11.

Emission sources in the United Kingdom were the main contributors to oxidized nitrogen deposition in the main OSPAR Regions I, II and III with 47, 103 and 20 kt N a^{-1}, respectively. For the main OSPAR Regions IV and V, international ship traffic on the Atlantic Ocean was the main source, contributing 34 and 96 kt N a^{-1}, respectively, to reduced nitrogen deposition.

Emission sources located in France were the largest contributors to reduced nitrogen deposition in Regions II, IV and V with 60, 26 and 21 kt N a^{-1}, respectively. The United Kingdom and Germany were the largest contributors to reduced nitrogen deposition in the main OSPAR Region I with 12 kt N a^{-1} each, whereas Ireland was the largest contributor to the main OSPAR Region III with 22 kt N a^{-1}.

The main contributor to total nitrogen deposition in the main OSPAR Regions I (Arctic Waters), II (Greater North Sea) and III (Celtic Seas) were emission sources located in the United Kingdom with 58, 158 and 40 kt N a^{-1}, respectively, whereas the main contributor to deposition in Regions IV (Bay of Biscay) and V (Wider Atlantic) was the international ship traffic on the Atlantic Ocean with 96 and 169 kt N a^{-1}, respectively.

Contributions of the selected emission sources of oxidized, reduced and total nitrogen to the deposition in each of 13 sub-regions of OSPAR Region II (Greater North Sea) in 2000 are shown in Figures 35, 36 and 37, respectively. Corresponding numerical values are given in Tables 12, 13 and 14.

For all types of nitrogen deposition, emission sources located in the United Kingdom, Germany and France were the main emission sources contributing to the deposition in most of the sub-regions of OSPAR Region II. In case of oxidized nitrogen deposition, international ship traffic on the North Sea was one of the major contributors as well. For sub-regions 7 and 12 of the Greater North Sea, Denmark was a major contributor to reduced nitrogen deposition, but countries like Belgium and the Netherlands also significantly contributed to the deposition in several sub-regions.

Three main contributors to oxidized, reduced and total nitrogen deposition in 13 sub-regions of the OSPAR Region II are shown in the Table below. The sub-regions of OSPAR Region II are shown in Figure 3.

Sub-region	**Main contributors for oxidized nitrogen**			**Main contributors for reduced nitrogen**			**Main contributors for total nitrogen**		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
1	UK	DE	NOS	UK	DE	FR	UK	DE	FR
2	UK	NOS	DE	UK	FR	DE	UK	DE	NOS
3	UK	NOS	DE	UK	DE	FR	UK	DE	FR
4	UK	NOS	DE	UK	FR	DE	UK	FR	DE
5	UK	NOS	FR	UK	FR	DE	UK	FR	NOS
6	UK	NOS	FR	FR	BE	NL	UK	FR	BE
7	UK	NOS	DE	DK	DE	FR	UK	DE	FR
8	UK	DE	NOS	DE	NL	FR	DE	NL	UK
9	UK	NOS	DE	UK	DE	FR	UK	DE	FR
10	UK	NOS	DE	UK	DE	FR	UK	DE	FR
11	UK	NOS	DE	UK	FR	DE	UK	FR	DE
12	DE	UK	NOS	DK	DE	FR	DE	DK	UK
13	UK	NOS	FR	UK	FE	ES	FR	UK	NOS

Note: ‘1’, ‘2’ and ‘3’ in the horizontal columns indicate the three main contributing countries to nitrogen deposition in descending sequence of their contributions.

2.7 Contributions of Individual Emission Sectors to the Five Main OSPAR Regions and 13 Sub-regions of OSPAR Region II (Greater North Sea)

National nitrogen emissions (NO_2 and NH_3) are 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 below.

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

Distribution of nitrogen oxides emissions and ammonia among the sectors is not uniform. The ranking of different sectors can be estimated based on the distribution from averaging sector data reported by all EMEP Parties. For nitrogen oxides emissions, the most important sectors are: Sector 7 (42 %), Sector 1 (24 %), Sector 8 (14 %), Sector 3 (9 %), Sector 2 (6 %) and Sector 4 (3 %). Nitrogen oxides emissions from Sector 5, Sector 7, Sector 9 and Sector 11 are 1 %, 1 %, 0 % and 0 %, respectively. For ammonia the most important sectors are: Sector 10 (84 %), Sector 9 (7 %), Sector 11 (4 %), Sector 4 (4 %) and Sector 7 (1 %). There is no ammonia emission from the remaining sectors. Therefore, for the analysis it is enough to take into account only 8 sectors for nitrogen oxides emissions and 5 sectors for ammonia emissions.

Therefore, to analyse the contribution of the selected emission sectors to nitrogen deposition in the year 2000, we needed to run the unified EMEP model 12 times: eight runs with nitrogen oxides emissions reduced by 25 % in each selected sector, and four runs with the ammonia emissions reduced by 25 % in each selected sector. Thereby not the contribution of each emission sector to the deposition was estimated, but rather the sensitivity of changes in deposition as a response to emission changes in the selected sectors. An approximate contribution from the actual sector was calculated by multiplying, by a factor of four, the estimated sensitivity towards a 25% reduction. The reason why the value 25 % was chosen is given in the EMEP Status report (Tarrason et al., 2003). Changes in emissions result in non-linear effects on deposition of sulphur and nitrogen, and air concentrations of ozone, sulphate, nitrate and ammonium. These non-linear responses of emission changes increase with the magnitude of the perturbation. Model runs with 25 % emission reduction gave much more linear results than the runs with full exclusion of emissions. In addition 25 ,% is realistic in terms of what can be achieved in the time frame of few years.

The reduction in annual oxidized, reduced and total nitrogen deposition (in percent of initial values) in the five main OSPAR regions, which is due to a 25 % reduction of nitrogen oxides emissions in each of the 10 SNAP sectors in the year 2000, is shown in Figures 38, 39 and 40, respectively. Corresponding numerical values are shown in Tables 15, 16 and 17.

The reduction of nitrogen oxides emissions in individual sectors mainly affected deposition of oxidized and total nitrogen in all main OSPAR regions. The effects on deposition of reduced nitrogen are negligible.

For Region I (Arctic Waters) and Region II (Greater North Sea), the ranking of the contributions from different sectors, measured in terms of oxidized nitrogen deposition reduction, is the same. It is listed below with the major contributor at the top:

Sector 7: Road transport
Sector 8: Other mobile sources and machinery
Sector 1: Combustion in energy and transformation industry
Sector 3: Combustion in manufacturing industry
Sector 2: Non-industrial combustion plants
Sector 4: Production processes

For Region III (Celtic Seas), Region IV (Bay of Biscay) and Region V (Wider Atlantic), the ranking of contributing sectors, measured in terms of oxidized nitrogen deposition reduction, is similar but with Sector 8 at the top:

Sector 8: Other mobile sources and machinery
Sector 7: Road transport
Sector 1: Combustion in energy and transformation industry
Sector 3: Combustion in manufacturing industry
Sector 2: Non-industrial combustion plants
Sector 4: Production processes

Since the deposition of reduced nitrogen is practically not affected by the reductions of oxidized nitrogen emissions in the sectors, the contribution ranking for total nitrogen deposition is the same as for oxidized nitrogen deposition.

The reduction of annual oxidized, reduced and total nitrogen deposition (in percent of initial values) in the five main OSPAR regions, which is due to a 25 % reduction in ammonia and VOC emissions in each of the 10 SNAP sectors in the year 2000, is shown in Figures 41, 42 and 43, respectively. Corresponding numerical values are shown in Tables 18, 19 and 20.

In this case, the reduction of ammonia and VOC (Volatile Organic Compounds) emissions in individual sectors mainly affects deposition figures of reduced and total nitrogen in all main OSPAR regions. The effects on deposition of oxidized nitrogen are negligible.

The effects of ammonia and VOC emission reductions in all sectors, except sector 10 (agriculture), are very small and practically negligible for all kinds of nitrogen deposition because ammonia emissions from sector 10 account for more than 70% of the total ammonia emissions. The largest reductions in the deposition of reduced (Figure 42) and total (Figure 43) nitrogen due to emission reduction in sector 10 was observed in Region III (Celtic Seas), only slightly lower reductions in Regions II (Greater North Sea) and IV (Bay of Biscay), and definitely smaller in Regions I (Arctic Waters) and V (Wider Atlantic).

The reduction in annual oxidized, reduced and total nitrogen deposition (in percent of initial values) in the 13 sub-regions of the main OSPAR Region II, which is due to a 25 % reduction in nitrogen oxides emissions in each of the 10 SNAP sectors in the year 2000, is shown in Figures 44, 45 and 46, respectively. Corresponding numerical values are shown in Tables 21, 22 and 23.

As for the main OSPAR regions, the reduction of nitrogen oxides emissions in individual sectors mainly affected deposition of oxidized and total nitrogen in all sub-regions of OSPAR Region II (Greater North Sea). The effects on deposition of reduced nitrogen were negligible. Also the ranking of the emission sectors which contribute to reduced and total nitrogen deposition in all sub-basins of the Greater North Sea was similar as for the main OSPAR regions:

Sector 7: Road transport
Sector 8: Other mobile sources and machinery
Sector 1: Combustion in energy and transformation industry
Sector 3: Combustion in manufacturing industry
Sector 2: Non-industrial combustion plants
Sector 4: Production processes

The reduction of annual oxidized, reduced and total nitrogen deposition (in percent of initial values) in the 13 sub-regions of the main OSPAR Region II, which is due to a 25 % reduction in ammonia and VOC emissions in each of the 10 SNAP sectors in the year 2000, is shown in Figures 47, 48 and 49, respectively. Corresponding numerical values are shown in Tables 24, 25 and 26.

As for the main OSPAR regions, the effects of ammonia and VOC emission reductions in all sectors, except sector 10 (agriculture), were very small, and practically negligible, for all kinds of nitrogen deposition in all sub-regions of OSPAR Region II (Greater North Sea).

2.8 Possible Uncertainties

A precise estimation of uncertainties in measurements, emission data and model results is always very difficult and, in some cases (e.g. source-receptor matrices), not possible at all. Therefore, in this section, comments are made only on uncertainties related to the data presented in the present report.

The uncertainties in the emissions lead to inaccuracies in the modelling of chemical transformation, deposition processes and transport. The regions Wider Atlantic and Artic Waters are close to the model domain boundary and thus the deposition here is largely affected by the boundary conditions. In the EMEP model, these conditions are based on observations. However, there is a large span in reported observations of, for example, ammonium and nitrate over the Atlantic Ocean, and therefore the accuracy in the estimation of contribution from the boundary condition values is uncertain.

However, comparisons of modelled and measured concentrations and deposition of nitrogen at stations scattered around Europe show that the annual average of most stations are computed within a factor of two (e.g. Fagerli *et al*., 2003).

Concerning computed concentrations and deposition of nitrogen, a typical value of uncertainty is 30 % (EMEP, 2002), but in some cases differences between measured and computed values can be much larger. Such a comparison of computed and measured wet deposition of nitrogen compounds is given in the next paragraph. The problem is more difficult when the uncertainty of the source-receptor relations is to be estimated. In case of nitrogen, such an analysis has not been done. In addition, computed source-receptor relationships cannot be compared with measurements because such measurements do not exist.

The EMEP model grid does not cover the entire area of the main OSPAR Region V (Wider Atlantic) (see Figure 1). The missing part in the South corresponds to 23 EMEP grid cells. This is a source of uncertainty which leads to a small underestimation of the computed nitrogen deposition in Region V. Assuming that deposition in the missing grid cells was not higher than deposition in the adjacent EMEP grid cells, the amount of deposition in the missing grids could be estimated not to exceed 30 tonnes for oxidized and reduced nitrogen and 60 tonnes for the total nitrogen. These values are lower than 0.1 % of the corresponding deposition in Region V.

3. Agreed International Reduction Measures for Nitrogen Emissions

3.1 Monitoring / EMEP

Transboundary air pollution within Europe is monitored under EMEP (European Monitoring and Evaluation Programme) by a network of more than 1000 stations in 25 countries. EMEP is monitoring, *inter alia*, atmospheric emissions of NO_x and NH_3 which are relevant for the work of the OSPAR Eutrophication Committee (EUC). EMEP provides figures on emissions from all sectors and deposition totals for individual nitrogen species. On the basis of the data delivered, EMEP develops balances on inputs and outputs per Contracting Party with respect to emitted and received pollutants, thereby demonstrating which country "hurts" the other and vice versa. Furthermore, comparable deposition figures are presented for maritime areas like the North Sea, Baltic Sea and the Atlantic.

3.2 National Emission Ceilings / Ambient Air Quality

There are three initiatives to limit national emission loads in Europe:

a. the Convention on Long-range Transboundary Air Pollution of the United Nations Economic Commission for Europe from 1979 (UNECE LRTAP);
b. the EC NECs Directive (Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants), and;
c. the Ambient Air Directive (Directive 96/62/EC on ambient air quality assessment and management) and the related Daughter Directive 1999/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air.

The centrepiece of regulations (a) and (b) are national ceilings for emissions (NECs) of major air pollutants including nitrogen (NO_x and NH_3). The NECs are linked to specific environmental targets and should be attained by the year 2010 at the latest. The ambient air directives (c) require that EU Member States shall take the measures necessary to ensure that concentrations of nitrogen dioxide and, where applicable, of oxides of nitrogen, in ambient air do not exceed the limit values laid down in Directive 1999/30/EC by July 2001 and January 2010, respectively.

The emission ceilings laid down in Annex 1 of the EC NECs Directive, and in the UNECE Protocol for NO_x and NH_3 (to be attained by 2010) as well as the reduction percentage compared to 1990 figures are presented in Tables a and b below.

Table a: Emission Ceilings for Nitrogen Oxides (kT NO_2 per year) under the UNECE Protocol for NO_x and NH_3 and under the EC NECs Directive 1999/30/EC

NO_x (as NO_2)	Emission levels 1990	UN ECE emission ceilings for 2010	% of reductions	EC NECs emission ceilings for 2010	% of reductions
Belgium	339	181	-47	176	-48
Denmark	782	127	-55	127	-55
Finland	300	170	-43	170	-43
France	1882	860	-54	810	-57
Germany	2693	1081	-60	1051	-61
Iceland*	–	–	–	–	–
Ireland	115	65	-43	65	-43
Luxembourg	23	11	-52	11	-52
Netherlands	580	266	-54	260	-55
Norway*	218	156	-28	–	–
Portugal	348	260	-25	250	-28
Spain	1113	847	-24	847	-24
Sweden	338	148	-56	148	-56
Switzerland*	166	79	-52	–	–
United Kingdom	2673	1181	-56	1167	-56

Note: ' – ' indicates emission ceilings not relevant for countries with asterisk.

Table b: Emission Ceilings for Ammonia (kT NH_3 per year) under the UNECE Protocol for NO_x and NH_3 and under the EC NECs Directive 1999/30/EC

NH_3	Emission levels 1990	UNECE emission ceilings for 2010	% of reductions	EC NECs emission ceilings for 2010	% of reductions
Belgium	107	74	-31	74	-31
Denmark	122	69	-43	69	-43
Finland	35	31	-11	31	-11
France	814	780	-4	780	-4
Germany	764	550	-28	550	-28
Iceland*	-	-	-	-	-
Ireland	126	116	-8	116	-8
Luxembourg	7	7	0	7	0
Netherlands	226	128	-43	128	-43
Norway*	23	23	0	-	-
Portugal	98	108	+10	90	-8
Spain	351	353	+1	353	+1
Sweden	61	57	-7	57	-7
Switzerland*	72	63	-13	-	-
United Kingdom	333	297	-11	297	-11

There are eight protocols to the UNECE LRTAP Convention. Relevant for nitrogen emissions are the 1988 NO_x Protocol (Sofia Protocol) and the 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol). The latter sets emission ceilings for, *inter alia*, NO_x and ammonia. Once the Protocol is fully implemented, Europe's NO_x emissions should be cut by 41 % and its ammonia emissions by 17 % compared to 1990. The Protocol also sets tight limit values for specific emission sources (e.g. combustion plants, electricity production, dry cleaning, traffic (cars and trucks)) and requires the use of Best Available Techniques (BAT) to keep emissions down. Farmers will have to take specific measures to control ammonia emissions. It has been estimated that, once the Protocol is implemented, the area in Europe with extensive levels of acidification will shrink from 93 million hectares to 15 million hectares. The areas with excessive levels of eutrophication will decrease from 165 million hectares in 1990 to 108 million hectares.

The EC NECs Directive covers emissions in the territory of the EU Member States and their exclusive economic zones from all sources which arise as a result of human activities except:

a. emissions from international maritime traffic;

b. aircraft emissions beyond the landing and take-off cycle;

c. for France, Spain and Portugal, emissions in the overseas territories, the Canary Islands, and Madeira and the Azores, respectively.

During the implementation of the EC NECs Directive, EU Member States presented their plans for national programmes to the European Commission, including estimates on the feasibility to attain the agreed goals by 2010 at the latest. These reports can be obtained via http://europa.eu.int/comm/environment/air/ceilings.htm. In 2006, Member States shall investigate, and possibly revise, their programmes. The Directive also foresees a reconsideration of the emission ceilings (with a view to their possible strengthening) before 2010 with regard to whether they suffice to ensure that the Directive's goals are achieved. Yearly reports on emissions shall be delivered by the EU Member States to the European Commission (deadline 31 December). The Commission made available a further study on air quality impacts of emissions from aviation.

According to the ambient air directives, Member States will have to prepare national programmes showing how the limit values will be met on time for those areas where attainments by "business as usual" cannot be presumed. These programmes must be made directly available to the public, and must also be sent to the European Commission. To facilitate a harmonized and structured way of reporting, detailed arrangements for Member States to submit the information on plans and programmes are laid down in Commission Decision 2004/224/EC.

3.3 Other Relevant Developments in the EC / Europe on Emissions to Air

3.3.1 Large Combustion Plants

The review of the 1988 EC Directive for large combustion plants (88/609/EC) resulted in the adoption of the new Directive on large combustion plants (2001/80/EC) in September 2001. The new Directive contains emission limit values for amongst others NO_x. The limit values are more stringent for all distinguished categories of installations (built before 1988, between 1988 and 2001, and after 2001) than in the former Directive. The European Commission is preparing a further review relating to the Large Combustion Plants Directive; the final report (July 2005) for consideration by the European Commission, with a lot of quantitative information, is available on the web site of DG Environment.

3.3.2 Incineration of Waste

The new Directive 2000/76/EC on the incineration of waste covers the incineration of hazardous and non-hazardous waste. This Directive aims at preventing or – where this is not practicable – reducing, as far as possible, negative effects on the environment (including marine and fresh water ecosystems) caused by the incineration and co-incineration of waste. This shall be achieved through stringent operational conditions and technical requirements and by setting up emission limit values for waste incineration plants. The emission limit values for NO and NO_2, as set out in Annex V of the Directive, shall not be exceeded.

3.3.3 Large Industrial Installations

a. IPPC Directive

The EU has a set of common rules for granting operation permits to large industrial installations. These rules are set out in Directive 96/61/EC concerning intergrated pollution prevention and control (the "IPPC Directive"). In essence, the IPPC Directive is about minimising pollution of the environment (amongst others air) from various point sources. All installations covered by *Annex I* of the Directive are required to obtain an authorisation (permit) from the authorities in the EU countries; for nitrogen emissions to air the main relevant sectors included are: intensive livestock farming, large combustion plants, refineries and large volume inorganic chemicals (ammonia, acids and fertilisers). The permits must be based on the concept of *Best Available Techniques* (*BAT*). The Directive aims at harmonising the procedures and requirements for granting operation permits in the European Union and contains basic rules for integrated permits. "Integrated" means that the permits must take into account the *whole* environmental performance of the plant, i.e. emissions to air, water and soil, generation of waste, use of raw materials, energy efficiency, noise, prevention of accidents, risk management, etc. By the end of October 1999, the EU Member States had to adjust their national legislation to comply with the Directive. Since October 1999, the Directive applies to all *new* installations as well as to existing installations which undergo substantial changes and are, therefore, subject to an environmental impact assessment (under Directive 85/337/EEC) because they may have significant negative effects on human beings or the environment. The Directive does not immediately apply to other *existing* installations. They were granted an additional period of grace of 8 years.

b. BREF

To give guidance to the licensing competent authorities on what is considered as BAT, the European Commission produces BAT Reference Documents (BREFs) for all sectors. The relevant BREFs for nitrogen emissions to air have not been finalised in total: the BREF for refineries was adopted in February 2003; the BREF for intensive livestock farming was adopted in July 2003; the development of BREFs for large combustion plants (final draft in November 2004) and large volume inorganic chemicals (ammonia, acids and fertilisers, most recent draft of March 2004) is still in progress. While the BREFs are intended to assist the permit granting national authorities, the final decision should still lie with these authorities, because Article 9 of the IPPC Directive establishes that they must take into account (a) the technical characteristics of the installation, (b) its geographical location and (c) the local environmental conditions. This very decentralised approach is counterbalanced by the fact that, according to Article 18 of the IPPC Directive, there are also cases where common and fixed EU emission limit values are justified.

c. EPER

The IPPC Directive also provides for the setting up of a European Pollutant Emission Register (EPER). On 17 July 2000, the European Commission adopted Decision 2000/479/EC on the implementation of an European Pollutant Emission Register (EPER) according to Article 15 of the IPPC Directive. National governments of all EU Member States are required to maintain inventories of emission data from specified industrial sources and to report emissions from individual facilities to the European Commission. The inventory concerns amongst others emissions to air of N_2O, NH_3, NMVOC and NO_x. The reported data is made accessible in the public register EPER, which is intended to provide environmental information on major industrial activities. EU Member States were required to submit their first report in June 2003; these reports covered emissions in 2001. The next report is due in June 2006 and will cover emissions in 2004.

The 2001 EPER results for the EU 15 can be summarised as follows (and can also be presented on a country-by-country basis):

Total NO_x emissions to air by EU15 IPPC plants in 2001: 3000 kt

Contribution to total in %	**Sector**
64%	Combustion installations
15%	Installations for the production of cement clinker, lime, glass, mineral substances
6%	Mineral oil and gas refineries
6%	Metal industry
2%	Basic organic chemicals
7%	Others

Total NH_3 emissions to air by EU15 IPPC plants in 2001: 110 kt

Contribution to total in %	**Sector**
77%	Installations for poultry, pigs or sows
12%	Basic inorganic chemical production
3%	Installations for the production of cement clinker, lime, glass, mineral substances
3%	Basic organic chemicals
2%	Pulp and paper production
4%	Others

3.3.4 Emissions from Seagoing Ships

In November 2002, the European Commission adopted a European Union Strategy to reduce atmospheric emissions from seagoing ships (COM(2002) 595 final). The Strategy reports on the magnitude and impact of ship emissions in the EU and sets out a number of actions to reduce the contribution of shipping to, among others, acidification and eutrophication. Air pollutant emissions from ships are also covered by Annex VI of the Marine Pollution Convention, MARPOL 73/78 of the International Maritime Organisation (IMO). This contains provisions on NO_x emissions standards for ships' engines. The new EU Strategy seeks to press for tighter NO_x standards than the IMO standards and to urge Member States to bring forward ratification of this important IMO instrument on air pollution. MARPOL Annex VI received its 15th ratification on 18 May 2004, and therefore finally entered into force on 19 May 2005. The European Parliament and the Council finalised their positions on the ships' emissions strategy in December 2003. The Council urged EU Member States to submit concrete proposals on tighter NO_x standards under MARPOL Annex VI. The Council recognised the need to investigate specific EU actions with respect to the reduction of NO_x by marine transportation and invited the European Commission to consider a proposal for tighter NO_x standards by the end of 2006 if IMO has not made any proposals for tighter standards by that date.

3.3.5 Clean Air for Europe

Clean Air for Europe (CAFE) is a programme of technical analysis and policy development to prepare a thematic strategy on air pollution under the Sixth Environmental Action Programme which was supposed to be adopted by mid-2005. The major elements of the CAFE programme are outlined in the Communication on CAFE (COM(2001) 245 final)). The programme was launched in March 2001. Its aim is to develop a long-term, strategic and integrated policy advice to protect human health and the environment against significant negative effects of air pollution. The integrated policy advice from the CAFE programme was supposed to be ready by the beginning of 2005. The European Commission was supposed to present its Thematic Strategy on Air Pollution during the first half year of 2005, outlining the environmental objectives for air quality and measures to be taken to achieve these objectives.

3.3.6 Agriculture

Agriculture is the largest contributor with regard to ammonia emissions. A significant reduction of these emissions cannot be achieved with technical measures for stables alone. Reduction measures have to address changes in production processes and restrictions in production. These measures would include:

- reform of the Common Agricultural Policy;
- promotion of organic farming;
- recommendation of codes for good agricultural practice;
- elaboration of recommendations for BAT for plants not subject to approval;
- promotion of reduction of lifestock;
- agri-environmental measures;
- promotion of introduction of techniques to reduce ammonia emissions.

3.3.7 Reduction of atmospheric nitrogen emissions

A far reaching reduction of atmospheric nitrogen emissions can only be achieved by a whole range of measures in different sectors in particular traffic, including shipping, industrial installations and power plants, private households and agriculture.

4. Conclusions and Recommendations

4.1 Monitoring of Atmospheric Nitrogen in Europe

Transboundary air pollution in Europe, including nitrogen, is monitored under EMEP (European Monitoring and Evaluation Programme) by a network of more than 1000 stations in 25 countries. EMEP is monitoring, *inter alia*, atmospheric emissions of NO_x and NH_3 which are relevant for the work of EUC. EMEP provides figures on emissions from all sectors and deposition totals for individual nitrogen species. On the basis of the data delivered, EMEP develops balances on inputs and outputs per Contracting Party with respect to emitted and received nitrogen, thereby demonstrating which country “hurts” the other and vice versa. Furthermore, comparable deposition figures are presented for maritime areas like the North-East Atlantic, including the North Sea, and the Baltic Sea.

4.2 Nitrogen Emissions

Emission inventories for all EMEP Parties (including OSPAR Contracting Parties) are available on a yearly basis within the EMEP programme and should be used for reporting to OSPAR.

International ship traffic on the OSPAR Convention waters is the largest single source of NO_2 emissions. Nevertheless the data with regard to these emissions are far from being satisfactory. The latest official data available are from 1990. There is an urgent need to improve the emission data from this sector.

4.3 Nitrogen Deposition

Deposition data for nitrogen are available from EMEP. There was a need to adapt the existing EMEP model for calculating nitrogen deposition to the OSPAR maritime area. Therefore the OSPAR Convention area was divided into the main OSPAR Regions I – V (Arctic Waters, Greater North Sea, Celtic Seas, Bay of Biscay, Wider Atlantic) according to the latest Quality Status Report 2000. Region II (the Greater North Sea) is further divided into 13 sub-regions according to the ICES boxes. In the course of the work on this overview report, a comparison of modelled and measured nitrogen deposition at the OSPAR coastal monitoring stations was carried out and showed good agreement.

This work provided an appropriate spatial resolution and data quality to answer OSPAR requests on deposition data on an overall as well as on a regional basis which should therefore be used for future assessments e.g. on the eutrophication status of the OSPAR maritime area.

EMEP data on atmospheric nitrogen (emissions and deposition) should be used to a much larger extent.

4.4 Source-receptor Interrelations

EMEP can provide information on source-receptor interrelations in a way to demonstrate where nitrogen deposition in a certain OSPAR region has its origin with regard to emissions. This important information should be used during discussions on the effectiveness of agreed international measures that could contribute to achieving the 2010 objective of the OSPAR Eutrophication Strategy and the European Marine

Startegy under preparation and whether there is a need for any additional measures.

4.5 Eutrophication Assessment According to the OSPAR Common Procedure

From the first application of the Comprehensive Procedure of the Common Procedure for the identification of the eutrophication status of the OSPAR maritime area it became obvious that atmospheric nitrogen input plays a major role for some regions (in particular coastal regions). It is recommended to consider how this deficit in the existing eutrophication assessment should be remedied for example with regard to the next application of the Comprehensive Procedure. In that assessment, the results of the recent EMEP report should be taken into account. For future applications of the Comprehensive Procedure an update of this EMEP report is recommended.

4.6 Integrated Assessment

EMEP data on atmospheric nitrogen emissions and deposition in conjunction with OSPAR data on riverine (and direct) nutrient inputs and concentrations associated with further assessment parameters for eutrophication should be used for an integrated assessment. This can, for example, assist in appraising the implementation of the OSPAR Eutrophication Strategy (see also §§ 3.5(b), 5.3 and 6 thereof).

This future OSPAR work would be facilitated by similar reporting on atmospheric nitrogen at the same time as reporting on PARCOM Recommendation 88/2. In this context it is recommended to make use of the results of EMEP and EPER and regular reporting under relevant EC Directives (e.g. EC-NECs Directive) and international conventions (e.g. UNECE LRTAP, United Nation Framework Convention on Climate Change (UNFCCC)) when assessing the effectiveness of measures to combat eutrophication. Any improvement of data on nitrogen emissions from shipping should be addressed as well.

For any comprehensive assessment of the ecological status of the relevant parts of the OSPAR maritime area under the EC Water Framework Directive and the European Marine Strategy, presently under preparation, there is a need to prepare an **integrated assessment** which covers the whole spectrum of considerations relating to nitrogen in the maritime area, i.e. **effects – concentrations – inputs – pathways – sources/sectors**. In addition, any factors which can influence impacts, concentrations or loads, such as anthropogenic activities and controls, remobilisation, degradation, sinks and the possibility of synergistic effects could be taken into account.

The *Joint Assessment of inputs and concentrations of nitrogen in the German Bight* from 2002 (made available in 2002 to OSPAR Working Groups) showed the feasibility of a first step of such an assessment but revealed also some deficits, in particular the need for a better harmonisation between monitoring stations for inputs and respective concentrations in the sea. The outcome was that certain further improvements, like e.g. inclusion of water-borne emissions need to be carried out in future to achieve a more sophisticated joint assessment. Furthermore, atmospheric nitrogen emissions and deposition should be included to complete the assessment. For those areas where a joint (integrated) assessment with regard to nitrogen will be appropriate and beneficial, an inclusion of the results of the recent EMEP study, or any possible follow-up work in this field, should be considered.

On the basis of

- the recent EMEP report “Atmospheric Nitrogen in the OSPAR Convention Area in the period 1990-2001”;
- the next report about the implementation of PARCOM Recommendation 88/2, as well as;
- the RID and CAMP data (e.g. RID Assessment, OSPAR publication no. 233 (2005)) for nitrogen for the period 1990 to 2002,

a first overview of nitrogen releases (by emissions to air and discharges/losses to inland surface waters in conjunction with waterborne and atmospheric inputs to the maritime area) could be elaborated. These input data should be used together with time series of nitrogen concentrations in the sea for the preparation of an integrated assessment as mentioned above.

Monitoring and modelling of atmospheric nitrogen emissions and deposition are adequately covered by EMEP and can therefore be used for several OSPAR purposes mentioned here.

HELCOM presented a good first example of an assessment of riverine, direct and atmospheric sources in the catchment area and inputs to the Baltic Sea for the year 2000 (“Nutrient Pollution to the Baltic Sea in 2000”), in which the link to the concentrations and effects in the Baltic Sea is still lacking.

4.7 Co-operation with EMEP and EC

In order to facilitate a regular reporting on emissions and deposition of nitrogen in the OSPAR Convention area, and the subsequent inclusion of the information in relevant assessments, EUC is invited to establish arrangements for a further co-operation with EMEP and the European Community.

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Figures

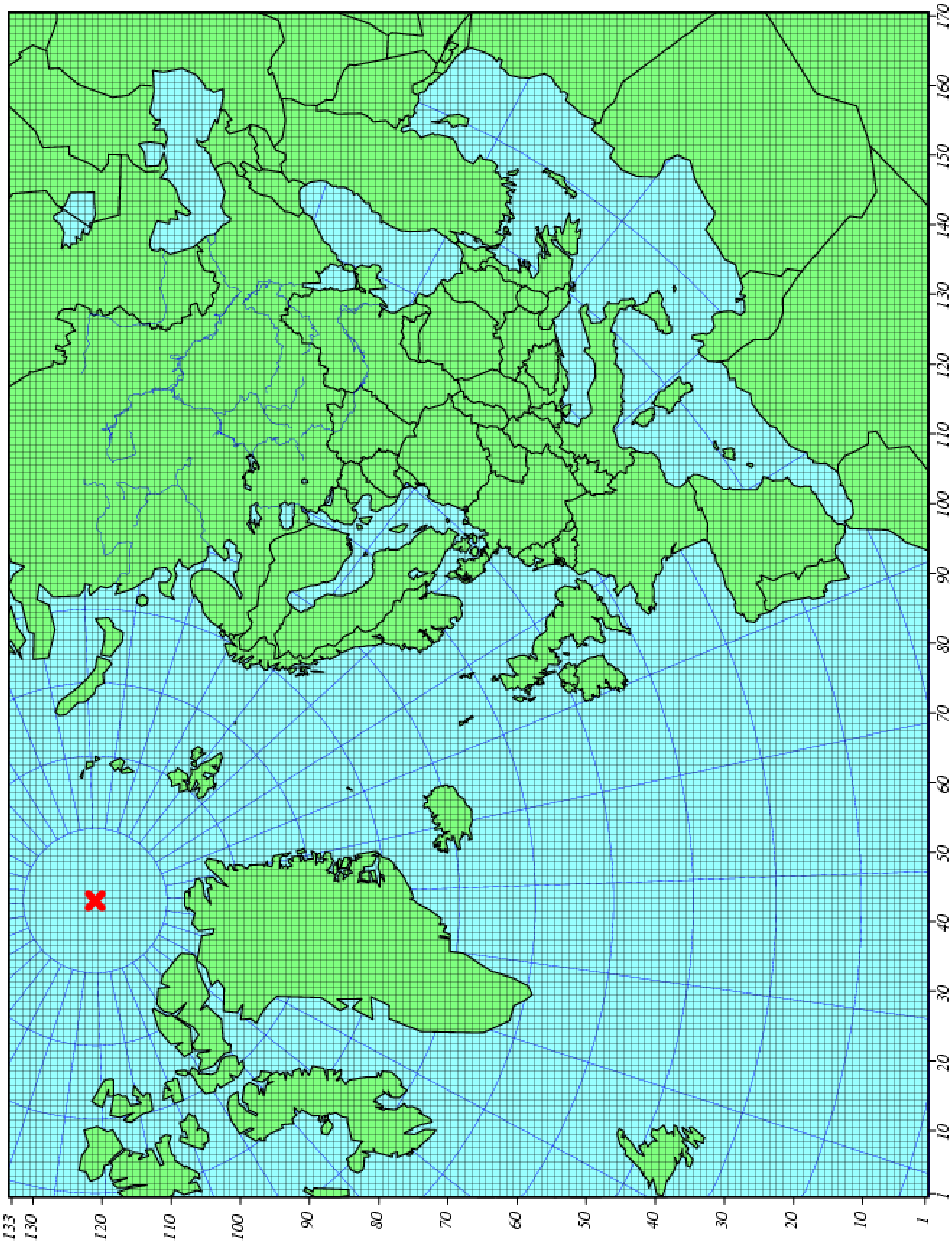

Figure 1. The EMEP grid system of the size 170 × 133 in the Polar Stereographic projection. The grid resolution is 50 km at 60^{o} N.

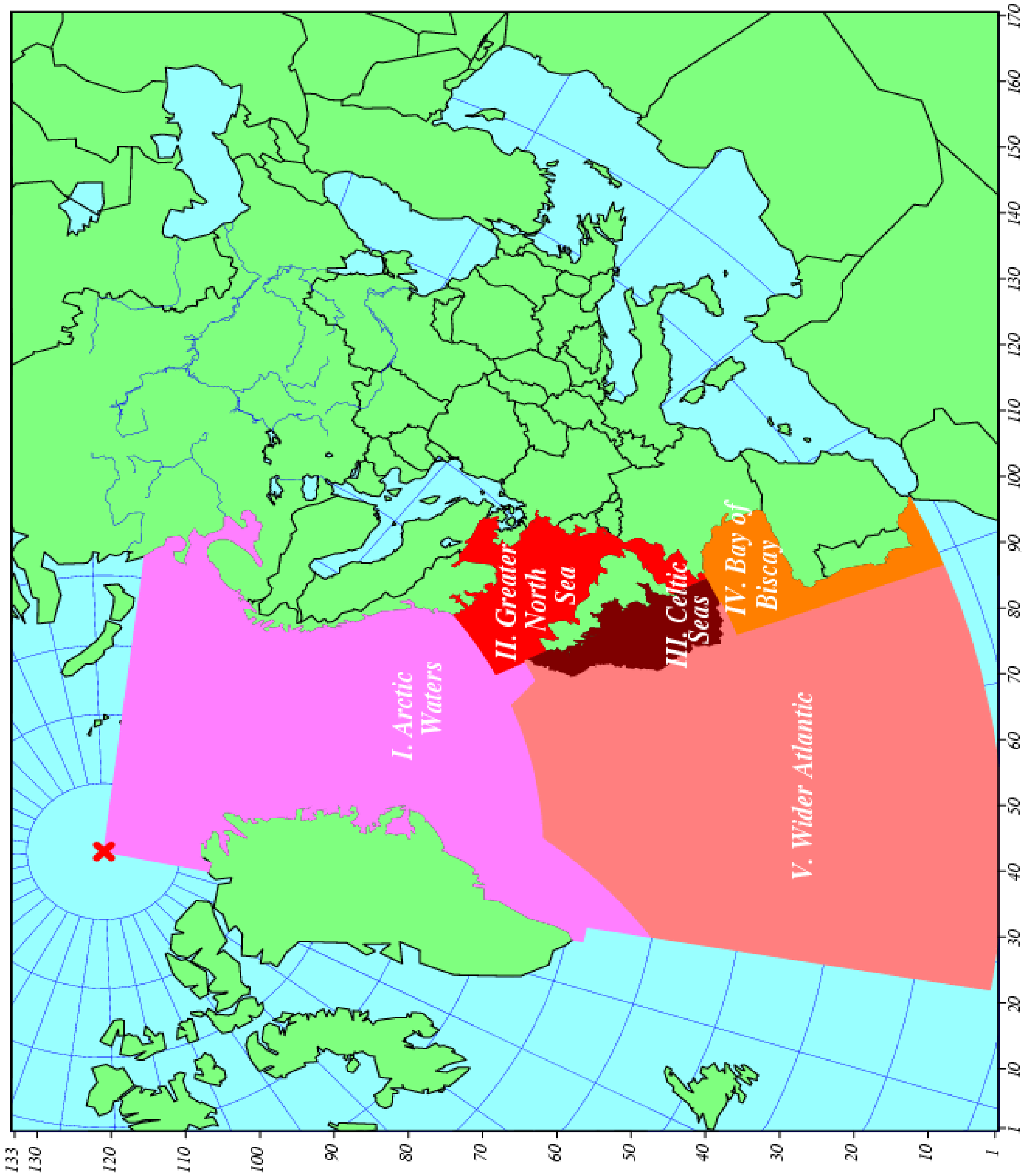

Figure 2. Borders of the five main OSPAR regions in the EMEP grid system.

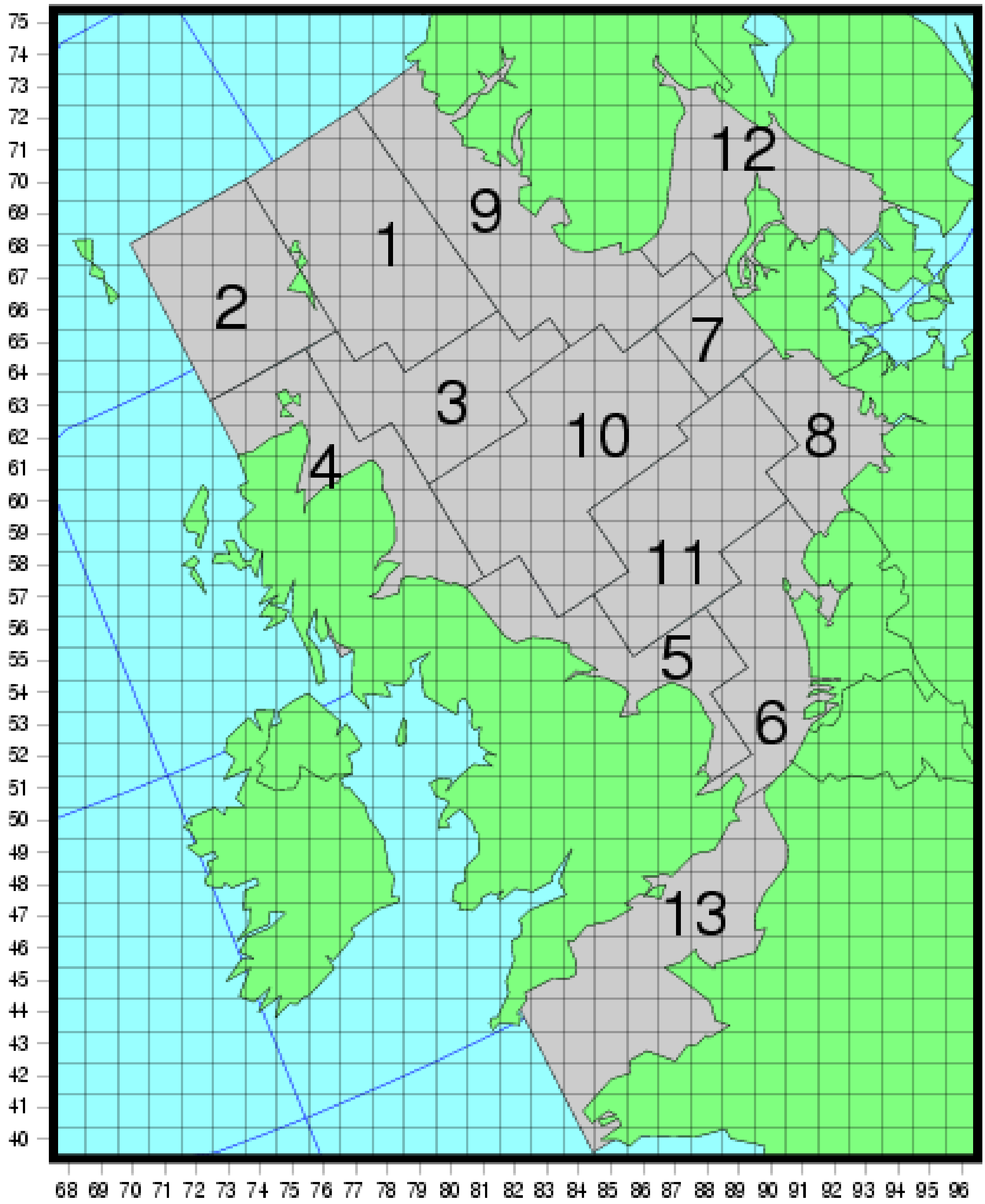

Figure 3. Borders of the 13 sub-regions of OSPAR Region II (Greater North Sea) in the EMEP grid system.

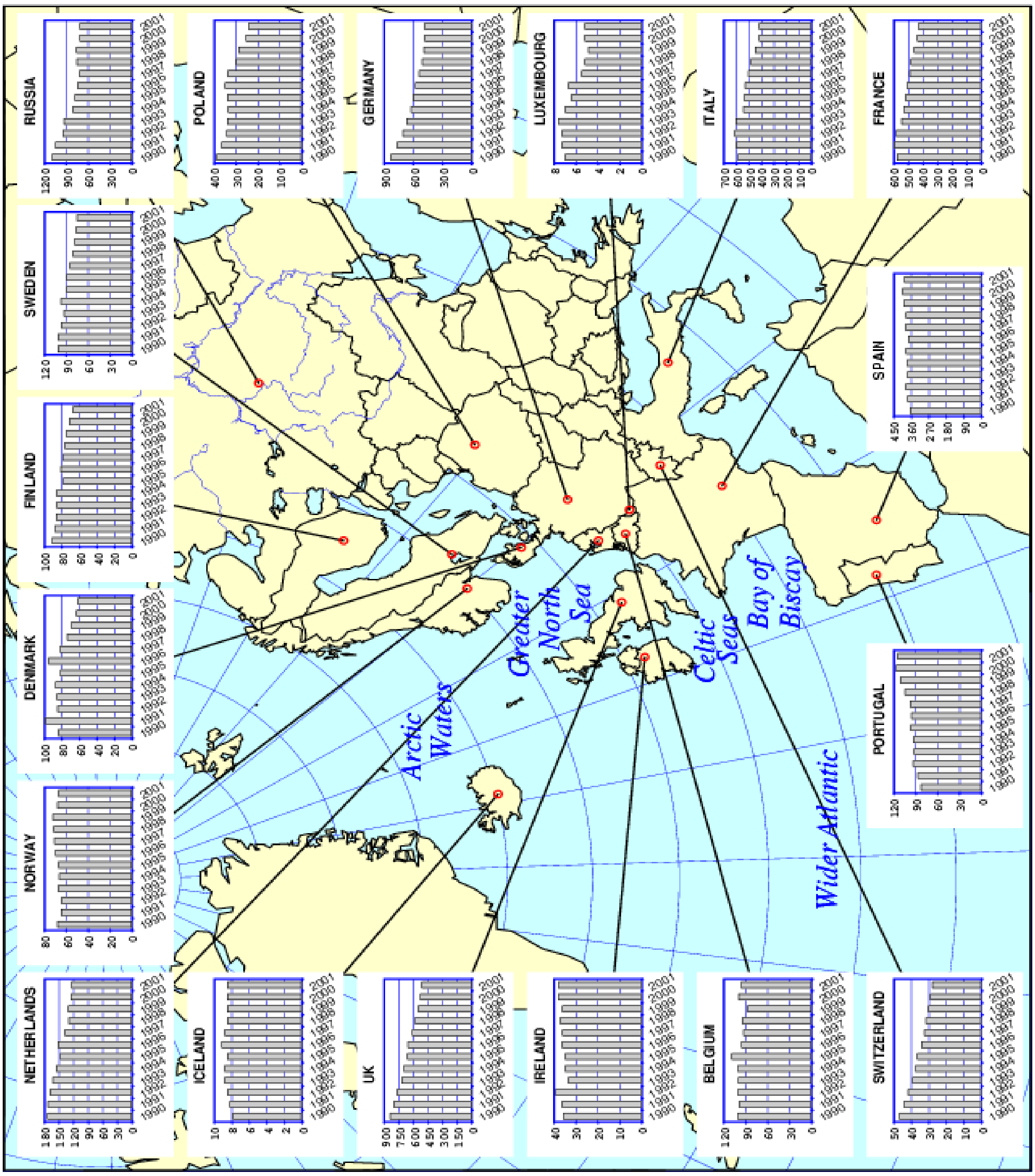

Figure 4. Time series of nitrogen oxides emissions (as NO_2) from the OSPAR Contracting Parties, and selected countries (Poland, Italy and part of the Russian Federation within the EMEP domain) with the largest contribution to deposition in the OSPAR maritime area. Unit: kt N a^{-1}. Different scales are used for emissions from different countries.

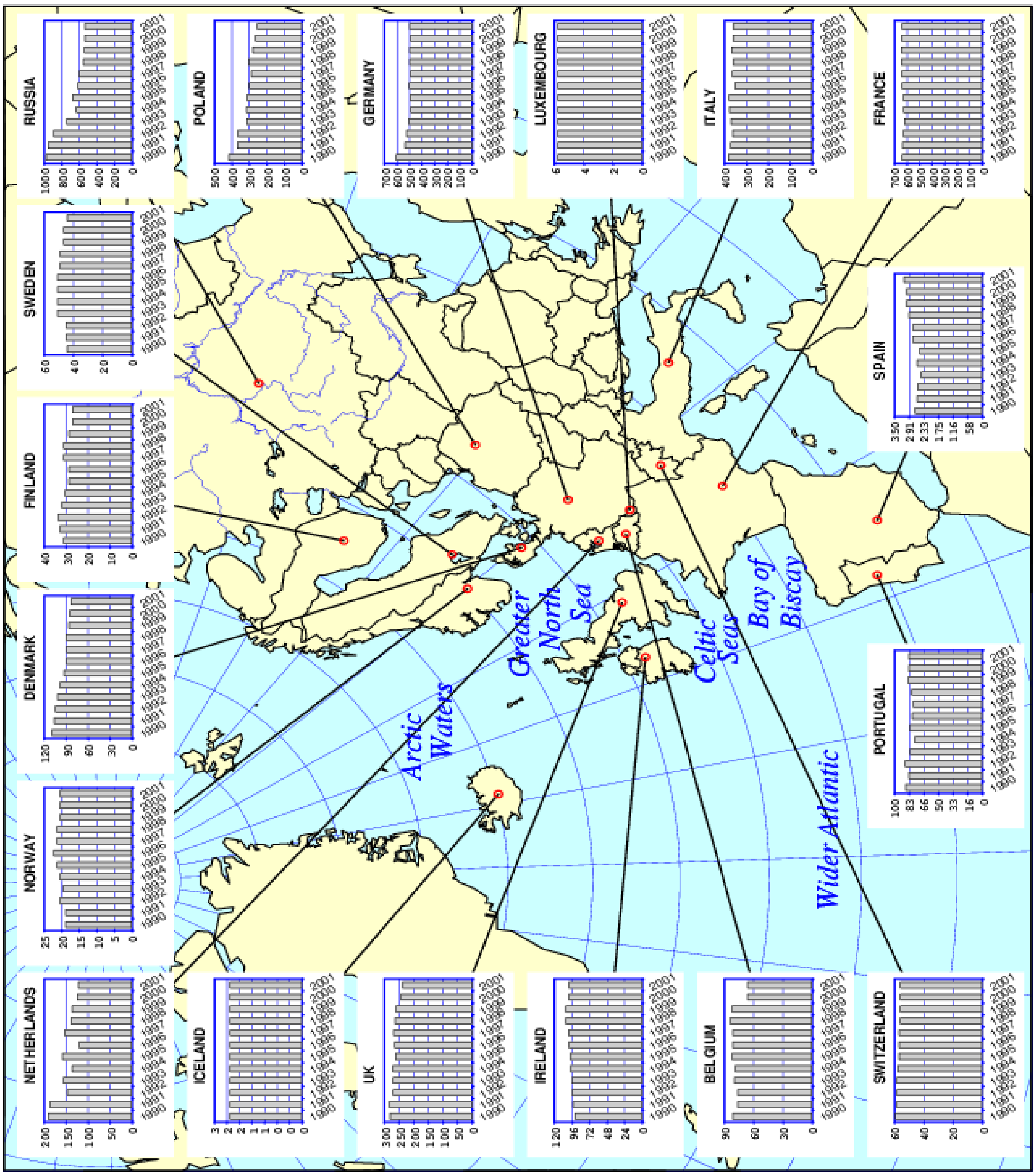

Figure 5. Time series of ammonia (NH_3) emissions from the OSPAR Contracting Parties, and selected countries (Poland, Italy and part of the Russian Federation within the EMEP domain) with the largest contribution to deposition in the OSPAR maritime area. Unit: kt N a^{-1}. Different scales are used for emissions from different countries.

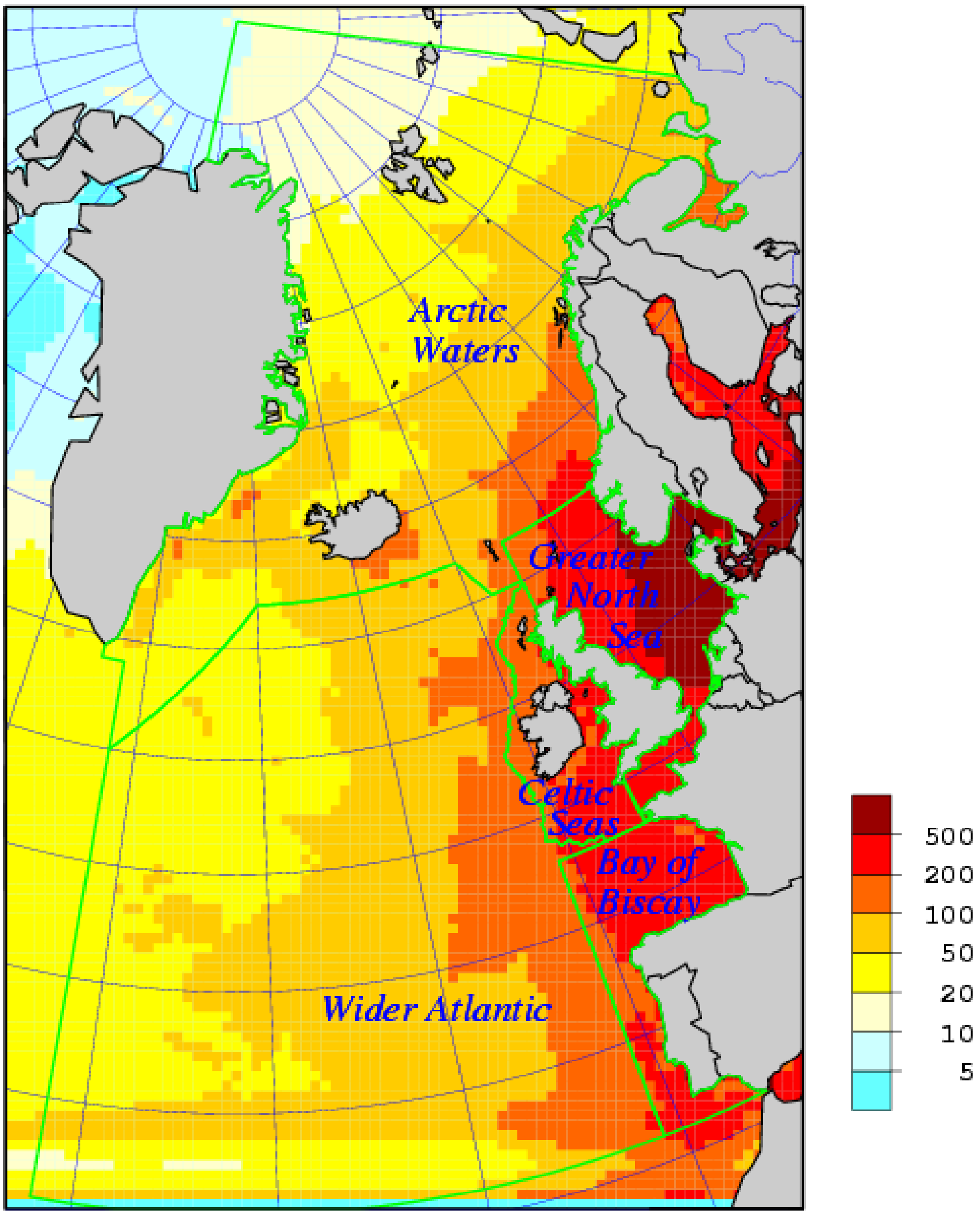

Figure 6. Map of modelled annual oxidized nitrogen deposition in the five main OSPAR regions in 1990. Unit: mg N m^{-2}.

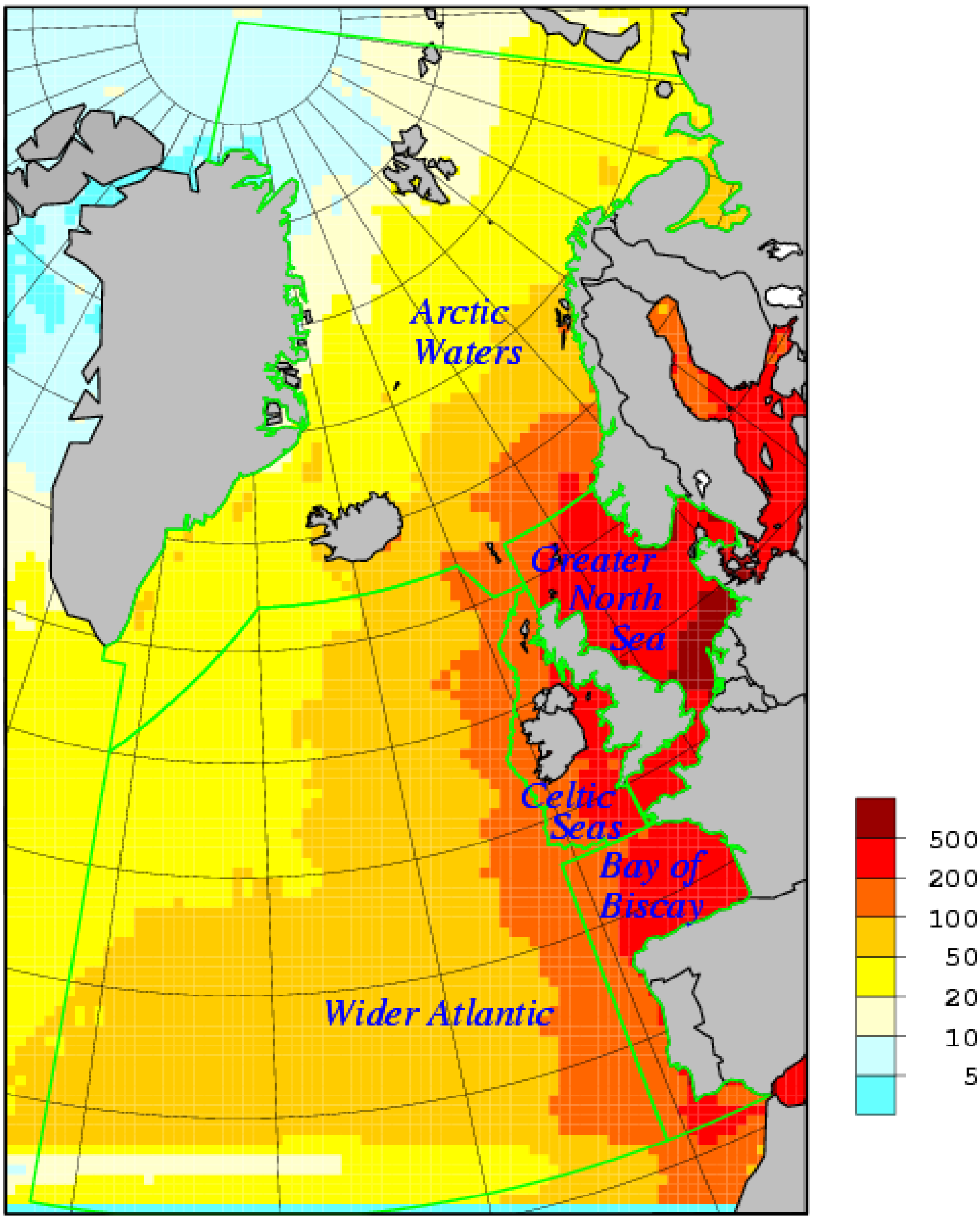

Figure 7. Map of modelled annual oxidized nitrogen deposition in the five main OSPAR regions in 2001. Unit: mg N m^{-2}.

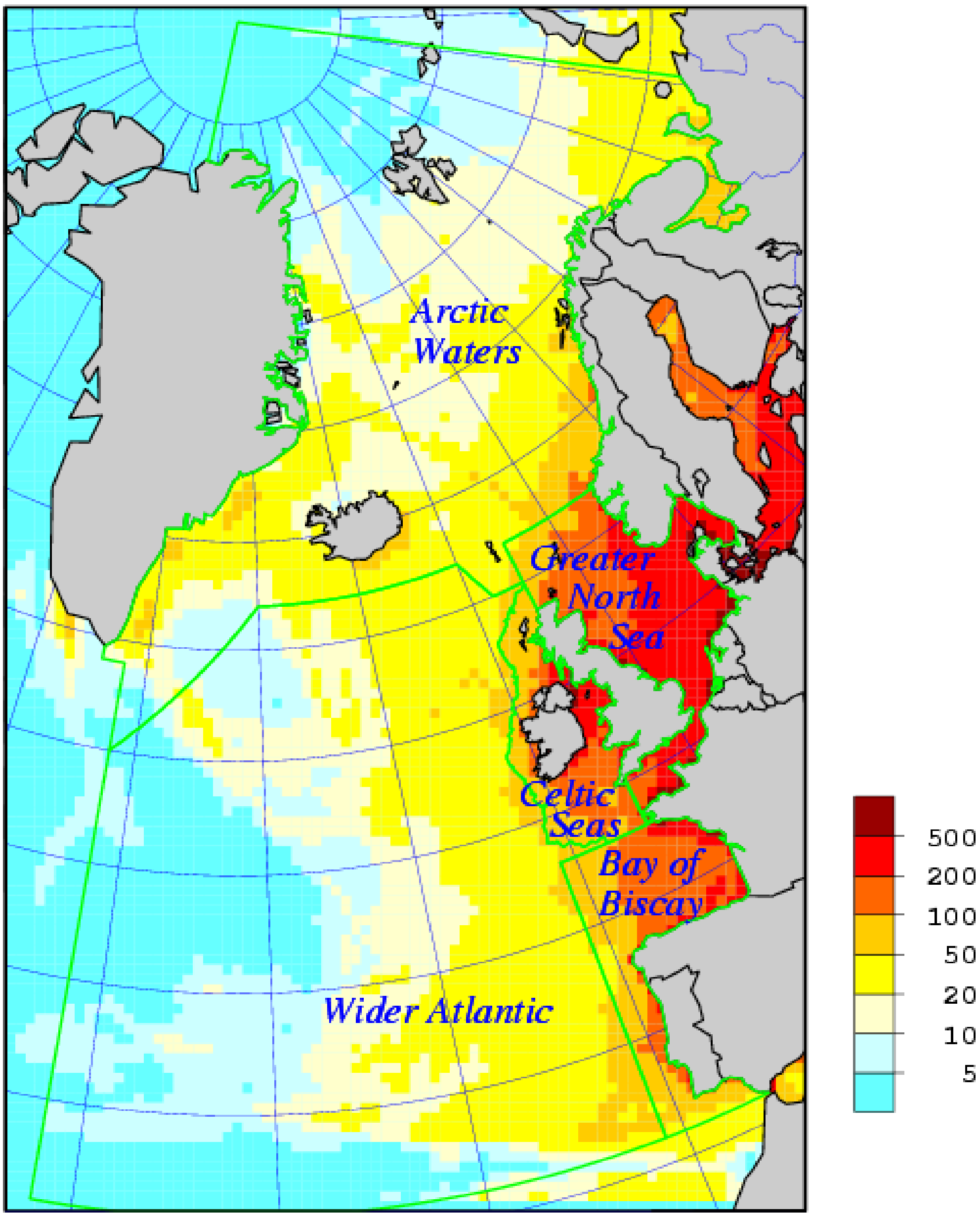

Figure 8. Map of modelled annual reduced nitrogen deposition in the five main OSPAR regions in 1990. Unit: mg N m^{-2}.

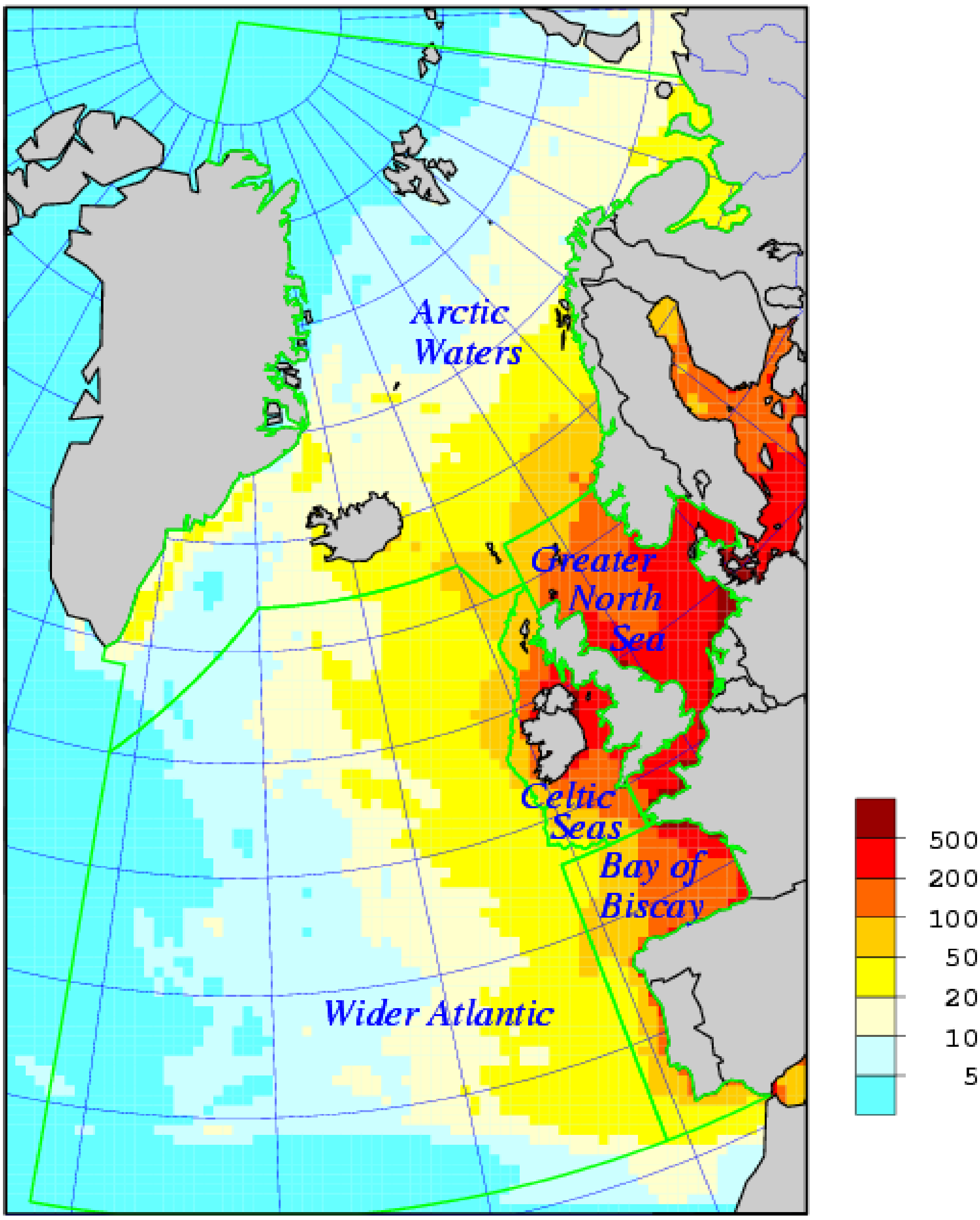

Figure 9. Map of modelled annual reduced nitrogen deposition in the five main OSPAR regions in 2001. Unit: mg N m^{-2}.

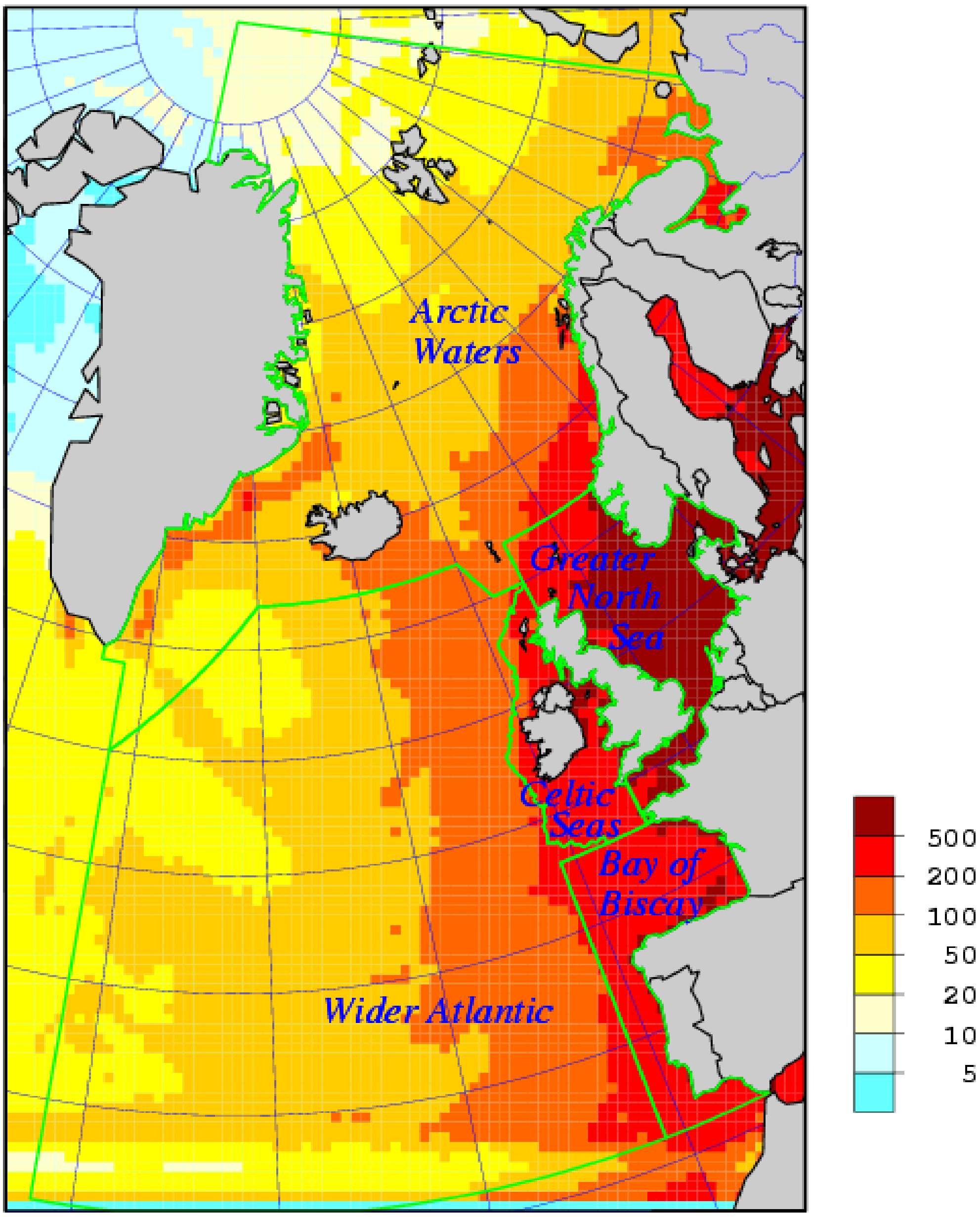

Figure 10. Map of modelled total annual nitrogen deposition in the five main OSPAR regions in 1990. Unit: mg N m^{-2}.

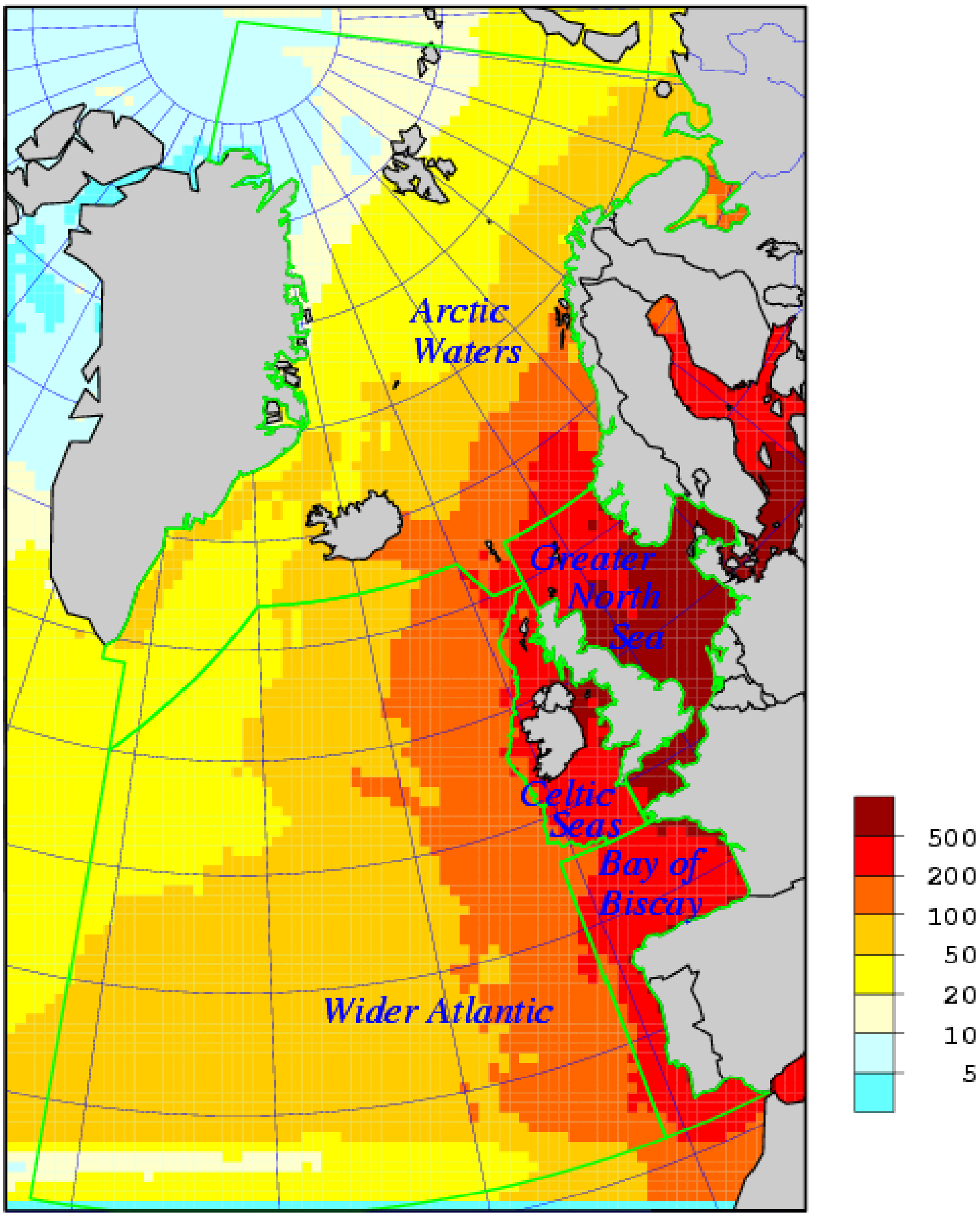

Figure 11. Map of modelled annual total nitrogen (oxidized and reduced) deposition in the five main OSPAR regions in 2001. Unit: mg N m^{-2}.

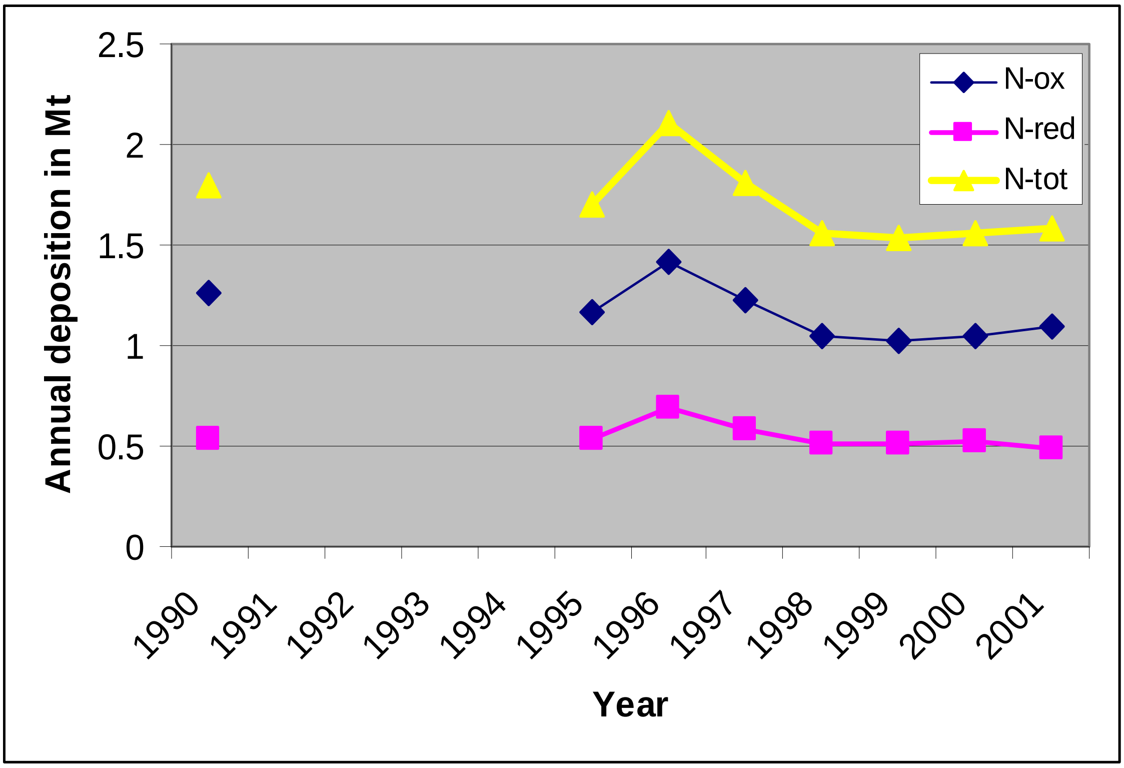

Figure 12. Annual oxidized (N-ox), reduced (N-red) and total (N-tot = N-ox + N-red) nitrogen deposition in the entire area of OSPAR Convention waters in the period 1990 - 2001. Unit: Mt N a^{-1}.

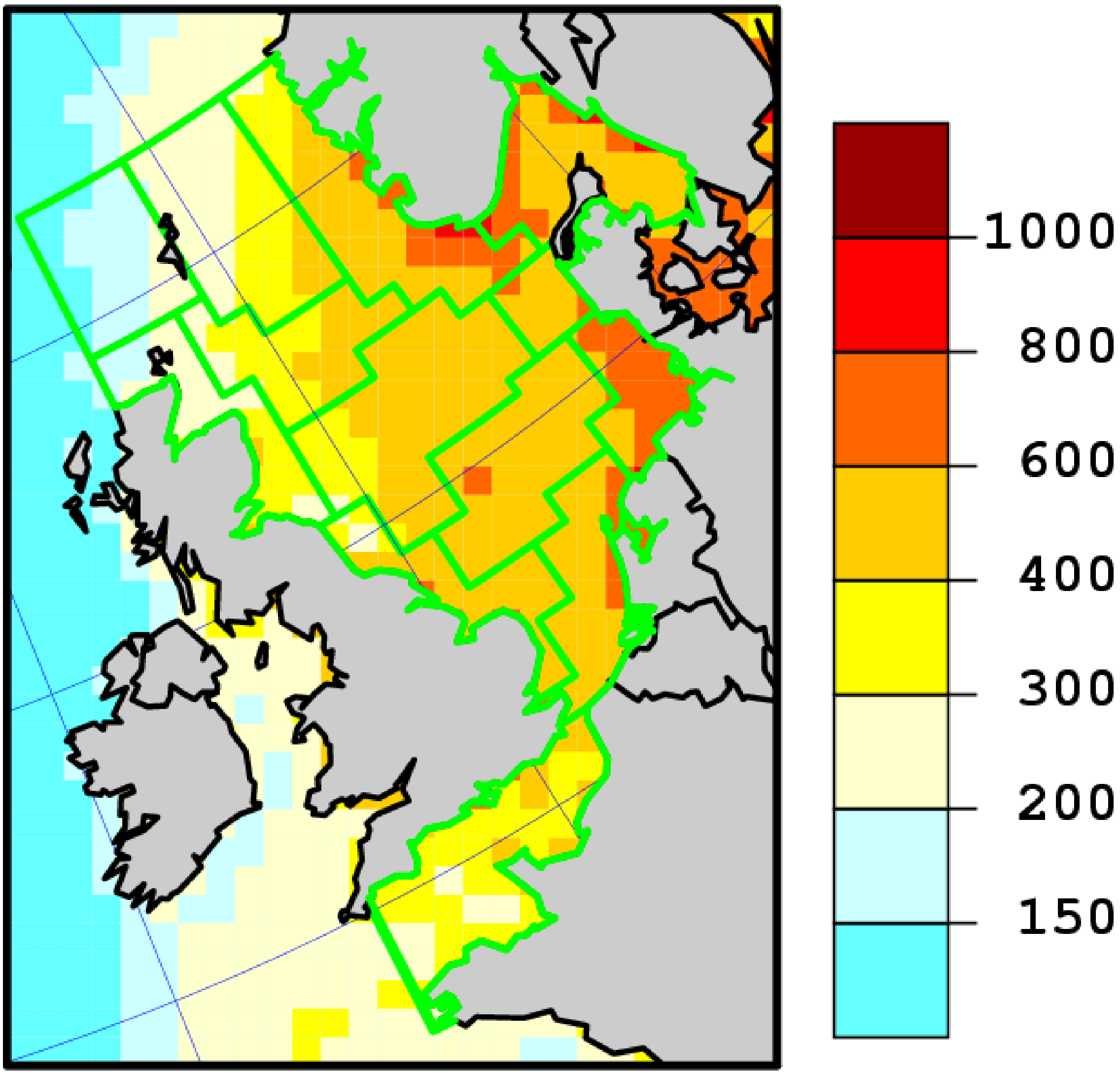

Figure 13. Map of modelled annual oxidized nitrogen deposition in 13 sub-regions of OSPAR Region II (Greater North Sea) in 1990. Unit: mg N m^{-2}.

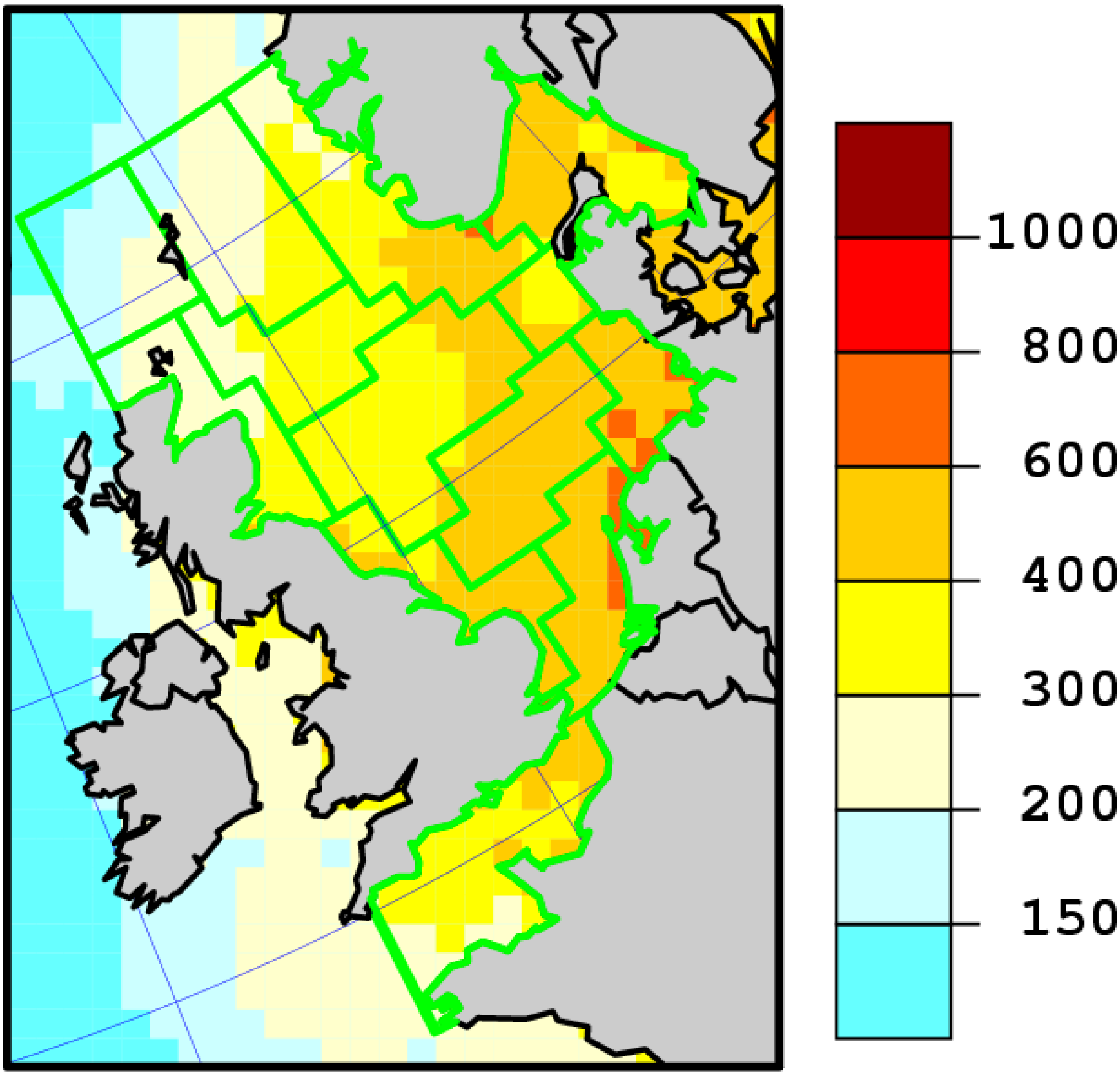

Figure 14. Map of modelled annual oxidized nitrogen deposition in 13 sub-regions of OSPAR Region II (Greater North Sea) in 2001. Unit: mg N m^{-2}.

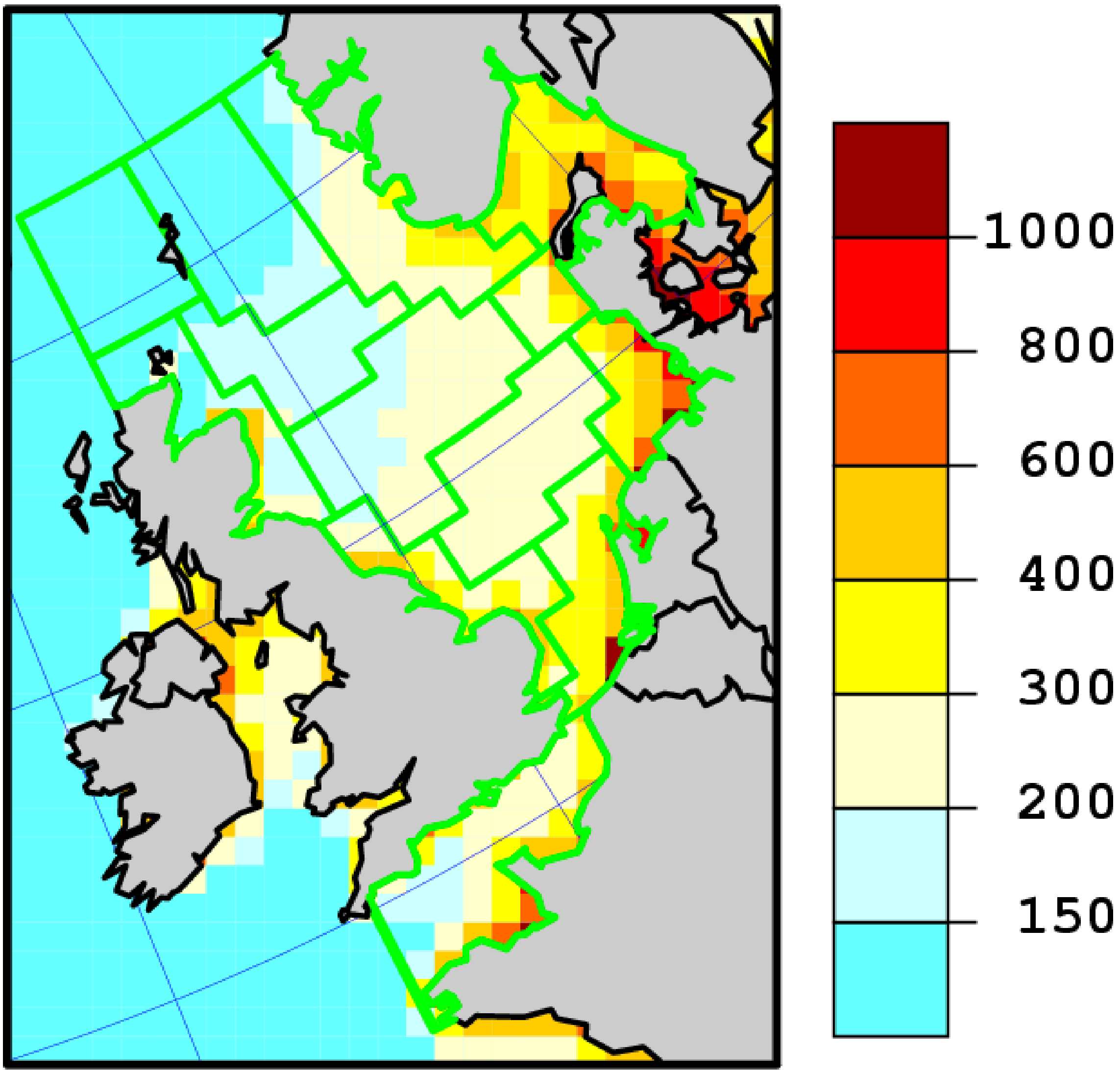

Figure 15. Map of modelled annual reduced nitrogen deposition in 13 sub-regions of OSPAR Region II (Greater North Sea) in 1990. Unit: mg N m^{-2}.

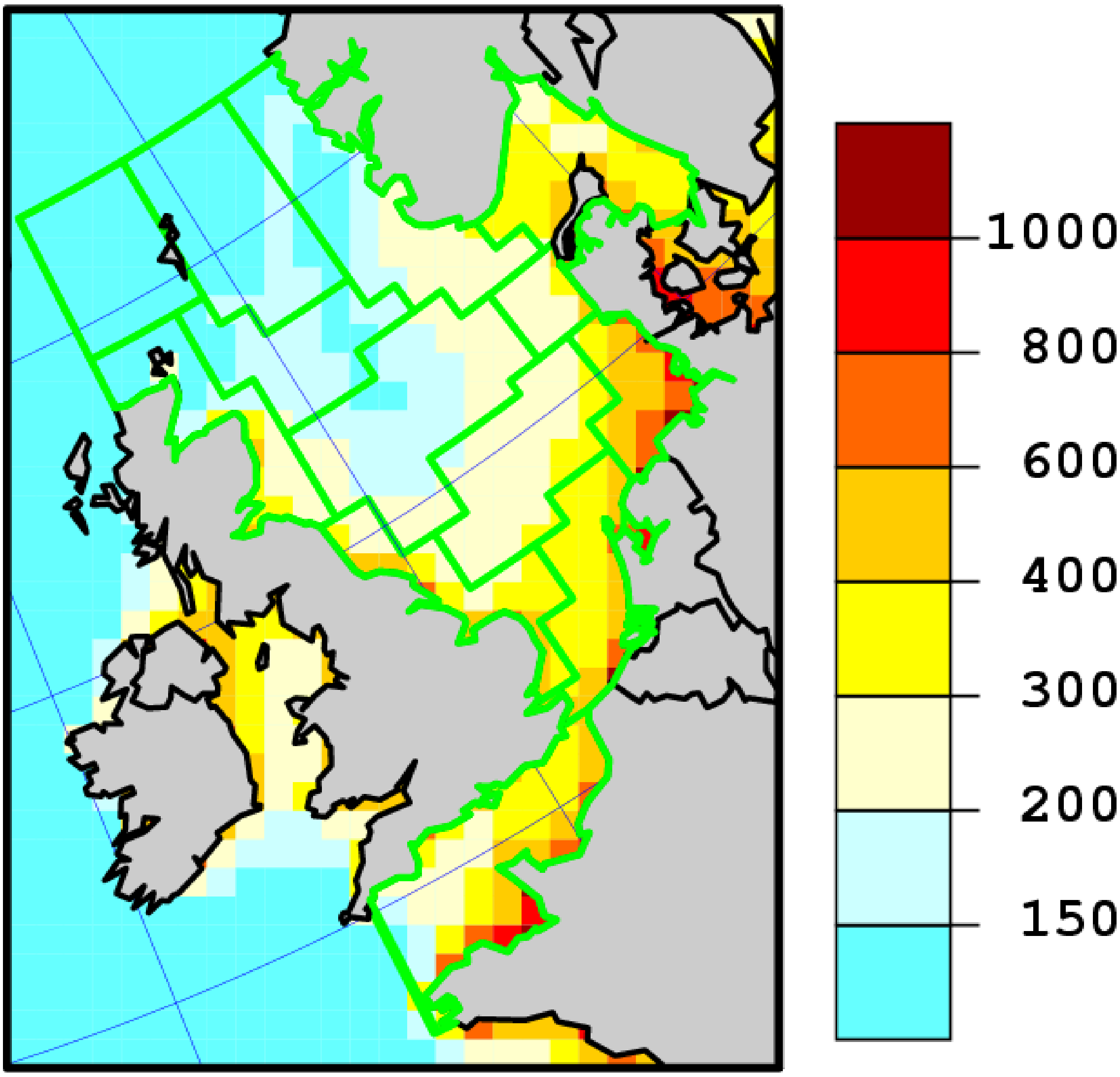

Figure 16. Map of modelled annual reduced nitrogen deposition in13 sub-regions of OSPAR Region II (Greater North Sea) in 2001. Unit: mg N m^{-2}.

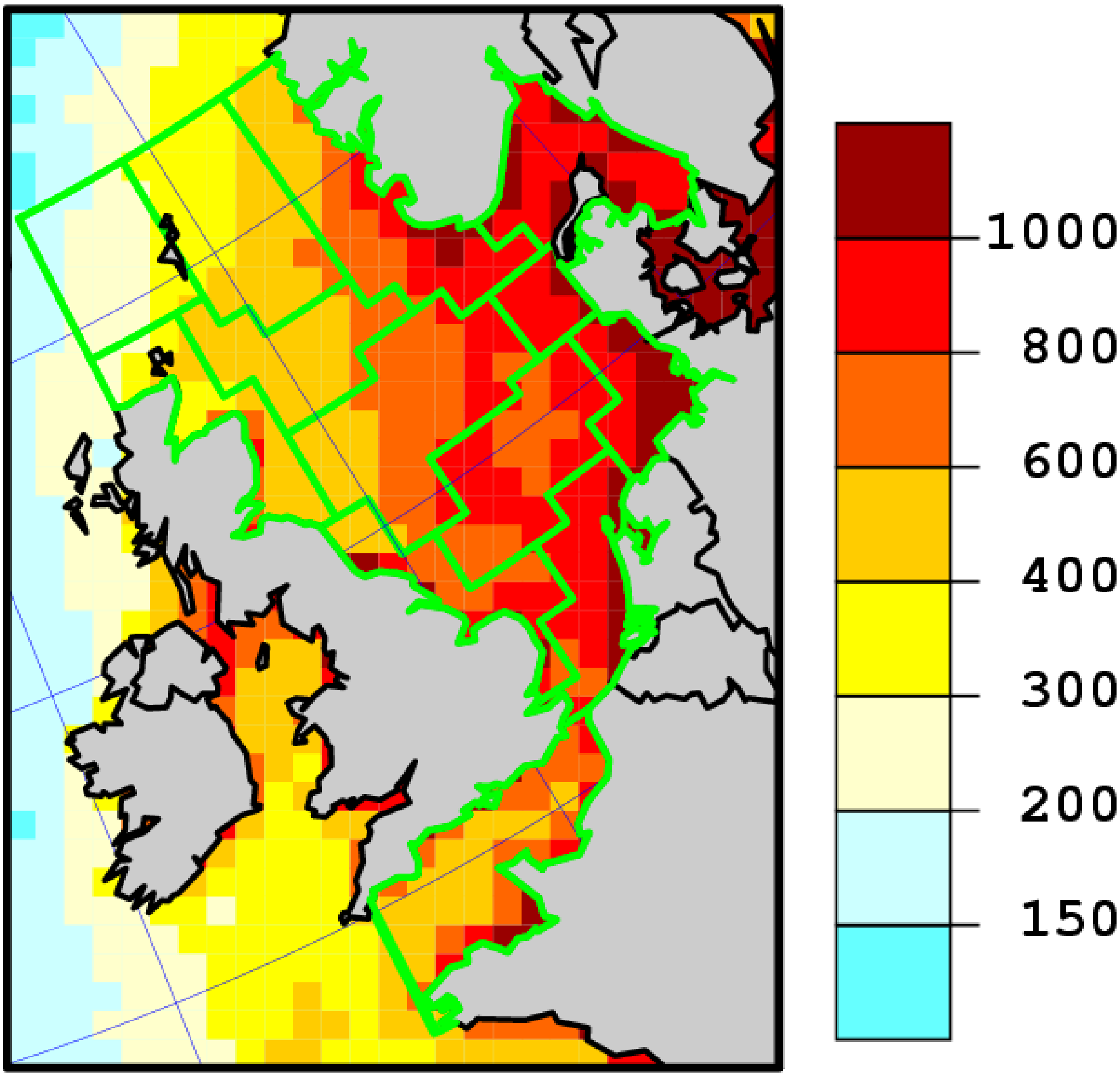

Figure 17. Map of modelled total annual nitrogen (oxidized and reduced) deposition in 13 sub-regions of OSPAR Region II (Greater North Sea) in 1990. Unit: mg N m^{-2}.

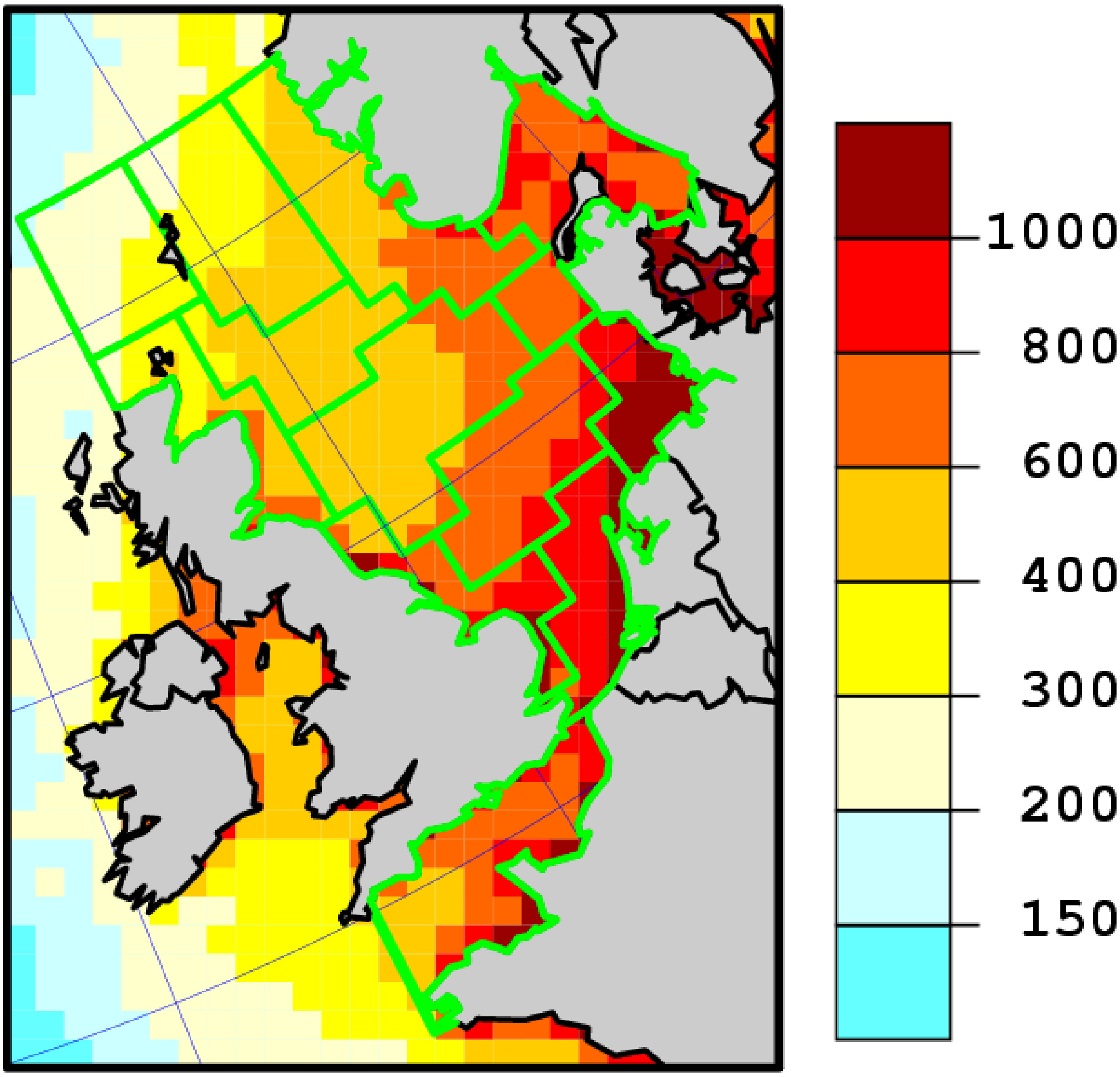

Figure 18. Map of modelled total annual nitrogen (oxidized and reduced) deposition in 13 sub-regions of OSPAR Region II (Greater North Sea) in 2001. Unit: mg N m^{-2}.

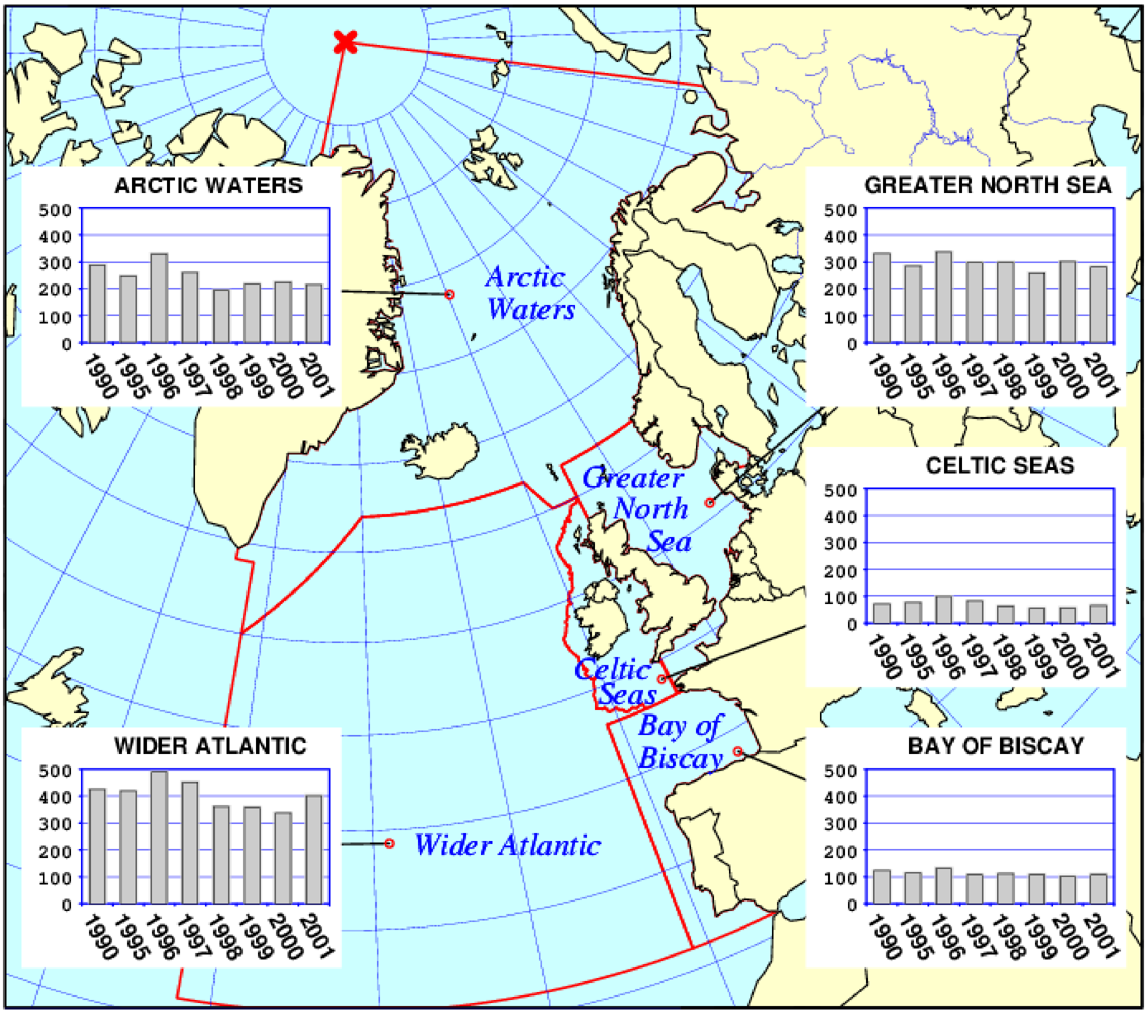

Figure 19. Map with time series of modelled annual oxidized nitrogen depositions in the five main OSPAR regions. Unit: kt N a^{-1}.

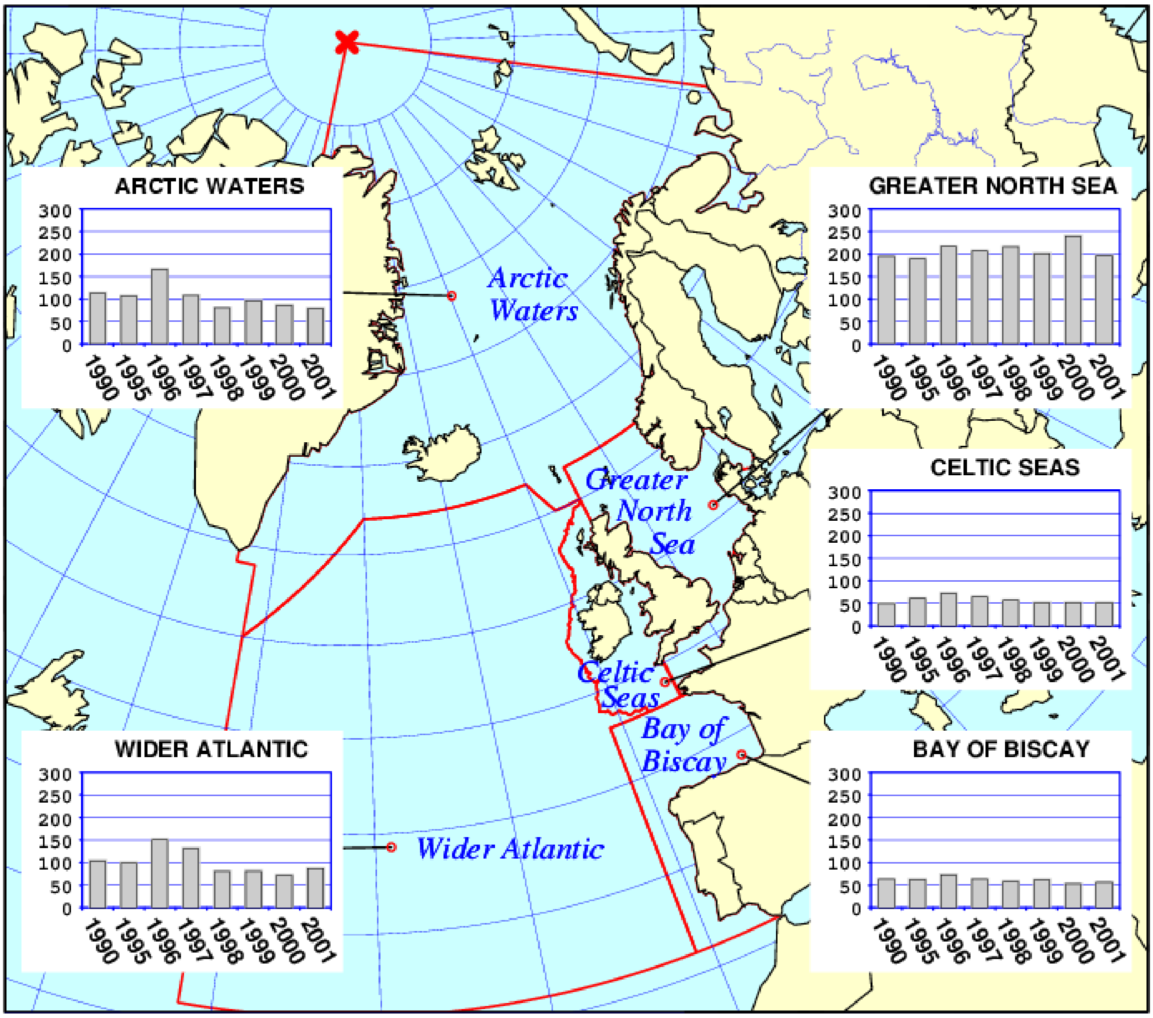

Figure 20. Map with time series of modelled annual reduced nitrogen depositions in the five main OSPAR regions. Unit: kt N a^{-1}.

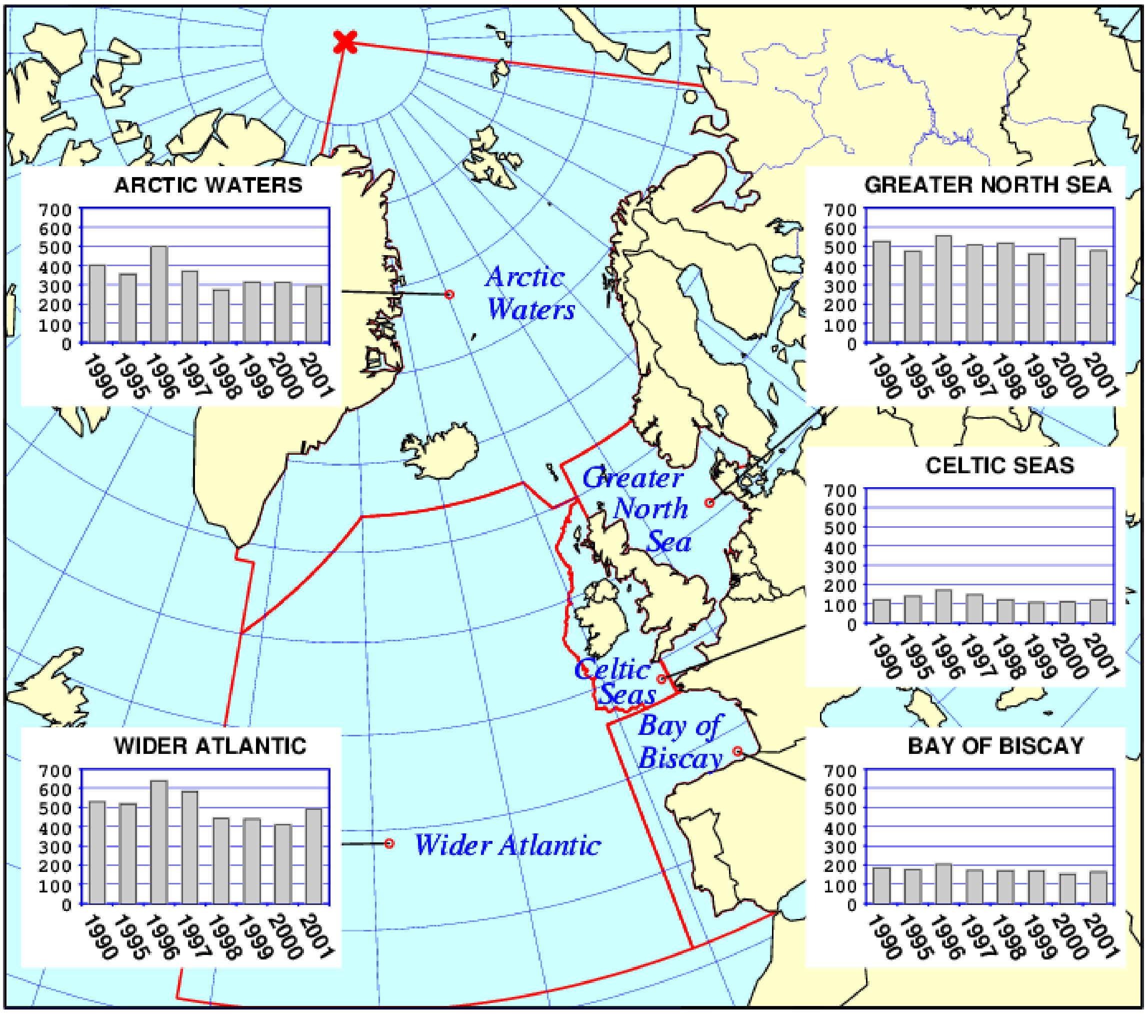

Figure 21. Map with time series of modelled total annual nitrogen (oxidized + reduced) deposition in the five main OSPAR regions. Unit: kt N a^{-1}.

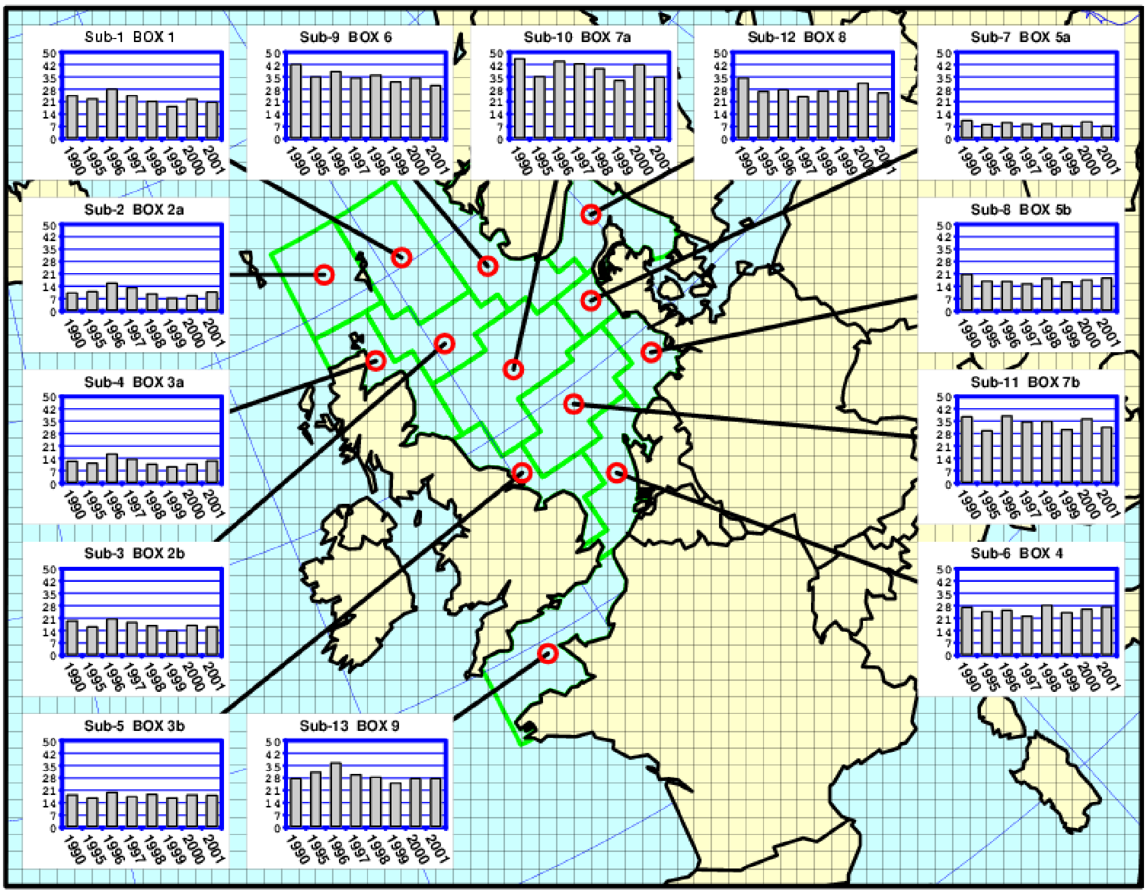

Figure 22. Map with time series of modelled annual oxidized nitrogen deposition in 13 sub-regions of OSPAR Region II (Greater North Sea). Unit: kt N a^{-1}.

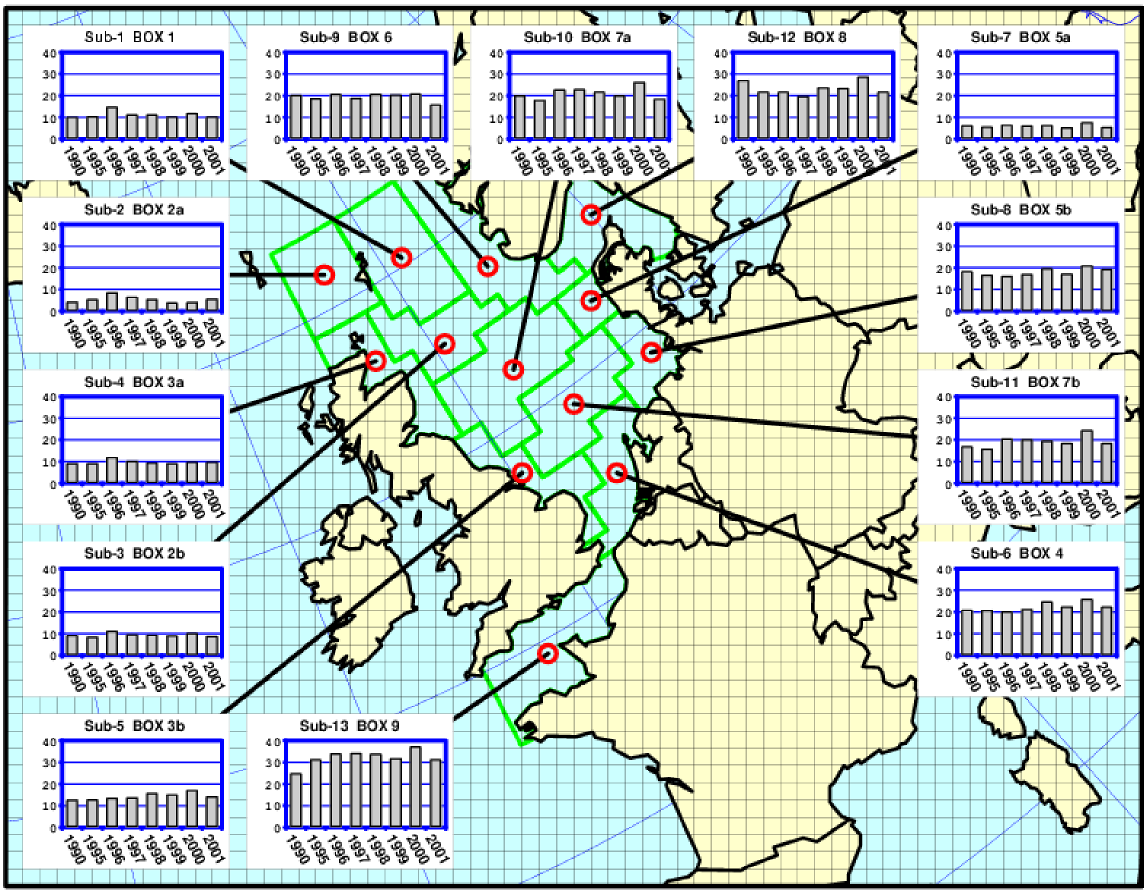

Figure 23. Map with time series of modelled annual reduced nitrogen deposition in 13 sub-regions of OSPAR Region II (Greater North Sea). Unit: kt N a^{-1}.

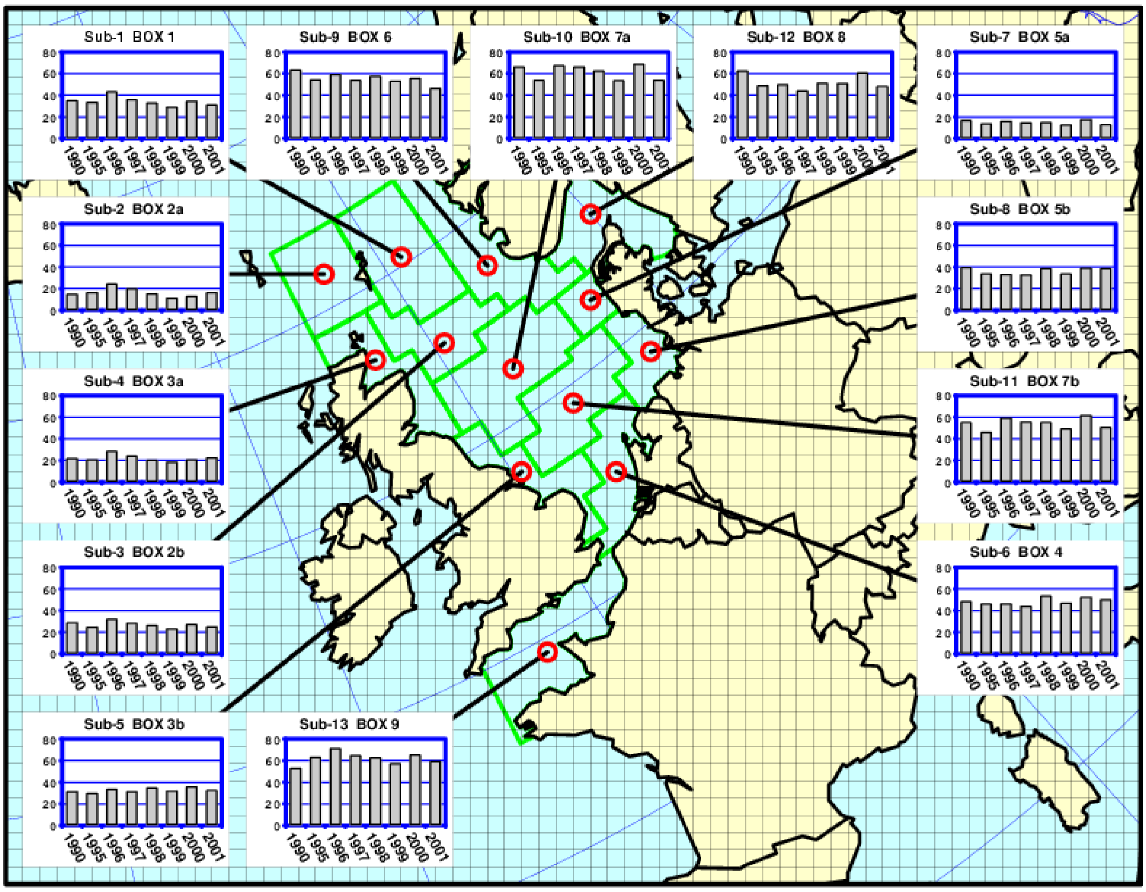

Figure 24. Map with time series of modelled total annual nitrogen (oxidized + reduced) deposition in 13 sub-regions of OSPAR Region II (Greater North Sea). Unit: kt N a^{-1}

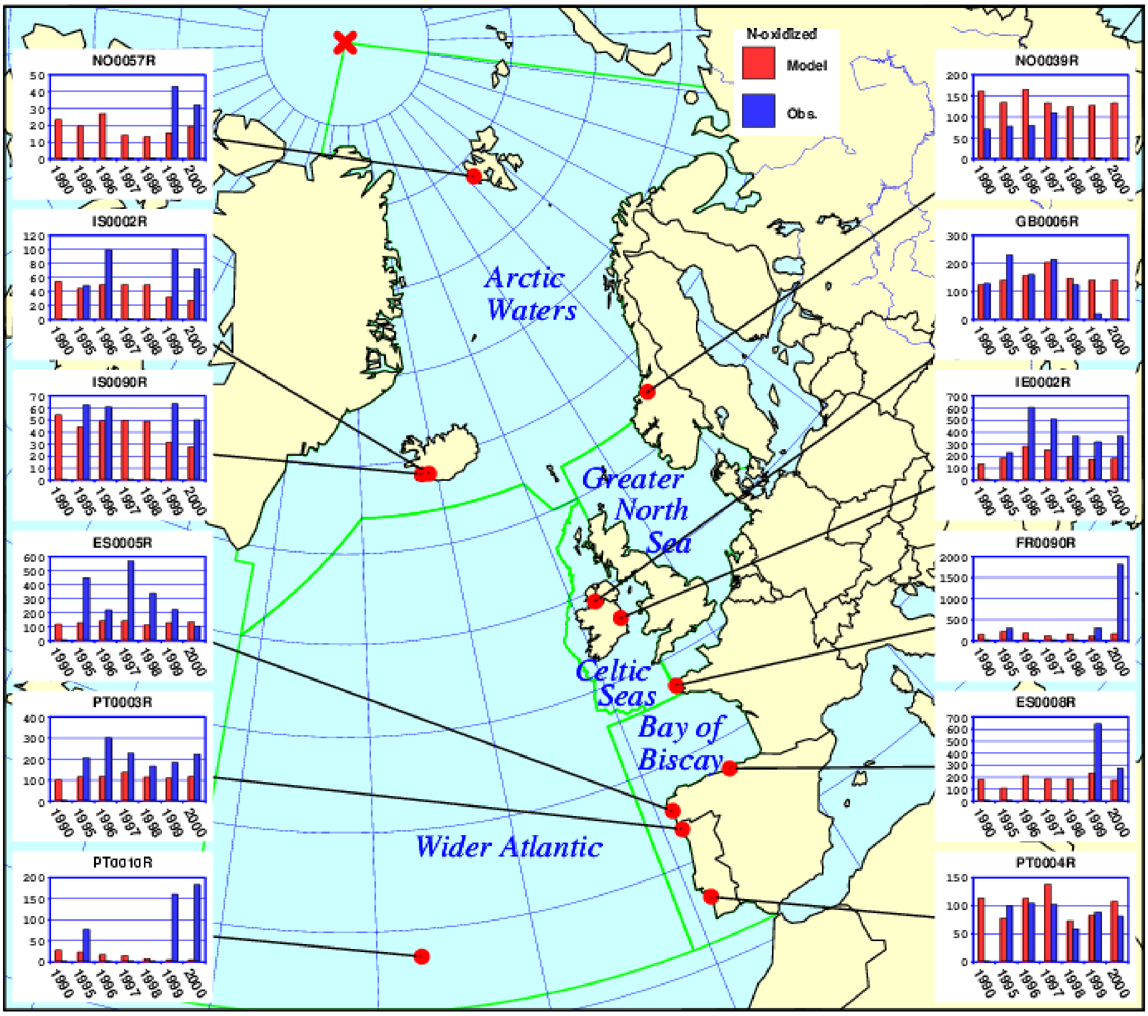

Figure 25. Map with time series of modelled versus measured annual oxidized nitrogen deposition at the coastal monitoring stations in the five main OSPAR regions. Unit: mg N m^{-2}.

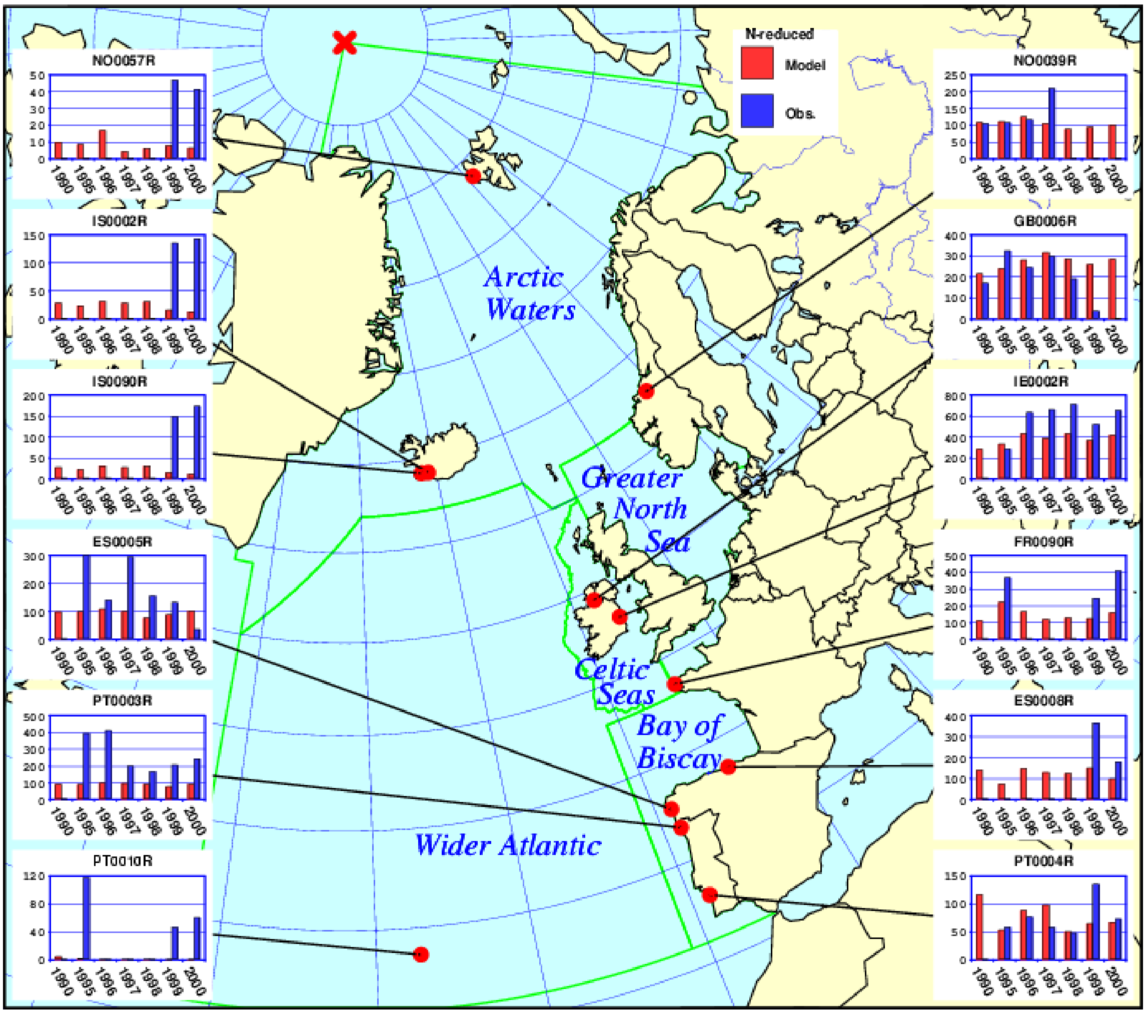

Figure 26. Map with time series of modelled versus measured annual reduced nitrogen deposition at the coastal monitoring stations in the five main OSPAR regions. Unit: mg N m^{-2}.

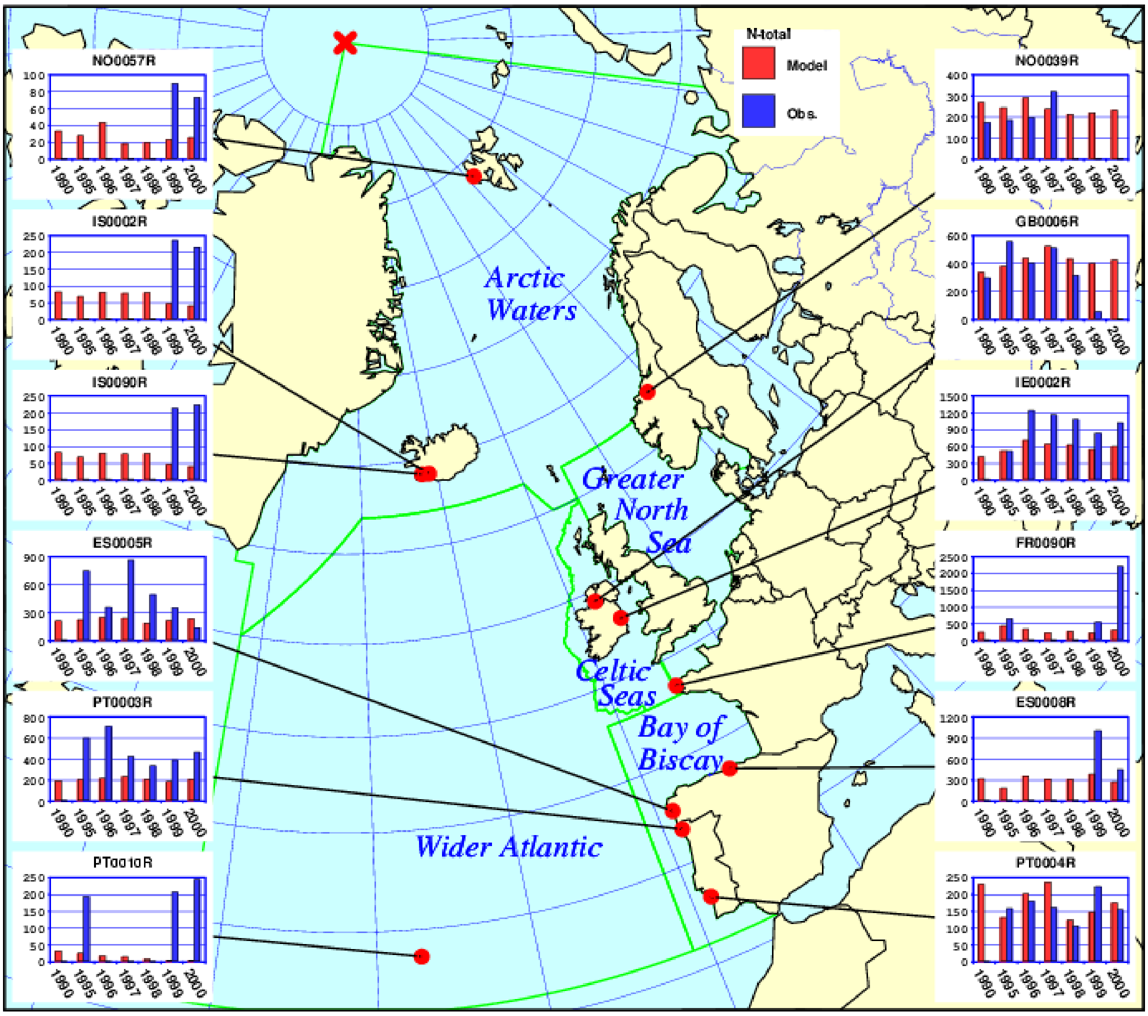

Figure 27. Map with time series of modelled versus measured total annual nitrogen (oxidized + reduced) deposition at the coastal monitoring stations in the five main OSPAR regions. Unit: mg N m^{-2}.

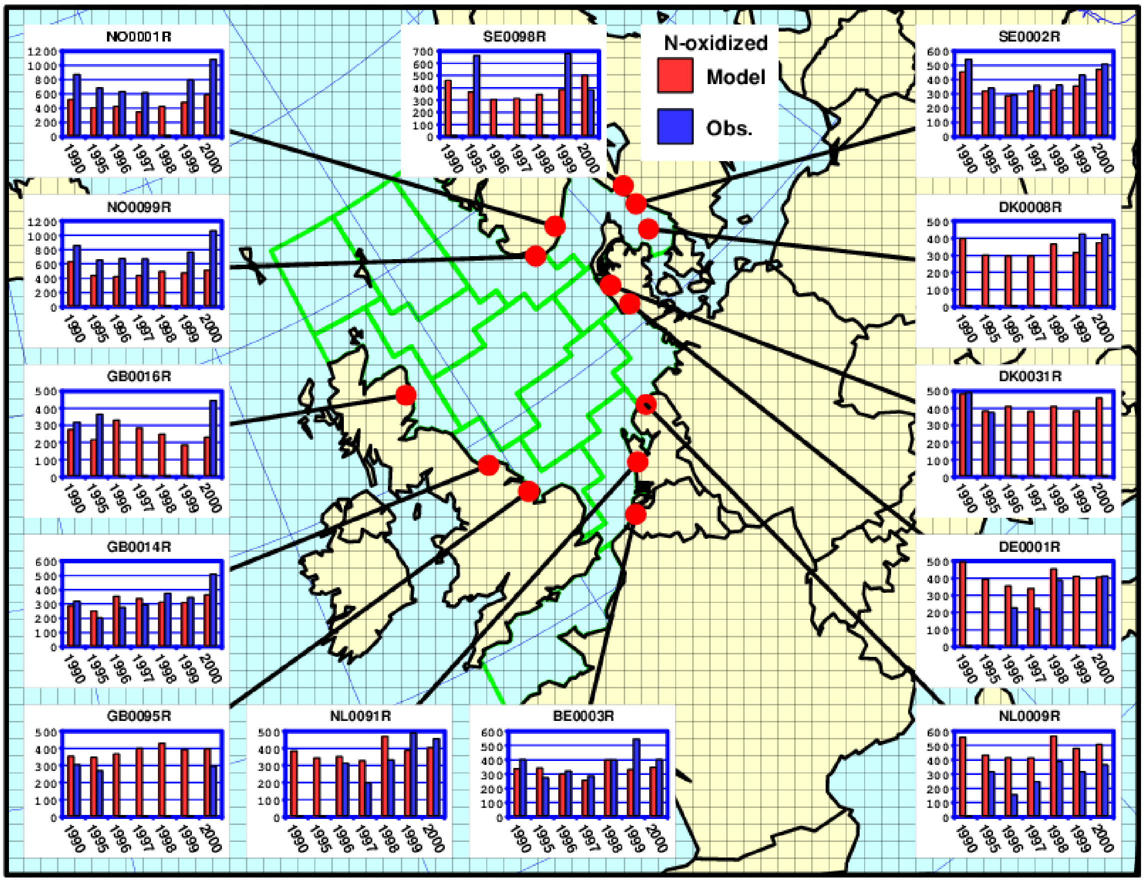

Figure 28. Map with time series of modelled versus measured annual oxidized nitrogen deposition at the coastal monitoring stations in OSPAR Region II (Greater North Sea) . Unit: mg N m^{-2}.

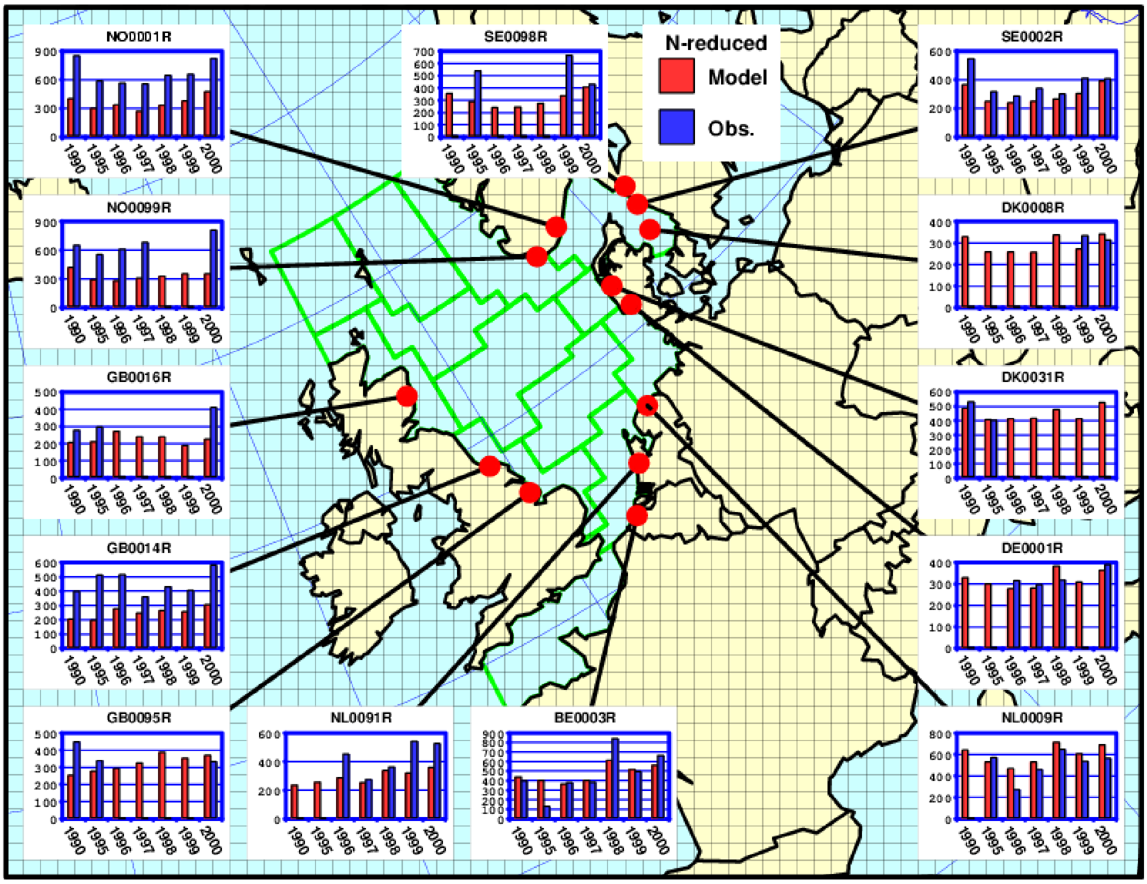

Figure 29. Map with time series of modelled versus measured annual reduced nitrogen deposition at the coastal monitoring stations in OSPAR Region II (Greater North Sea). Unit: mg N m^{-2}.

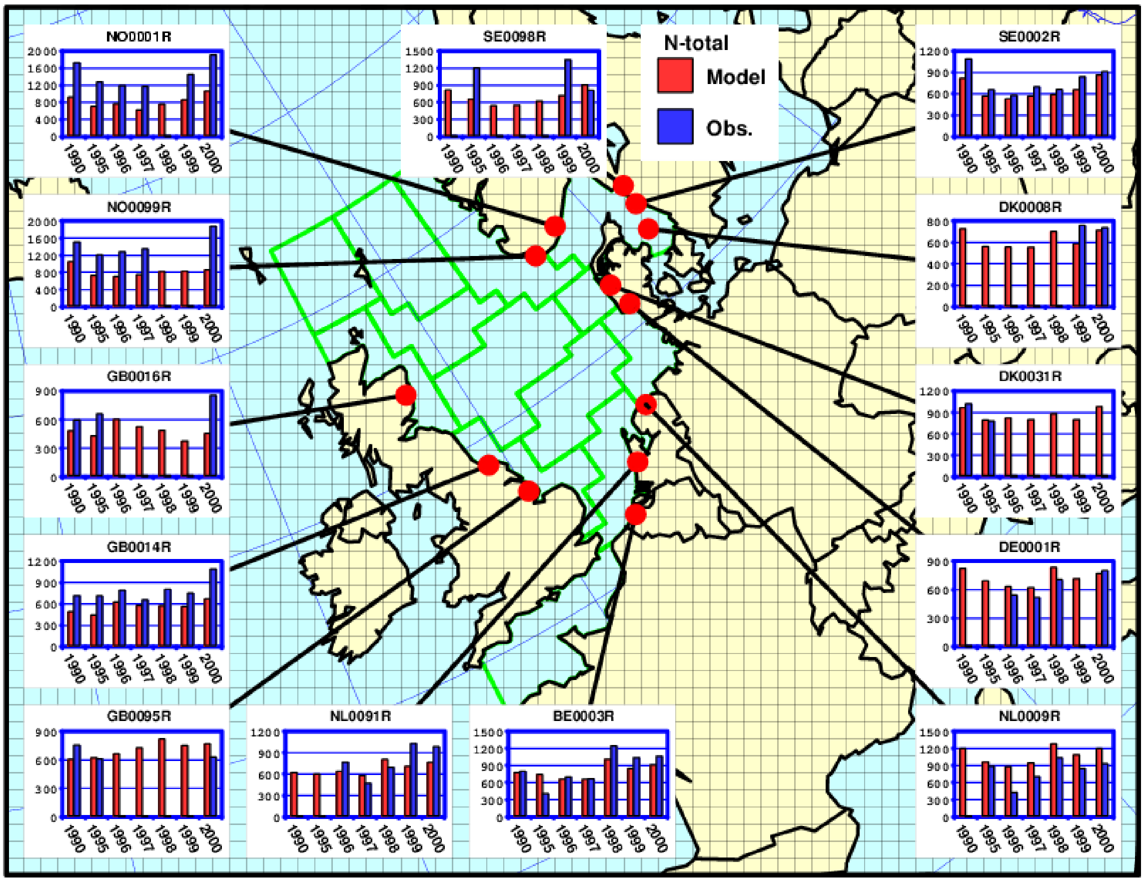

Figure 30. Map with time series of modelled versus measured total annual nitrogen (oxidized + reduced) deposition at the coastal monitoring stations in OSPAR Region II (Greater North Sea). Unit: mg N m^{-2}.

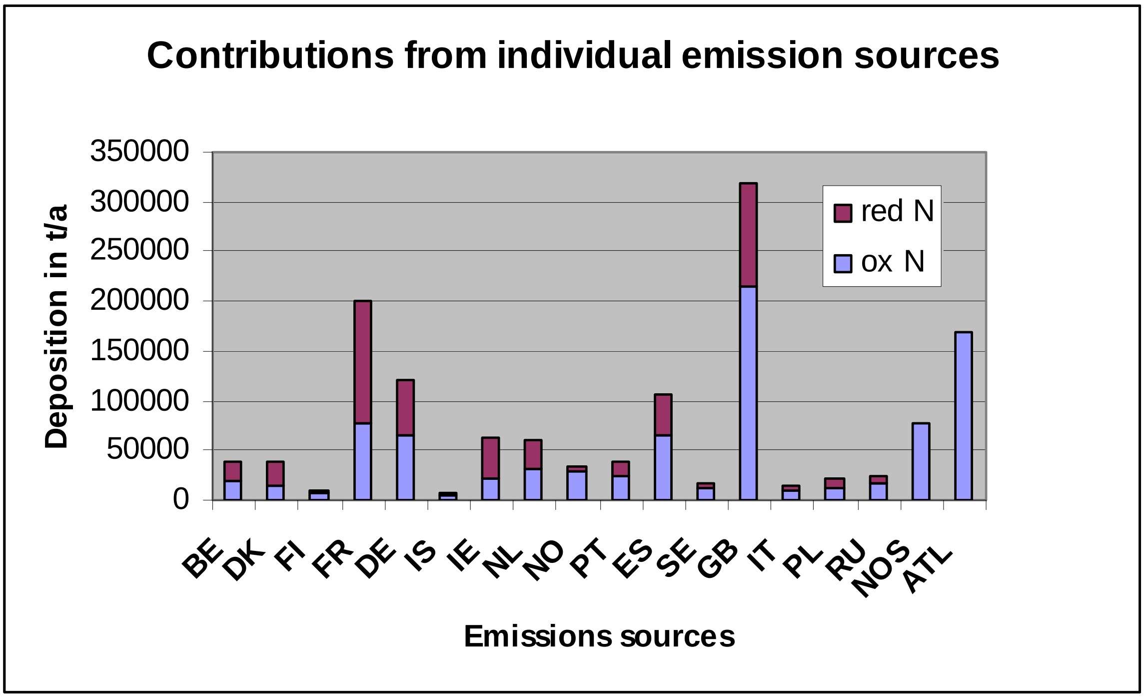

Figure 31. Contributions of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on the Atlantic Ocean) to total annual (oxidized + reduced) nitrogen deposition in the OSPAR Convention Waters in the year 2000. Unit: t/a. This is a part of the emission from each source country, which is deposited in the OSPAR Convention Waters (see also Table 11).

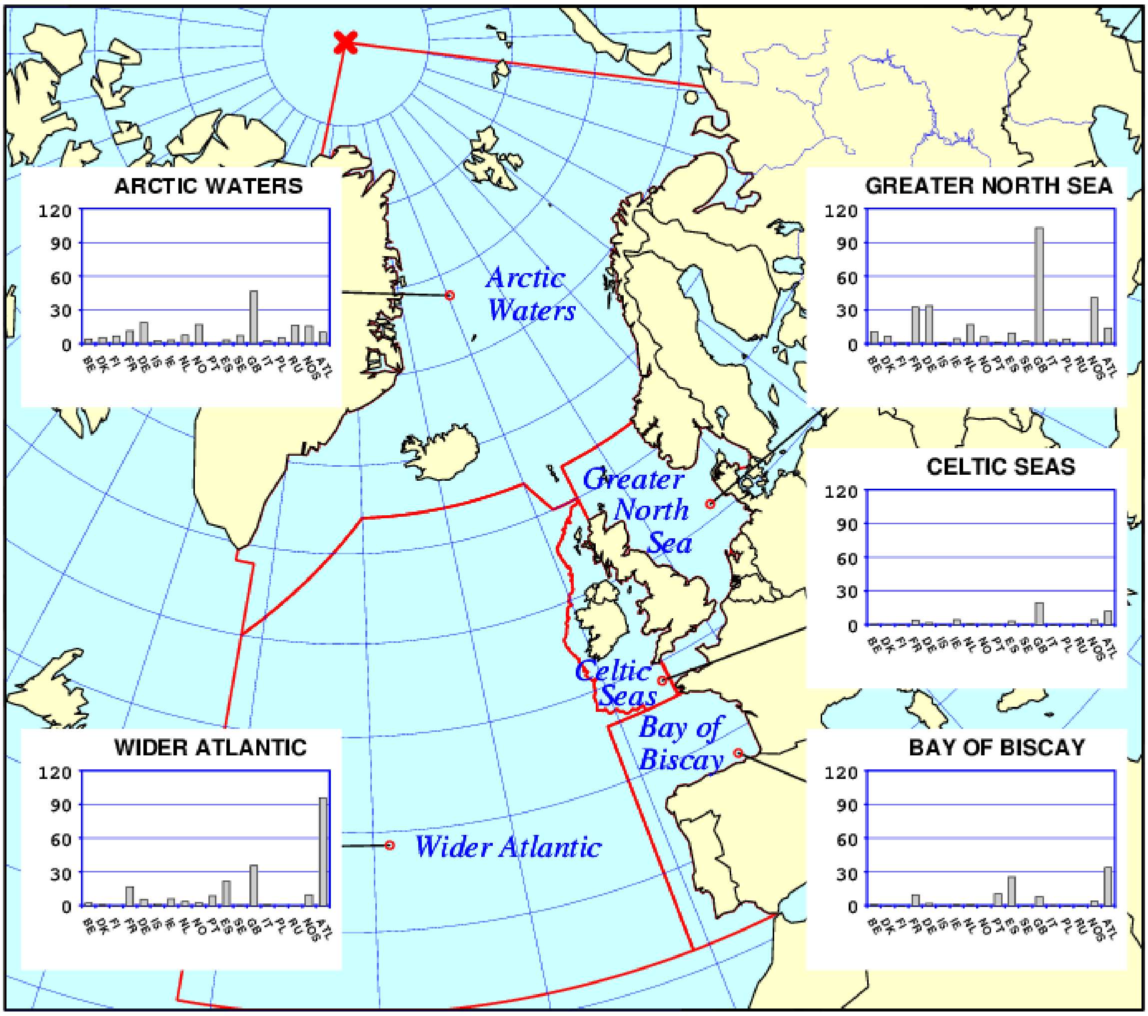

Figure 32. Maps with contribution of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on the Atlantic Ocean) to annual oxidized nitrogen deposition in the 5 main OSPAR regions in the year 2000. Unit: t N a^{-1}.

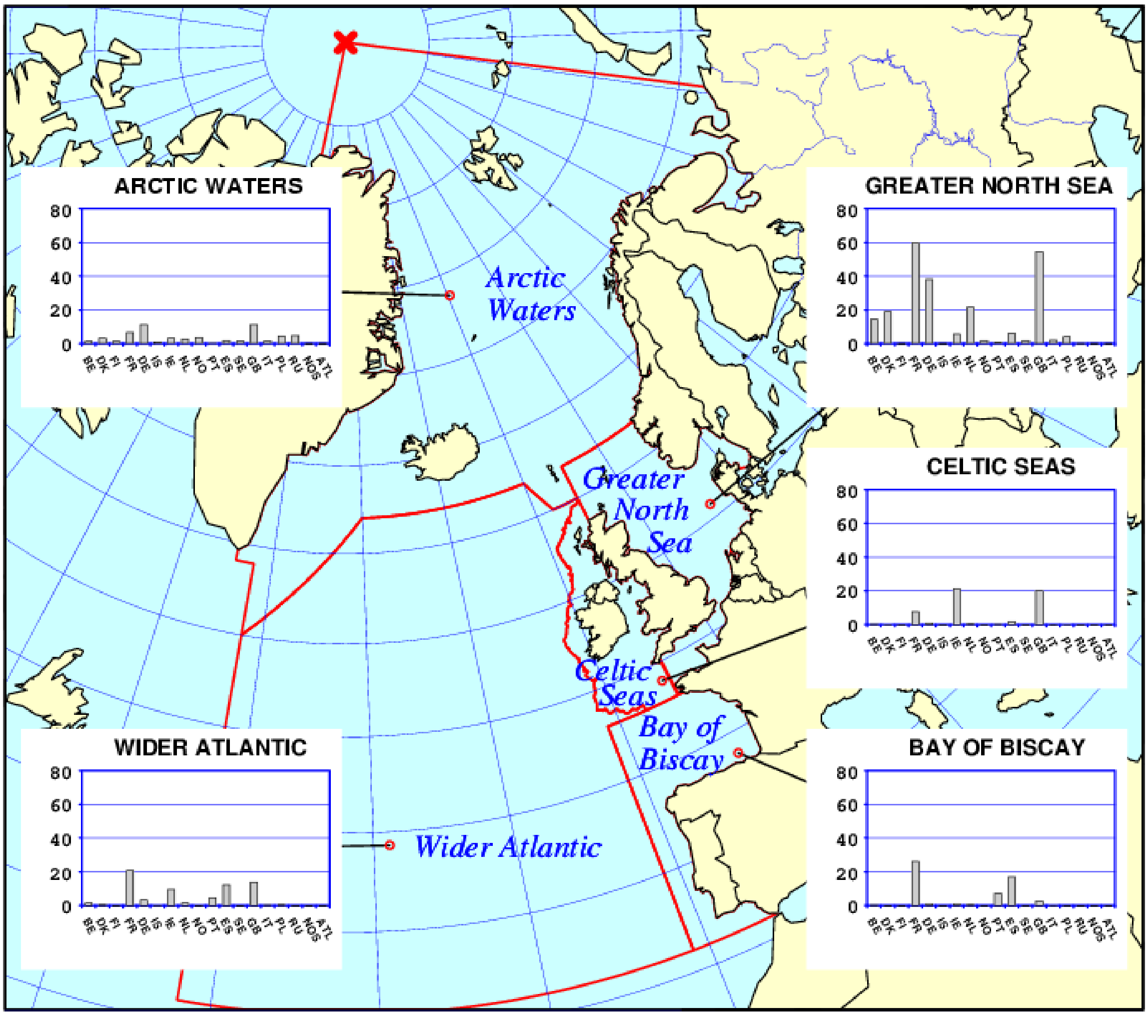

Figure 33. Map with contributions of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on the Atlantic Ocean) to annual reduced nitrogen deposition in the 5 main OSPAR regions in the year 2000. Unit: t N a^{-1}.

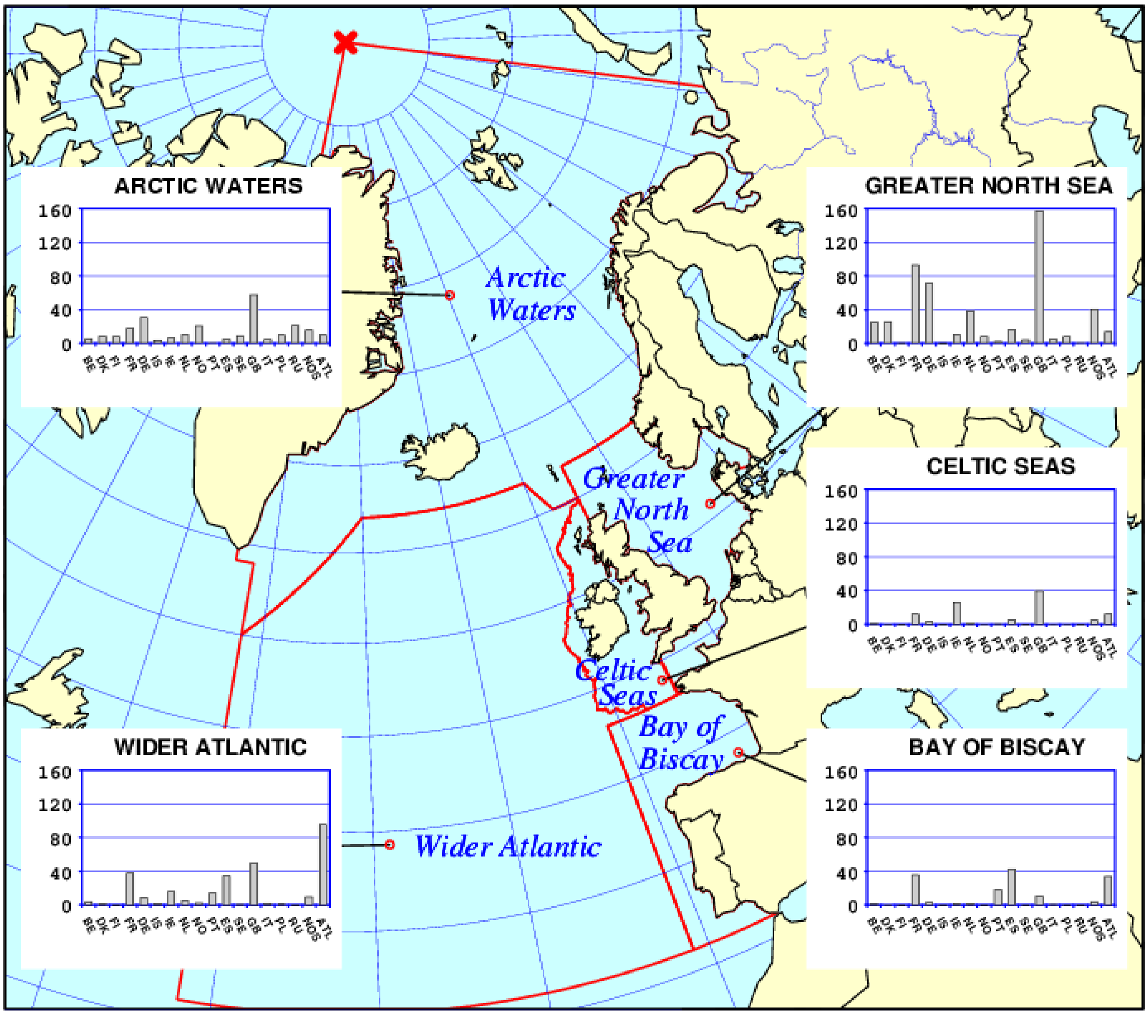

Figure 34. Map with contributions of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on the Atlantic Ocean) to total annual nitrogen deposition in the 5 main OSPAR regions in the year 2000. Unit: t N a^{-1}.

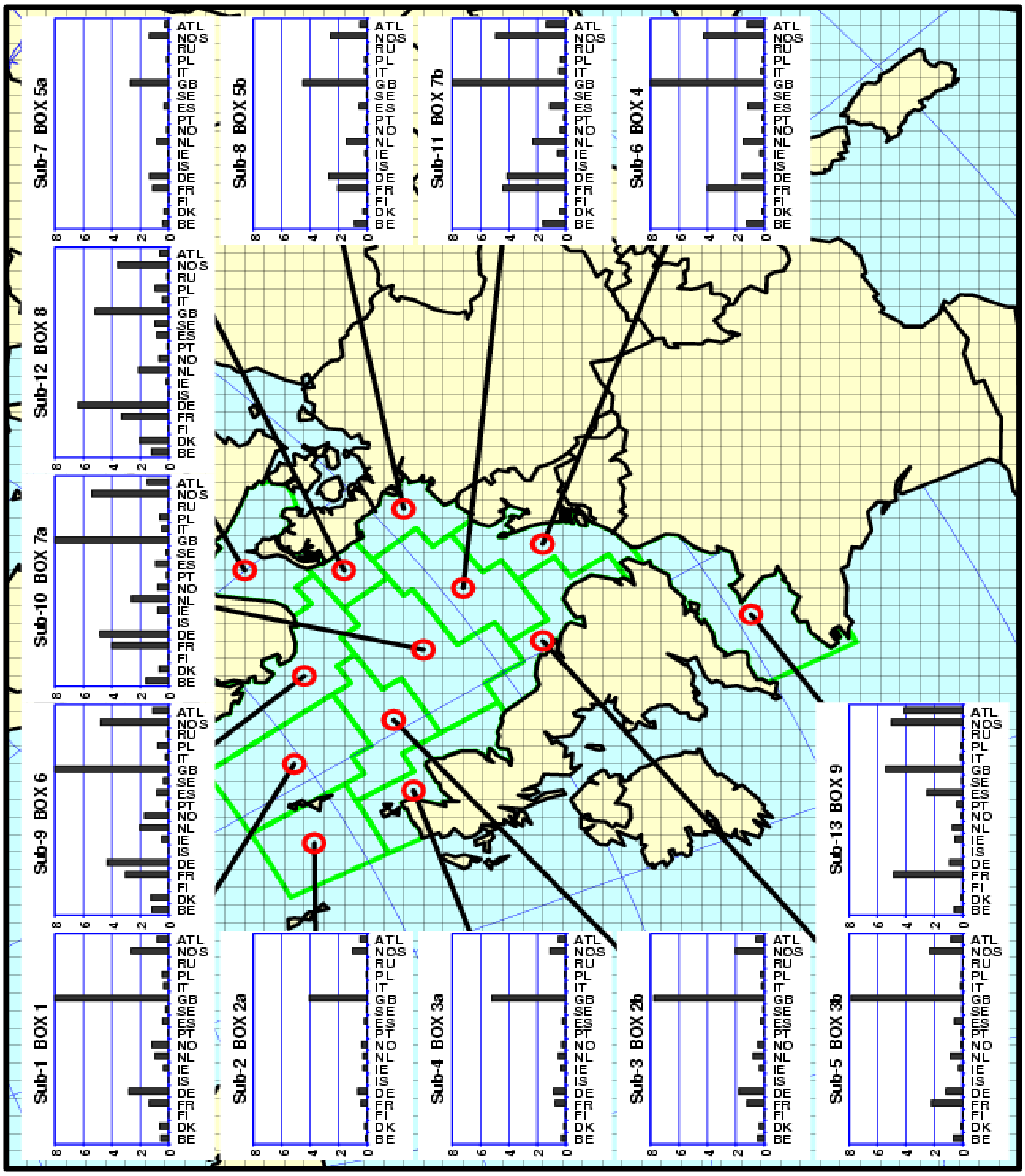

Figure 35. Map with contributions of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on the Atlantic Ocean) to annual oxidized nitrogen deposition in 13 sub-regions of OSPAR Region II in the year 2000. Unit: t N a^{-1}. All contributioins above 8 t N a^{-1} are truncated (see Table 12 for details).

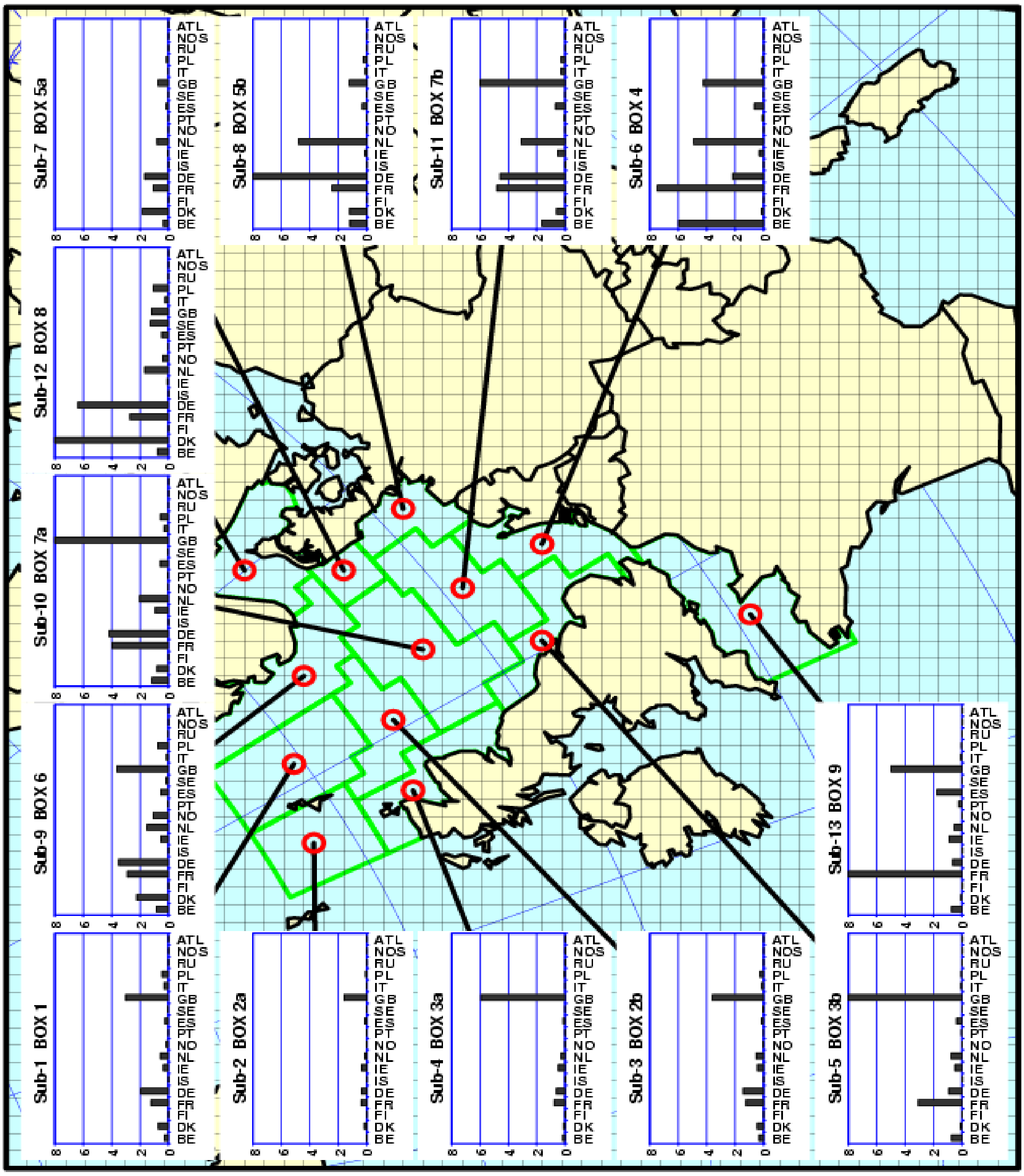

Figure 36. Map with contribution of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on the Atlantic Ocean) to annual reduced nitrogen deposition in 13 sub-regions of OSPAR Region II in the year 2000. Unit: t N a^{-1}. All contributioins above 8 t N a^{-1} are truncated (see Table 13 for details).

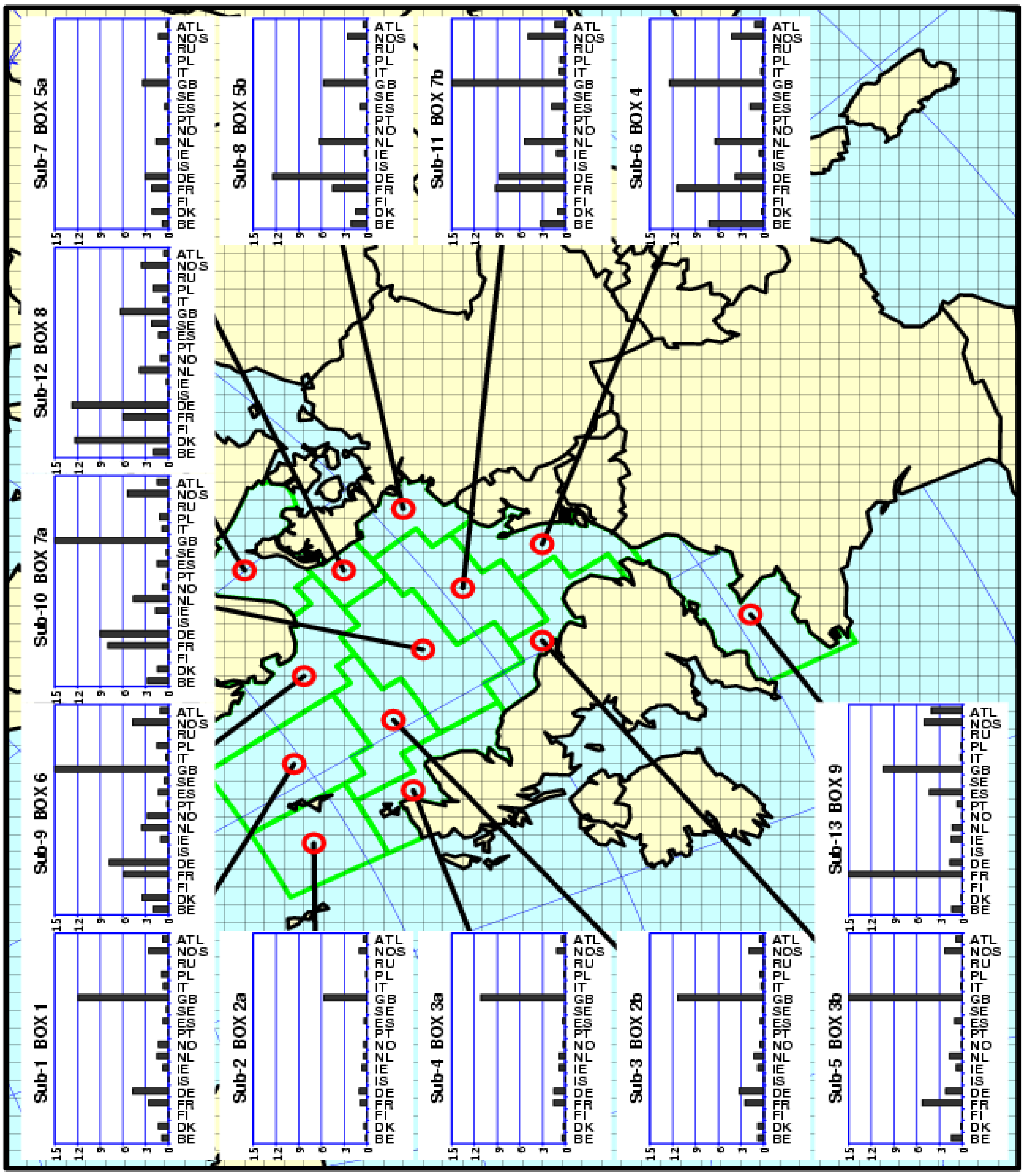

Figure 37. Map with contribution of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on the Atlantic Ocean) to total annual nitrogen deposition in 13 sub-regions of OSPAR Region II in the year 2000. Unit: t N a^{-1}. All contributioins above 8 t N a^{-1} are truncated (see Table 14 for details).

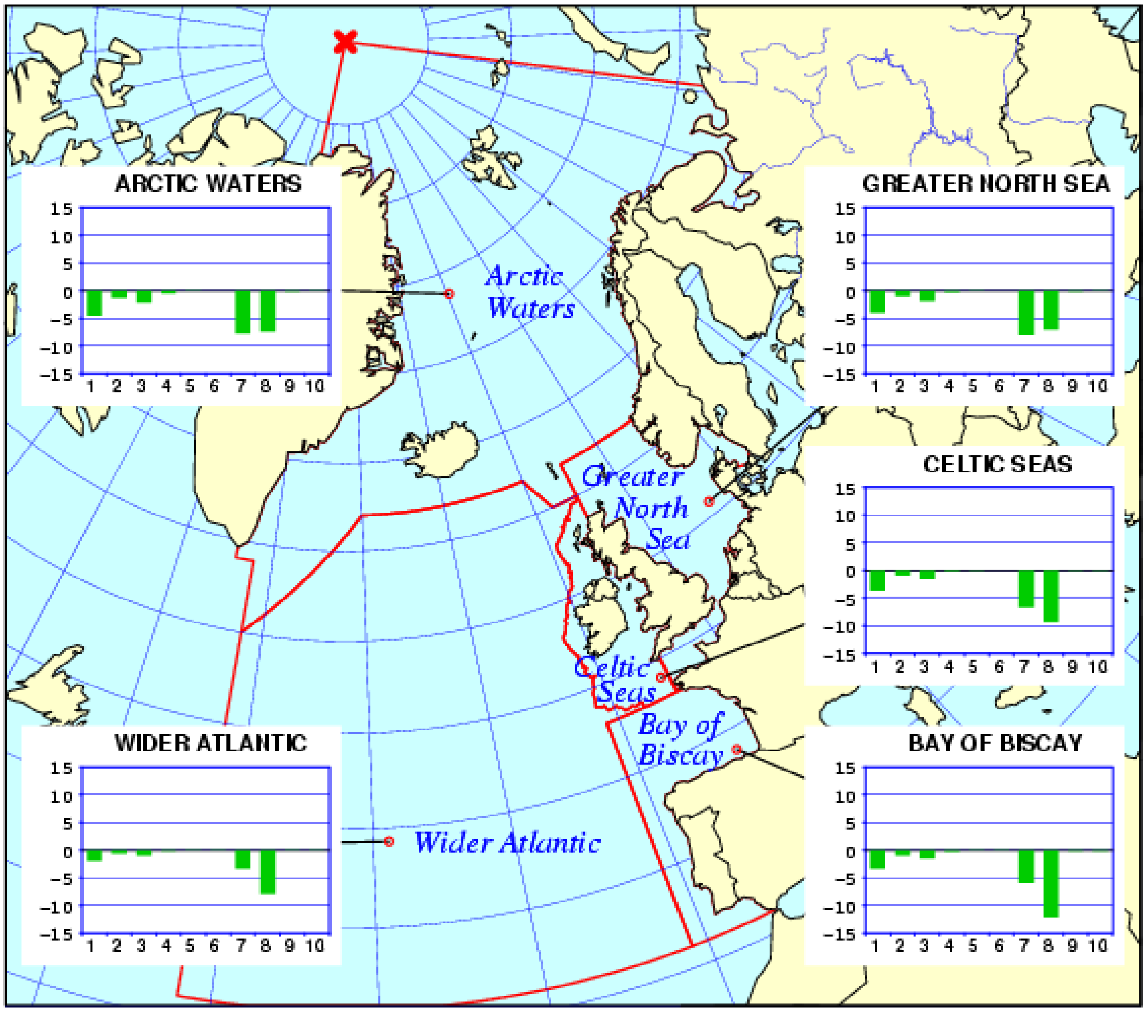

Figure 38. Reduction of annual oxidized nitrogen deposition (in percent of initial deposition) due to 25 % reduction of NO_x emissions in each of 10 SNAP sectors in the year 2000. Green color denotes reduction of deposition and red color denotes increased deposition from given sector.

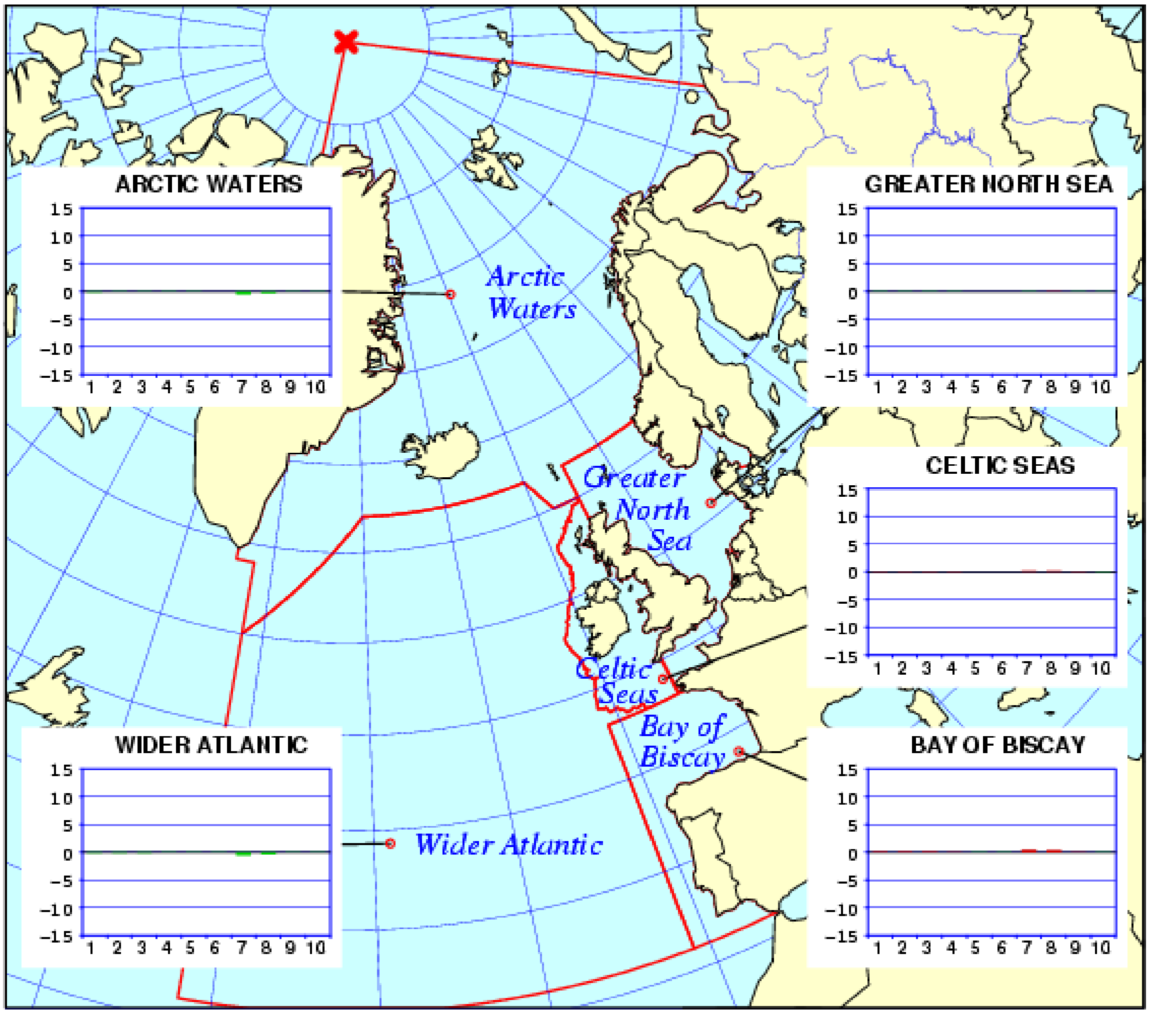

Figure 39. Reduction of annual reduced nitrogen deposition (in percent of initial deposition) due to 25 % reduction of NO_x emissions in each of 10 SNAP sectors in the year 2000. Green color denotes reduction of deposition and red color denotes increased deposition from given sector.

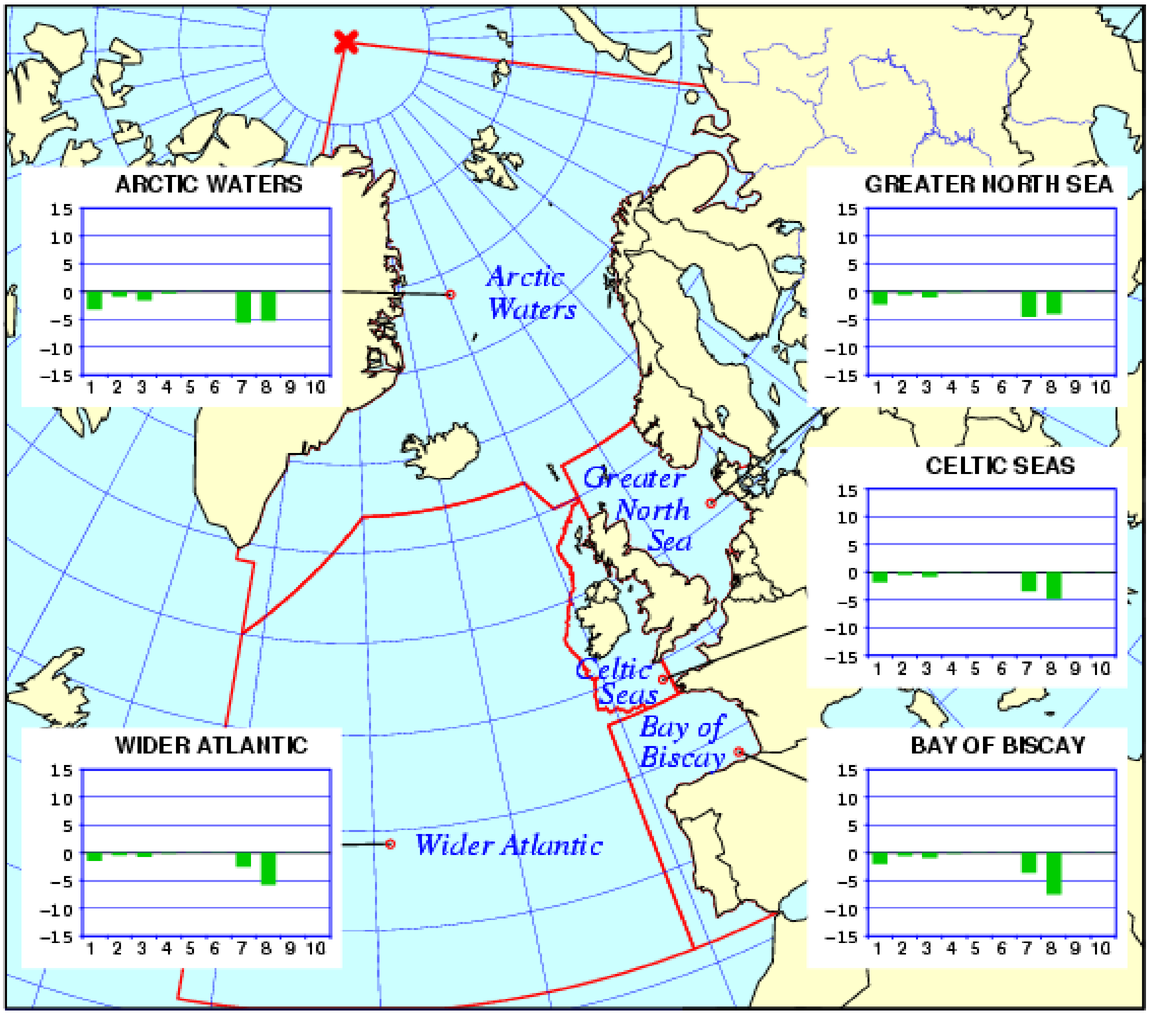

Figure 40. Reduction of total annual nitrogen deposition (in percent of initial deposition) due to 25 % reduction of NO_x emissions in each of 10 SNAP sectors in the year 2000. Green color denotes reduction of deposition and red color denotes increased deposition from given sector.

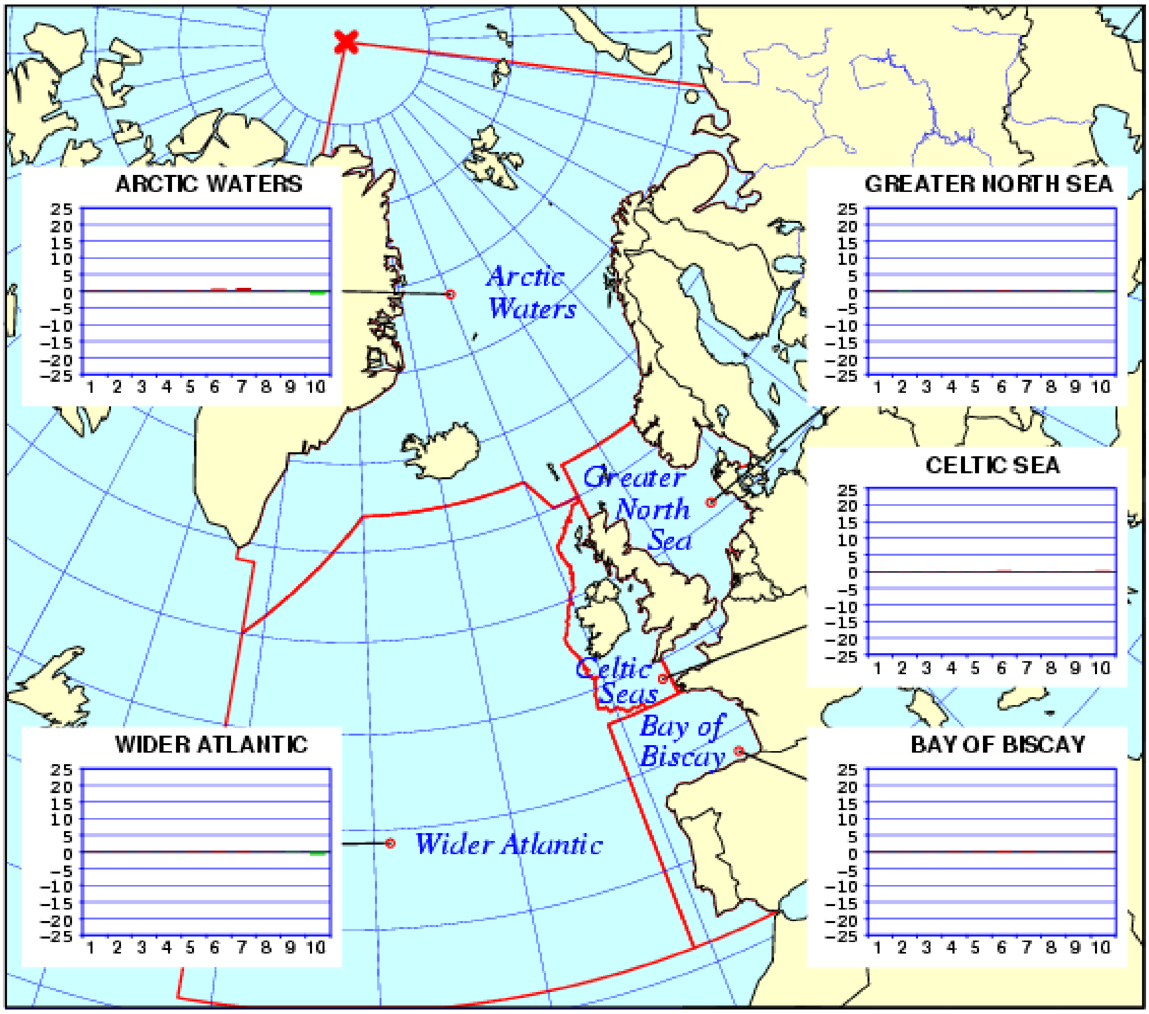

Figure 41. Reduction of annual oxidized nitrogen deposition (in percent of initial deposition) due to 25 % reduction of NH_3 and VOC emissions in each of 10 SNAP sectors in the year 2000. Green color denotes reduction of deposition and red color denotes increased deposition from given sector.

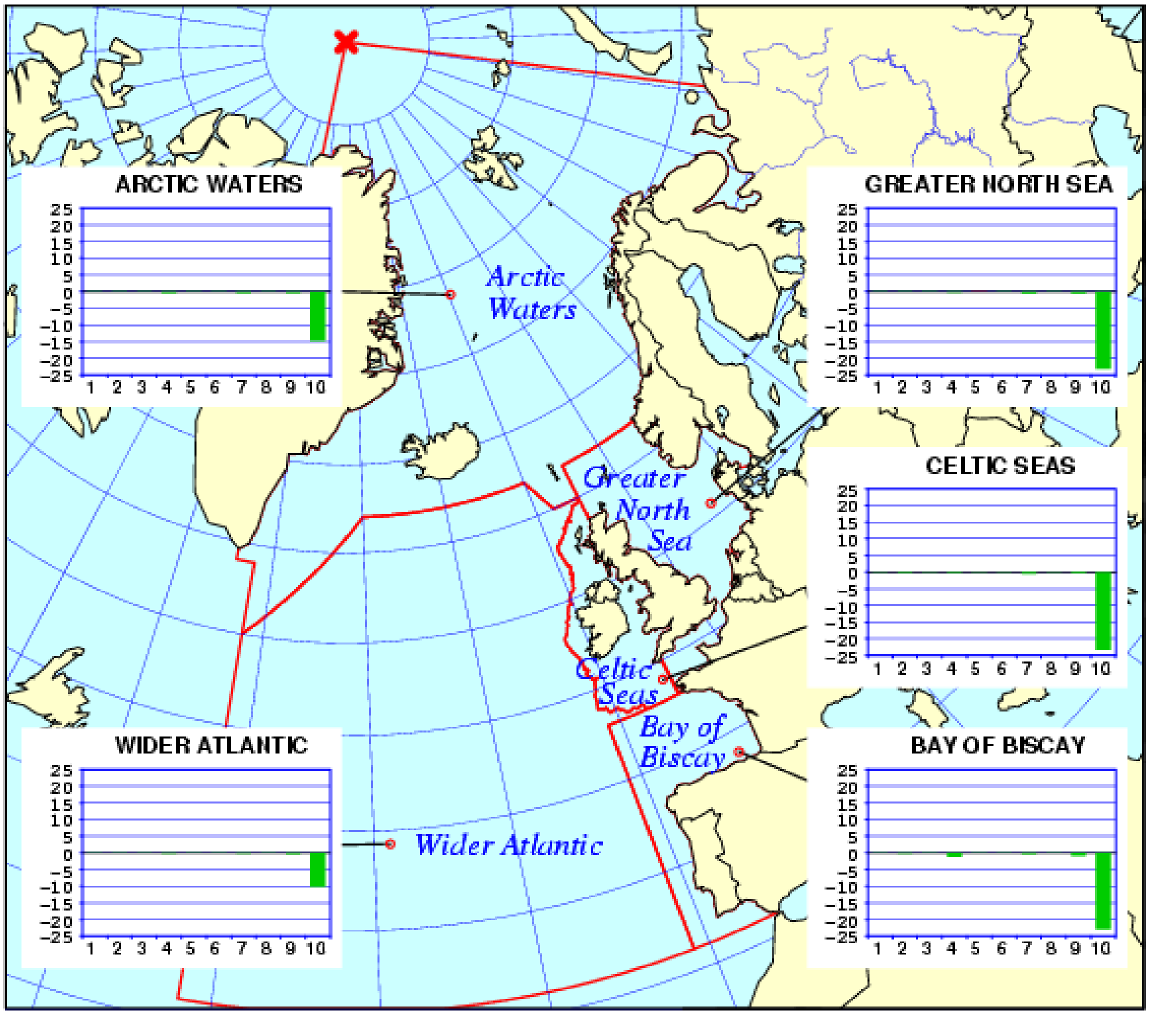

Figure 42. Reduction of annual reduced nitrogen deposition (in percent of initial deposition) due to 25 % reduction of NH_3 and VOC emissions in each of 10 SNAP sectors in the year 2000. Green color denotes reduction of deposition and red color denotes increased deposition from given sector.

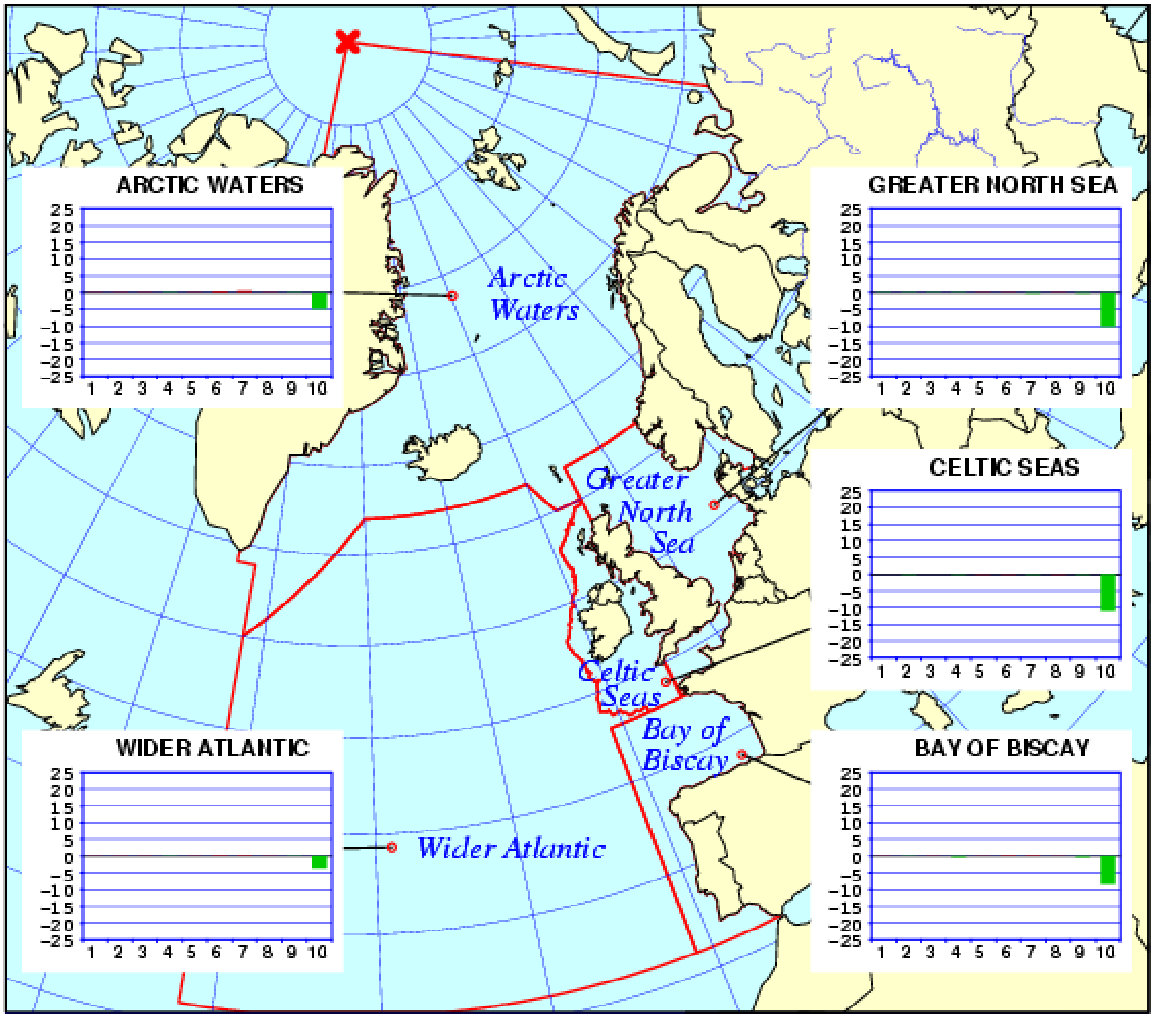

Figure 43. Reduction of total annual nitrogen deposition (in percent of initial deposition) due to 25 % reduction of NH_3 and VOC emissions in each of 10 SNAP sectors in the year 2000. Green color denotes reduction of deposition and red color denotes increased deposition from given sector.

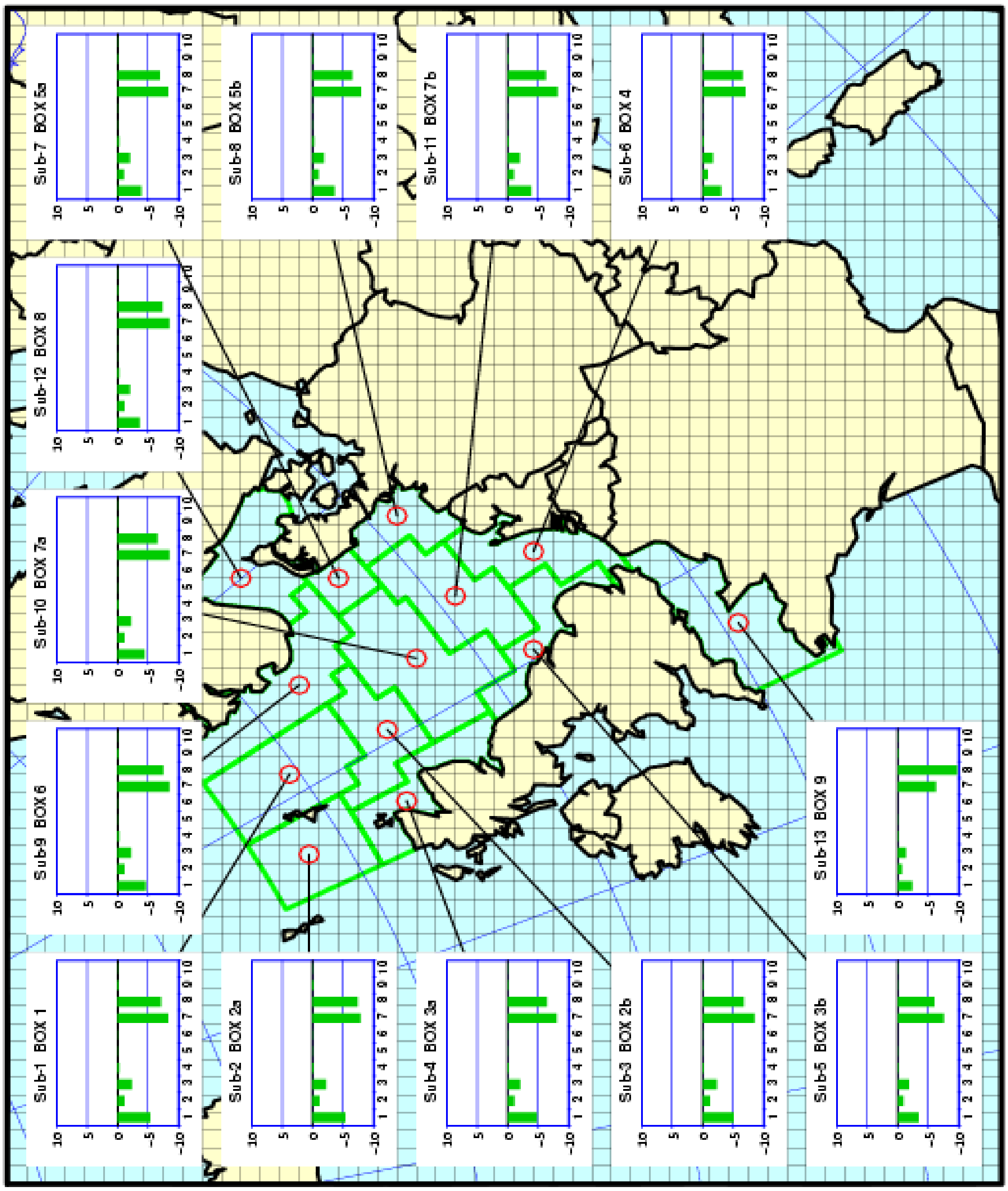

Figure 44. Reduction of annual oxidized nitrogen deposition (in percent of initial deposition) due to 25 % reduction of NO_x emissions in each of 10 SNAP sectors in the year 2000. Green color denotes reduction of deposition and red color denotes increased deposition from given sector.

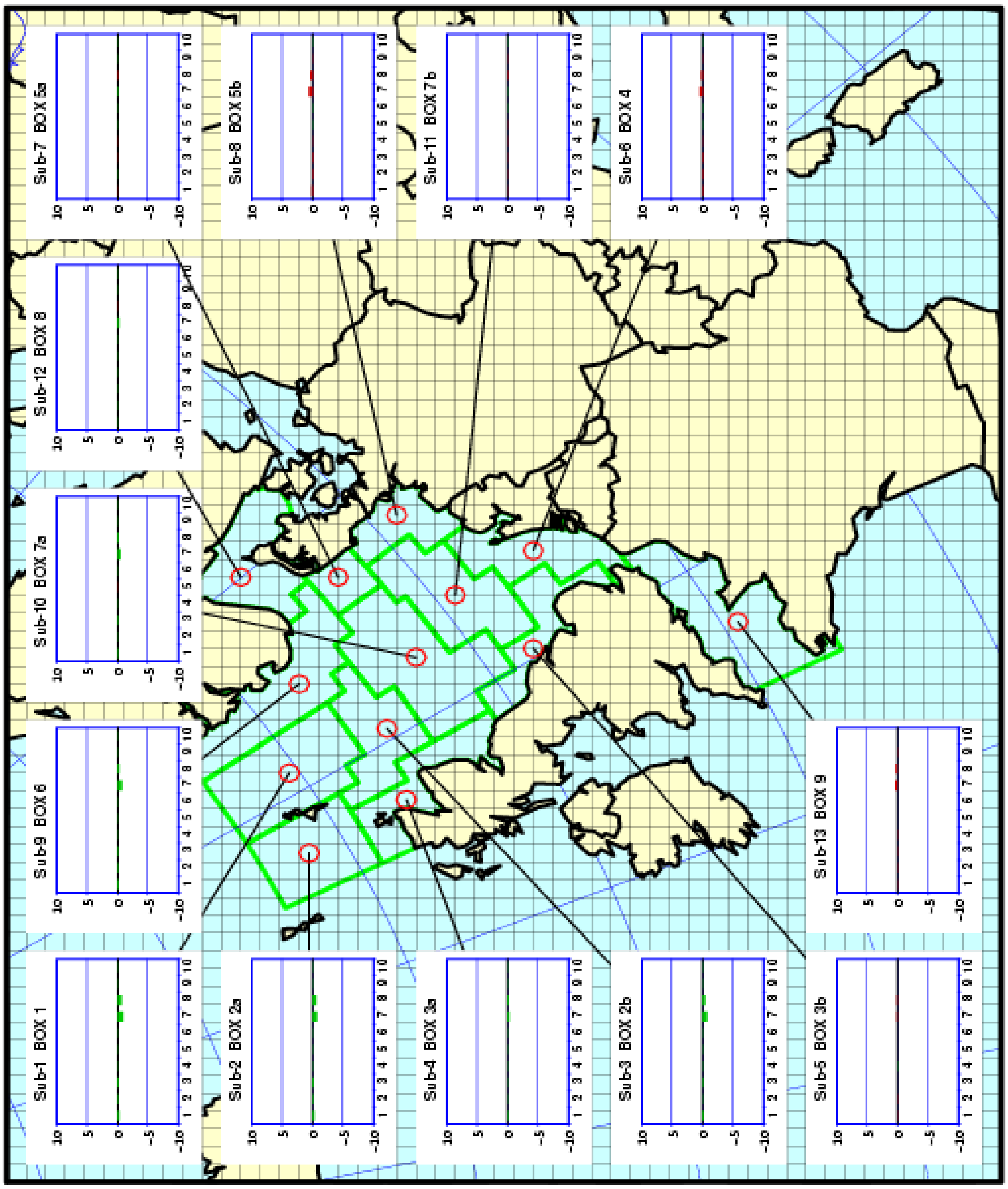

Figure 45. Reduction of annual reduced nitrogen deposition (in percent of initial deposition) due to 25 % reduction of NO_x emissions in each of 10 SNAP sectors in the year 2000. Green color denotes reduction of deposition and red color denotes increased deposition from given sector.

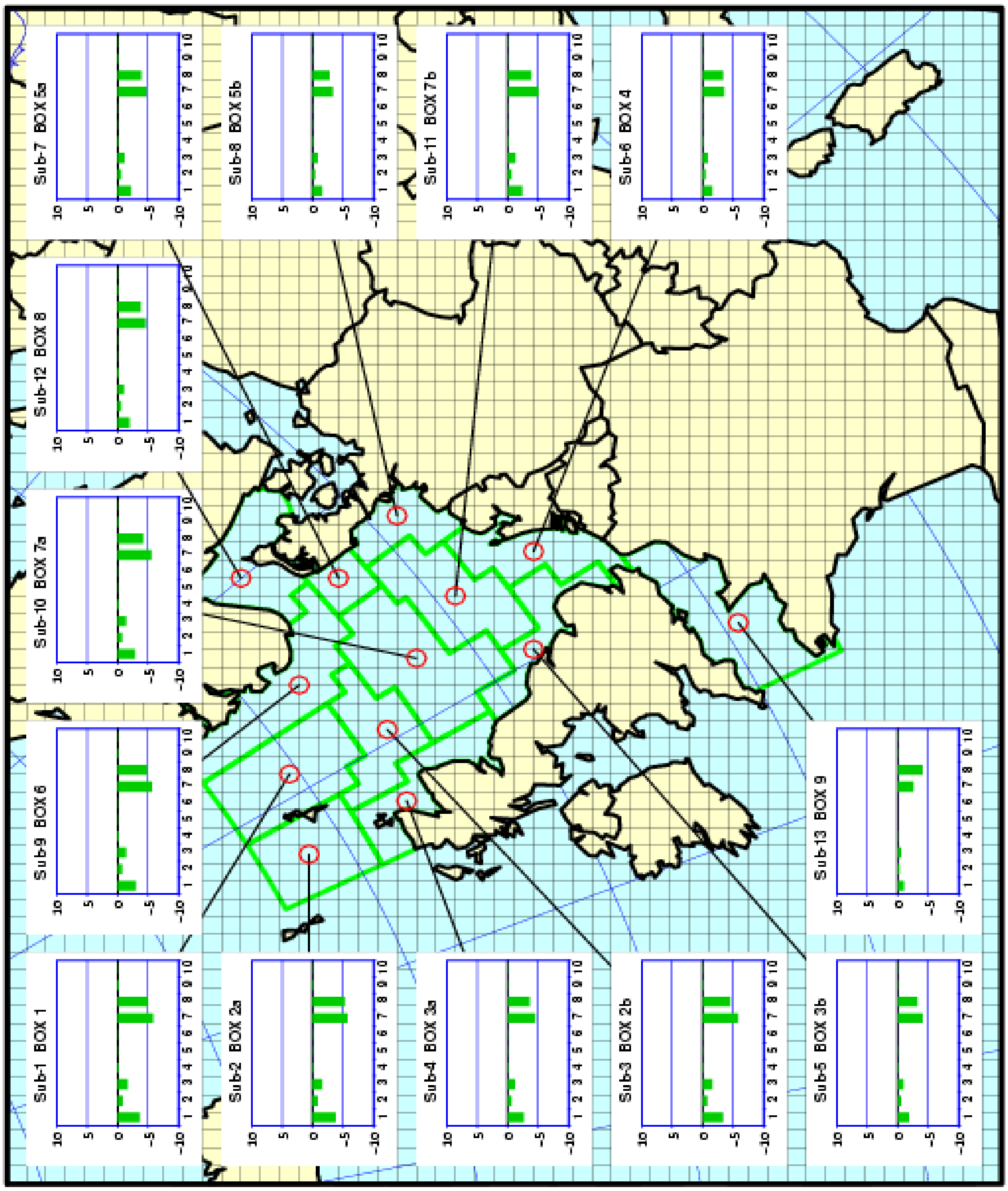

Figure 46. Reduction of total annual nitrogen deposition (in percent of initial deposition) due to 25 % reduction of NO_x emissions in each of 10 SNAP sectors in the year 2000. Green color denotes reduction of deposition and red color denotes increased deposition from given sector.

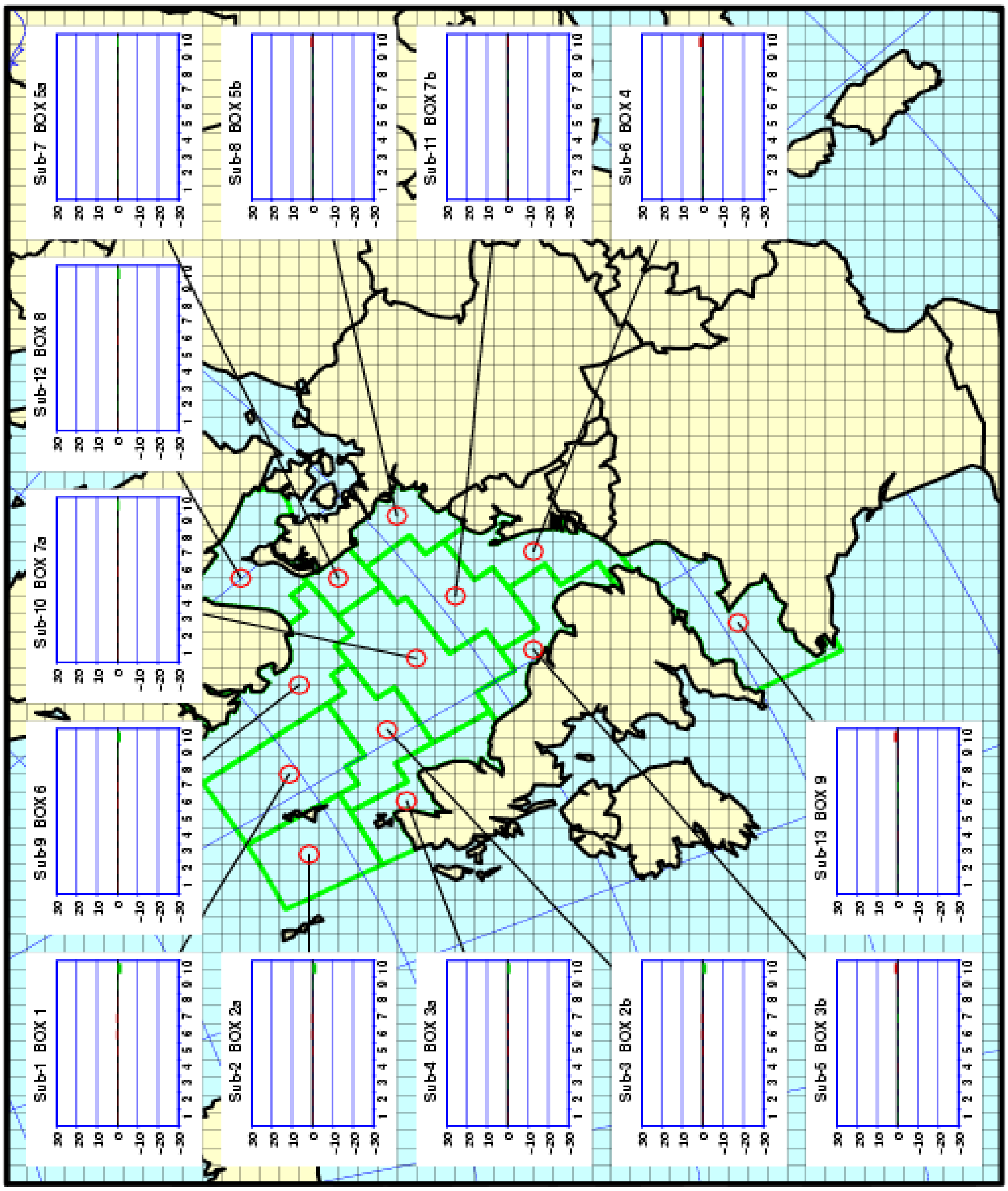

Figure 47. Reduction of annual oxidized nitrogen deposition (in percent of initial deposition) due to 25 % reduction of NH_3 and VOC emissions in each of 10 SNAP sectors in the year 2000. Green color denotes reduction of deposition and red color denotes increased deposition from given sector.

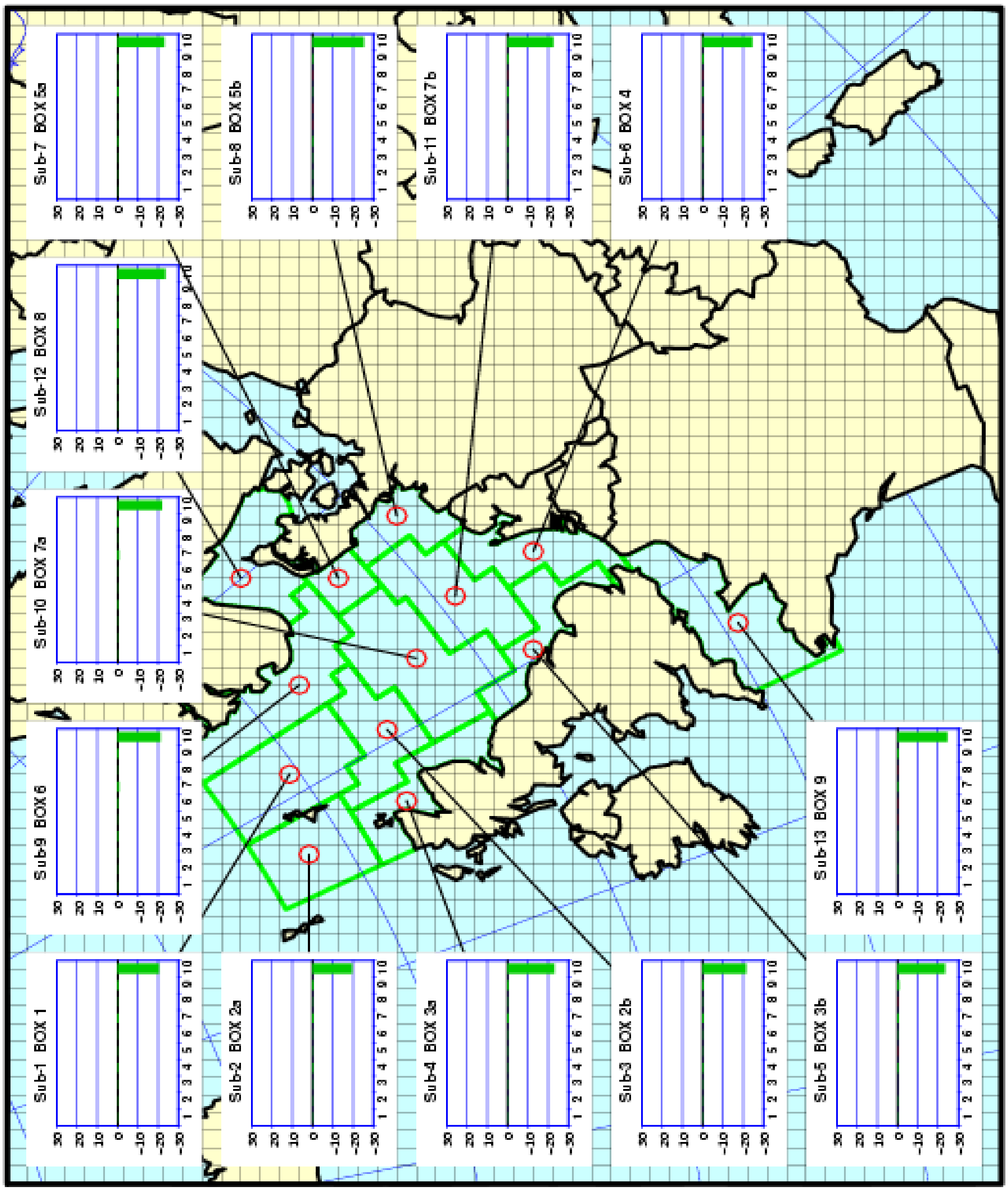

Figure 48. Reduction of annual reduced nitrogen deposition (in percent of initial deposition) due to 25 % reduction of NH_3 and VOC emissions in each of 10 SNAP sectors in the year 2000. Green color denotes reduction of deposition and red color denotes increased deposition from given sector.

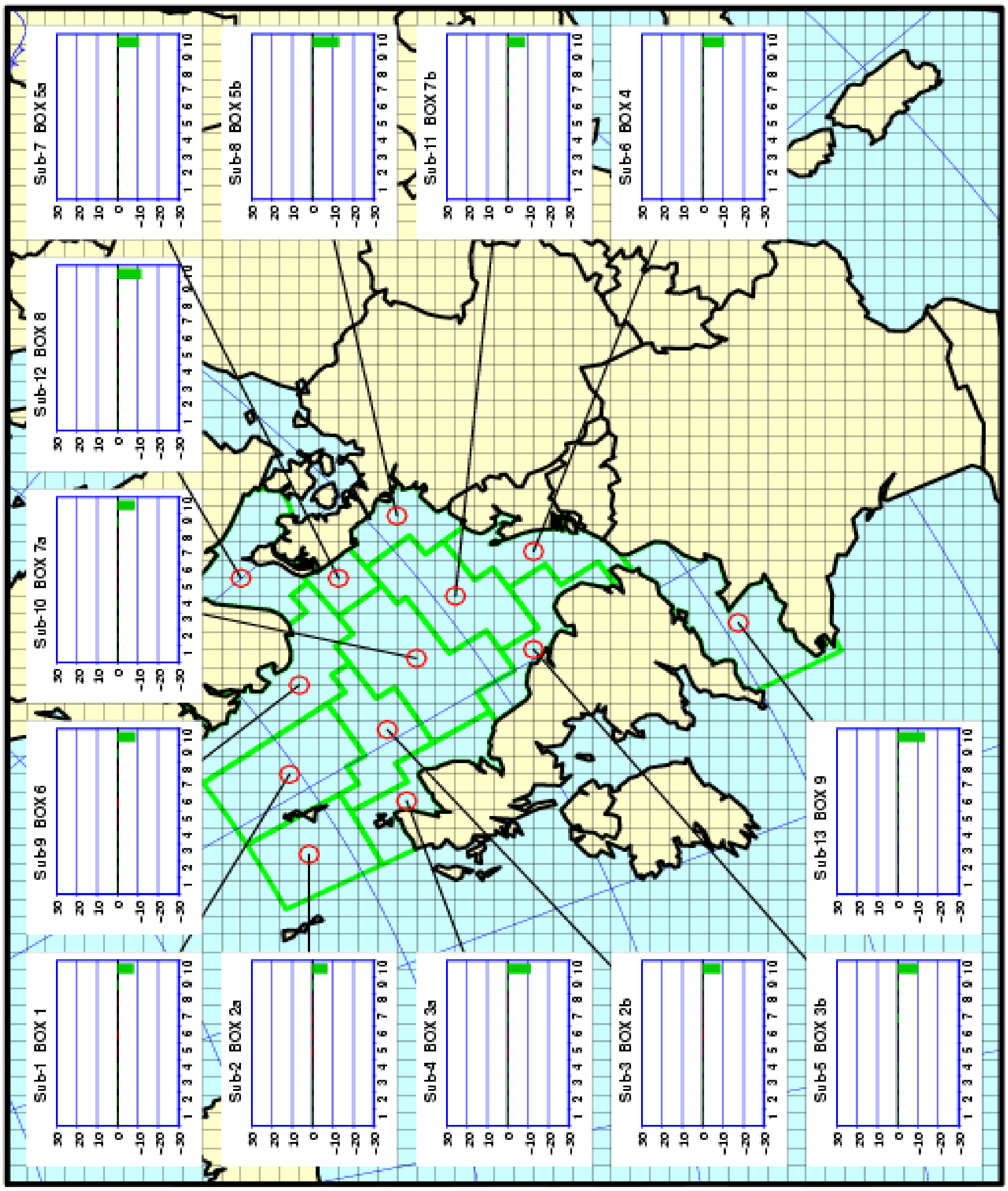

Figure 49. Reduction of total annual nitrogen deposition (in percent of initial deposition) due to 25 % reduction of NH_3 and VOC emissions in each of 10 SNAP sectors in the year 2000. Green color denotes reduction of deposition and red color denotes increased deposition from given sector.

Tables

Table 1. Annual nitrogen oxides emissions (as NO_2) from the OSPAR Contracting Parties and three main contributors to deposition. Unit: kt N a^{-1}.

Country	Year											
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Belgium	102	99	102	100	101	109	96	93	95	88	100	96
Denmark	84	99	85	86	87	82	95	82	74	69	64	62
Finland	91	88	86	86	86	79	82	79	77	75	72	68
France	577	598	584	547	532	520	511	490	485	462	439	429
Germany	830	765	707	672	625	604	577	543	510	493	482	485
Iceland	8	8	9	9	9	9	9	9	9	9	9	9
Ireland	36	37	40	33	35	35	37	36	37	36	38	38
Luxembourg	7	7	7	8	7	6	7	5	5	5	5	5
Netherlands	173	173	169	163	155	148	152	138	130	131	126	125
Norway	68	65	65	68	67	67	70	71	72	72	68	67
Portugal	83	87	94	92	93	97	96	98	105	111	117	115
Spain	367	380	389	381	383	387	375	389	387	400	406	397
Switzerland	47	44	42	39	38	37	34	33	32	30	29	28
Sweden	102	102	97	93	97	90	90	85	81	79	77	75
UK	840	801	771	720	700	662	659	612	584	551	529	511
Italy	590	604	612	606	544	538	531	506	485	452	418	418
Poland	390	367	344	341	336	341	351	339	302	289	255	245
Russia	1096	1045	950	929	812	782	751	724	757	759	717	717

Table 2. Annual ammonia emissions (NH_3) from the OSPAR Contracting Parties and three main contributors to deposition. Unit: kt N a^{-1}.

Country	Year											
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Belgium	82	77	77	80	79	82	82	82	84	82	67	67
Denmark	110	106	105	102	99	93	90	90	91	86	86	84
Finland	31	33	34	32	30	29	29	31	31	29	27	27
France	642	637	630	623	628	631	640	645	646	648	646	642
Germany	606	538	524	506	490	497	501	493	497	497	491	500
Iceland	2	2	2	2	2	2	2	2	2	2	2	2
Ireland	92	95	96	96	98	99	100	101	105	105	100	100
Luxembourg	6	6	6	6	6	6	6	6	6	6	6	6
Netherlands	191	188	48	157	137	159	120	155	140	137	125	122
Norway	19	19	21	20	21	21	22	21	21	21	21	21
Portugal	87	84	88	82	77	82	80	79	81	85	84	84
Spain	269	260	259	244	260	250	278	278	293	303	303	313
Switzerland	59	58	58	58	58	57	57	57	56	56	56	56
Sweden	44	45	45	51	51	51	51	49	49	47	47	44
UK	281	282	270	270	271	263	265	268	264	260	245	239
Italy	384	371	362	370	378	380	354	365	361	369	360	360
Poland	418	371	368	315	316	313	300	288	306	281	265	254
Russia	981	956	893	744	636	679	617	601	556	541	535	535

Table 3. Modelled annual oxidized nitrogen deposition in the main regions of the OSPAR maritime area. Unit: t N a^{-1}.

Year	Main OSPAR Regions				
	I. Arctic Waters	**II. Greater North Sea**	**III. Celtic Seas**	**IV. Bay of Biscay**	**V. Wider Atlantic**
1990	292564	336108	75928	127986	429163
1995	253791	290341	81957	117441	423612
1996	335480	341975	104599	136082	493623
1997	266470	303393	87920	112022	455901
1998	199275	303801	68760	116728	364924
1999	223288	265423	60049	112508	362455
2000	230034	307430	61123	105985	341703
2001	219990	286368	70778	112894	406477

Table 4. Modelled annual reduced nitrogen (NH_3^--N + NH_4^+-N) deposition in the main regions of the OSPAR maritime area. Unit: t N a^{-1}.

Year	Main OSPAR Regions				
	I. Arctic Waters	**II.Greater North Sea**	**III. Celtic Seas**	**IV. Bay of Biscay**	**V. Wider Atlantic**
1990	116220	198289	52213	66181	106737
1995	110635	192534	64090	65434	103163
1996	169805	219973	75331	76454	154243
1997	111158	209527	67192	66514	134577
1998	83814	219440	60242	61396	83789
1999	100138	204010	54654	64570	84169
2000	89388	242805	55282	56012	74937
2001	81483	199678	55135	59194	90193

Table 5. Modelled total annual (NO_x-N + NH_4-N) nitrogen deposition in the main regions of the OSPAR maritime area. Unit: t N a^{-1}.

Year	Main OSPAR Regions				
	I. Arctic Waters	**II.Greater North Sea**	**III. Celtic Seas**	**IV. Bay of Biscay**	**V. Wider Atlantic**
1990	408784	534397	128140	194168	535900
1995	364426	482875	146047	182875	526774
1996	505285	561948	179931	212536	647866
1997	377628	512920	155112	178536	590479
1998	283089	523241	129002	178124	448714
1999	323426	469433	114703	177078	446624
2000	319422	550235	116405	161997	416640
2001	301473	486047	125913	172089	496670

Table 6 Modelled annual oxidized nitrogen deposition in the sub-regions of OSPAR Region II (Greater North Sea) of the OSPAR maritime area. Unit: t N a^{-1}.

Year	Sub-regions of OSPAR Region II Greater North Sea												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1990	24901	10343	19808	12557	18776	27653	10541	21062	42967	46008	38155	35139	28103
1995	23081	11147	16331	11546	16966	25217	8205	17171	35704	35884	30119	27282	31827
1996	28592	15961	21010	16700	20136	25906	9386	17038	38670	44629	38713	28203	37062
1997	24853	13433	18881	13789	17687	22572	8421	15643	34976	43312	35177	24249	30409
1998	21687	9850	16971	10866	19104	28749	8567	18868	36723	40488	35594	27391	28880
1999	18682	7434	13940	9349	16972	24512	7472	16590	32888	33640	30845	27460	25578
2000	22751	8808	17114	10939	18798	26478	9844	17827	34966	42616	37086	32015	28125
2001	20928	10960	16399	12798	18463	27778	7353	19076	30575	35421	32109	26383	28116

Table 7. Modelled annual reduced nitrogen deposition in the sub-regions of OSPAR Region II (Greater North Sea) of the OSPAR maritime area. Unit: t N a^{-1}.

Year	Sub-regions of OSPAR Region II Greater North Sea												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1990	9993	4193	8998	8993	12582	20759	6047	18198	20054	19912	16742	26997	24743
1995	10269	5265	8285	8955	12639	20665	5357	16492	18531	17845	15672	21577	31168
1996	14556	8326	10963	11727	13374	19948	6391	16052	20436	22543	20323	21583	33844
1997	10964	6318	9423	10088	13596	21138	5984	16877	18805	22757	20025	19627	34077
1998	11013	5275	9242	9277	15645	24549	6188	19457	20513	21589	19398	23593	33660
1999	10005	3763	8846	8876	15026	22233	5089	16935	20132	19811	18310	23313	31668
2000	11650	4014	9983	9521	17048	25733	7570	20744	20626	26031	24255	28559	37057
2001	10103	5458	8547	9625	14042	22200	5340	19273	15684	18327	18396	21574	31150

Table 8. Modelled total annual nitrogen deposition in the sub-regions of OSPAR Region II (Greater North Sea) of the OSPAR maritime area. Unit: t N a^{-1}.

Year	Sub-regions of OSPAR Region II Greater North Sea												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1990	34894	14535	28805	21550	31358	48412	16588	39260	63021	65919	54898	62137	52845
1995	33350	16412	24615	20501	29605	45882	13563	33662	54234	53728	45790	48859	62995
1996	43148	24287	31972	28427	33510	45854	15776	33090	59105	67172	59035	49786	70906
1997	35818	19750	28305	23877	31284	43710	14405	32520	53782	66069	55201	43876	64486
1998	32701	15125	26213	20143	34749	53298	14755	38325	57235	62078	54992	50984	62540
1999	28687	11197	22786	18225	31997	46745	12560	33525	53020	53451	49155	50773	57247
2000	34401	12822	27097	20460	35846	52211	17414	38572	55593	68647	61341	60575	65182
2001	31031	16418	24946	22423	32505	49978	12693	38349	46259	53748	50505	47957	59267

Table 9 Contribution of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on Atlantic Ocean) to annual oxidized nitrogen deposition in the main OSPAR regions in the year 2000. Unit: t N a^{-1}.

Country	Main OSPAR Regions					OSPAR Waters
	I. Arctic Waters	II. Greater North Sea	III. Celtic Seas	IV. Bay of Biscay	V. Wider Atlantic	
Belgium	4459	11247	995	1057	2654	20413
Denmark	6007	7078	460	316	1241	15102
Finland	7363	333	67	30	364	8157
France	11823	33195	4787	10124	17279	77208
Germany	19650	33959	2191	2367	6106	64273
Iceland	2910	228	92	86	1729	5044
Ireland	3519	5053	4827	1068	6410	20876
Netherlands	8072	17423	1506	1548	3939	32489
Norway	17445	6786	715	324	2639	27910
Portugal	803	1704	743	11258	9332	23841
Spain	3540	10319	3460	25893	22504	65717
Sweden	7780	2534	231	146	781	11471
UK	46940	103443	19794	8516	35763	214456
Italy	3120	3392	277	832	1696	9317
Poland	5998	4544	370	142	604	11658
Russia	16670	618	39	19	350	17695
North Sea	16198	41476	5076	4159	10180	77089
Atlantic	10967	14244	12765	34380	96227	168583

Table 10. Contribution of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on Atlantic Ocean) to annual reduced nitrogen deposition in the main OSPAR regions in the year 2000. Unit: t N a^{-1}.

Country	Main OSPAR Regions					OSPAR Waters
	I. Arctic Waters	II. Greater North Sea	III. Celtic Seas	IV. Bay of Biscay	V. Wider Atlantic	
Belgium	1646	14561	643	644	1635	19129
Denmark	3581	19234	388	202	720	24125
Finland	1725	53	15	11	29	1833
France	6913	60253	8003	26380	21133	122681
Germany	11524	38582	1310	1160	3557	56132
Iceland	1295	30	34	15	331	1704
Ireland	3479	5977	21555	1167	9879	42057
Netherlands	3052	22001	728	723	1762	28267
Norway	4077	2078	83	37	220	6494
Portugal	464	1024	443	7602	4999	14532
Spain	2246	6518	2102	17142	12628	40636
Sweden	1934	2050	111	80	134	4309
UK	11547	54710	20160	2961	14255	103633
Italy	1931	2280	141	416	669	5437
Poland	4941	4429	383	121	909	10783
Russia	5190	213	17	19	27	5466
North Sea	0	0	0	0	0	0
Atlantic	0	0	0	0	0	0

Table 11. Contribution of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on Atlantic Ocean) to total annual nitrogen deposition in the main OSPAR regions in the year 2000. Unit: t N a^{-1}.

Country	Main OSPAR Regions					OSPAR Waters
	I. Arctic Waters	II. Greater North Sea	III. Celtic Seas	IV. Bay of Biscay	V. Wider Atlantic	
Belgium	6106	25808	1638	1701	4289	39542
Denmark	9588	26312	848	518	1961	39227
Finland	9089	385	81	41	394	9990
France	18735	93448	12790	36504	38412	199889
Germany	31174	72541	3501	3526	9663	120405
Iceland	4204	258	126	100	2060	6748
Ireland	6998	11030	26381	2236	16289	62933
Netherlands	11124	39424	2234	2272	5701	60755
Norway	21522	8864	798	361	2859	34404
Portugal	1267	2728	1186	18861	14331	38373
Spain	5786	16837	5561	43035	35133	106352
Sweden	9714	4584	342	226	915	15781
UK	58487	158153	39954	11477	50018	318089
Italy	5051	5673	418	1248	2365	14754
Poland	10939	8972	753	263	1513	22440
Russia	21860	831	56	37	377	23161
North Sea	16198	41476	5076	4159	10180	77089
Atlantic	10967	14244	12765	34380	96227	168583

Table 12. Contribution of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on the Atlantic Ocean) to annual oxidized nitrogen deposition in 13 sub-regions of OSPAR Region II, (Greater North Sea) in the year 2000. Unit: t N a^{-1}.

Year	Sub-regions of OSPAR Region II - Greater North Sea												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
BE	586	166	505	298	695	1276	456	909	1201	1626	1652	1234	634
DK	659	214	381	164	153	193	347	317	1293	681	453	2072	119
FI	23	9	15	11	19	15	9	11	63	38	26	77	17
FR	1406	470	1248	768	2217	4033	1150	2099	3056	4028	4461	3354	4909
DE	2802	658	1827	906	1237	1601	1377	2738	4358	4864	4146	6397	967
IS	26	22	15	13	16	16	4	7	35	23	22	10	19
IE	389	313	364	332	318	332	106	194	528	795	595	194	599
NL	977	320	810	530	914	1528	856	1507	2074	2624	2340	2152	772
NO	1218	410	491	284	150	160	154	189	1711	786	401	698	122
PT	87	48	49	43	108	188	47	79	152	165	173	120	454
ES	460	231	295	251	618	1193	339	586	865	932	1166	864	2553
SE	228	80	113	69	63	59	68	75	382	216	117	980	78
GB	8948	4101	7793	5239	7896	8232	2689	4537	11782	17818	13690	5205	5475
IT	373	43	219	61	181	271	97	211	245	524	498	473	190
PL	479	90	293	119	94	134	149	220	785	666	385	970	145
RU	64	19	26	9	22	33	20	24	140	48	40	142	29
NOS	2643	1056	2050	1145	2354	4313	1383	2625	4800	5448	4957	3611	5085
ATL	839	522	611	529	888	1253	299	536	1137	1526	1424	662	4132

Table 13. Contribution of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on the Atlantic Ocean) to annual reduced nitrogen deposition in 13 sub-regions of OSPAR Region II, (Greater North Sea) in the year 2000. Unit: t N a^{-1}.

Year	Sub-regions of OSPAR Region II - Greater North Sea												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
BE	310	68	347	183	757	6008	393	1219	873	1194	1661	784	760
DK	728	205	471	145	133	188	1866	1239	2256	831	636	10318	93
FI	1	2	2	3	5	3	0	0	11	8	3	14	0
FR	1241	416	1264	817	3106	7514	1115	2491	2925	3989	4833	2718	2805
DE	1968	387	1468	645	964	2213	1687	9747	3521	4204	4615	6398	672
IS	3	9	2	4	2	1	0	0	4	2	2	0	0
IE	383	383	461	514	510	329	103	167	560	952	575	120	935
NL	579	166	540	323	786	4952	833	4815	1531	2059	3123	1697	575
NO	193	57	67	35	19	11	31	16	1107	66	42	426	5
PT	44	50	36	30	70	108	23	35	89	103	97	61	281
ES	279	169	193	161	398	667	197	340	549	598	710	481	1801
SE	84	36	78	40	33	23	44	34	215	80	44	1304	26
GB	3040	1625	3618	5950	9926	4280	749	1254	3673	8358	6017	1225	5041
IT	344	40	170	42	90	155	57	136	164	349	338	282	109
PL	474	106	286	94	82	105	160	265	777	583	316	1102	62
RU	16	14	7	3	7	10	3	5	66	19	11	43	8
NOS	0	0	0	0	0	0	0	0	0	0	0	0	0
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 14. Contribution of emitter countries (13 OSPAR Contracting Parties plus three largest outside contributors + ship traffic on the North Sea and on the Atlantic Ocean) to total annual nitrogen deposition in 13 sub-regions of OSPAR Region II, (Greater North Sea) in the year 2000. Unit: t N a^{-1}.

Year	Sub-regions of OSPAR Region II - Greater North Sea												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
BE	896	234	852	481	1452	7284	848	2128	2075	2820	3313	2019	1394
DK	1388	419	852	309	287	381	2213	1556	3548	1513	1089	12390	212
FI	24	11	17	14	24	19	9	11	73	46	29	92	17
FR	2647	886	2511	1585	5324	11547	2265	4590	5981	8017	9294	6072	32934
DE	4769	1045	3295	1551	2201	3814	3064	12484	7879	9067	8762	12795	1639
IS	29	31	17	17	18	17	4	7	39	26	23	10	20
IE	773	695	825	846	828	661	210	362	1087	1748	1170	315	1535
NL	1556	486	1350	853	1700	6480	1689	6322	3606	4683	5463	3849	1347
NO	1411	466	558	319	169	171	184	205	2817	852	442	1124	128
PT	131	97	86	73	178	296	70	114	242	268	270	181	735
ES	738	400	488	412	1015	1859	536	926	1414	1531	1875	1345	4354
SE	313	116	190	109	97	82	113	109	597	296	161	2284	105
GB	11988	5726	11412	11188	17822	12512	3438	5791	15455	26176	19707	6431	10516
IT	718	83	389	102	270	426	154	347	409	873	835	755	299
PL	953	196	579	213	176	240	309	485	1562	1249	701	2071	206
RU	80	33	33	12	29	43	23	29	206	68	50	184	38
NOS	2643	1056	2050	1145	2354	4313	1383	2625	4800	5448	4957	3611	5085
ATL	839	522	611	529	888	1253	299	536	1137	1526	1424	662	4132

Table 15 Deposition of oxidized nitrogen in the main OSPAR regions in the year 2000 after 25 % reduction of NO_2 emissions in each of the 10 emission sectors. Unit: t N a^{-1}.

Sector	Main OSPAR Regions					OSPAR Waters
	I. Arctic Waters	II. Greater North Sea	III. Celtic Seas	IV. Bay of Biscay	IV. Wider Atlantic	
1	226928	304164	61682	103547	353973	1050295
2	234782	313557	63455	106107	358807	1076708
3	232520	310520	62980	105520	357558	1069097
4	236578	316167	63949	106879	360546	1084119
5	237560	316801	64031	107088	360956	1086435
6	237721	316827	64032	107089	360963	1086632
7	219319	291514	59774	100755	348853	1020215
8	220209	294408	58124	94151	332486	999378
9	237383	316437	63985	106978	360768	1085552
10	237660	316736	64013	106977	360929	1086315

Table 16. Deposition of reduced nitrogen in the main OSPAR regions in the year 2000 after 25 % reduction of NO_2 emissions in each of the 10 emission sectors. Unit: t N a^{-1}.

Sector	Main OSPAR Regions					OSPAR Waters
	I. Arctic Waters	II. Greater North Sea	III. Celtic Seas	IV. Bay of Biscay	V. Wider Atlantic	
1	97643	243066	58152	62592	145634	607087
2	97756	243072	58134	62603	145742	607306
3	97718	243046	58131	62587	145713	607195
4	97795	243075	58111	62543	145862	607387
5	97816	243081	58111	62537	145882	607427
6	97818	243081	58111	62538	145883	607430
7	97288	242902	58212	62837	145104	606343
8	97482	243155	58216	62831	145324	607007
9	97814	243079	58112	62543	145871	607418
10	97815	243074	58110	62535	145882	607416

Table 17. Deposition of total (oxidized + reduced) nitrogen in the main OSPAR regions in the year 2000 after 25 % reduction of NO_2 emissions in each of the 10 emission sectors. Unit: t N a^{-1}.

Sector	Main OSPAR Regions					OSPAR Waters
	I. Arctic Waters	II. Greater North Sea	III. Celtic Seas	IV. Bay of Biscay	V. Wider Atlantic	
1	324571	547230	119834	166140	499608	1657383
2	332537	556628	121589	168710	504548	1684013
3	330237	553566	121111	168107	503272	1676293
4	334373	559242	122060	169422	506409	1691506
5	335376	559881	122141	169626	506838	1693862
6	335539	559907	122143	169627	506846	1694062
7	316607	534416	117987	163591	493958	1626558
8	317691	537564	116340	156982	477809	1606385
9	335197	559516	122096	169521	506639	1692969
10	335475	559809	122123	169512	506810	1693730

Table 18. Deposition of oxidized nitrogen in the main OSPAR regions in the year 2000 after 25 % reduction of NH_3 and VOC emissions in each of the 10 emission sectors. Unit: t N a^{-1}.

Sector	Main OSPAR Regions					OSPAR Waters
	I. Arctic Waters	II. Greater North Sea	III. Celtic Seas	IV. Bay of Biscay	V. Wider Atlantic	
1	237788	316835	64034	107105	360985	1086747
2	238059	316809	64041	107159	361169	1087238
3	237760	316826	64034	107100	360978	1086698
4	237874	317067	64088	107279	361109	1087416
5	238235	317104	64107	107198	361265	1087908
6	239347	317437	64177	107494	361842	1090297
7	239954	316937	64130	107467	361905	1090393
8	238025	316848	64050	107162	361124	1087209
9	237694	316824	64041	107116	360896	1086570
10	235540	316084	64203	107193	357713	1080734

Table 19. Deposition of reduced nitrogen in the main OSPAR regions in the year 2000 after 25 % reduction of NH_3 and VOC emissions in each of the 10 emission sectors. Unit: t N a^{-1}.

Sector	Main OSPAR Regions					OSPAR Waters
	I. Arctic Waters	II. Greater North Sea	III. Celtic Seas	IV. Bay of Biscay	V. Wider Atlantic	
1	97784	243014	58108	62534	145871	607311
2	97762	242886	58010	62386	145759	606804
3	97804	243045	58110	62536	145876	607371
4	97477	242403	58017	61804	145541	605241
5	97812	243087	58107	62529	145877	607412
6	97738	242960	58084	62496	145821	607097
7	97400	241871	57848	62316	145526	604961
8	97801	243074	58109	62530	145868	607382
9	97487	241903	57911	61985	145383	604669
10	83421	186628	44508	48245	130905	493707

Table 20. Deposition of total (oxidized + reduced) nitrogen in the main OSPAR regions in the year 2000 after 25 % reduction of NH_3 and VOC emissions in each of the 10 emission sectors. Unit: t N a^{-1}.

Sector	Main OSPAR Regions					OSPAR Waters
	I. Arctic Waters	II. Greater North Sea	III. Celtic Seas	IV. Bay of Biscay	V. Wider Atlantic	
1	335571	559849	122142	169638	506857	1694057
2	335821	559695	122051	169546	506929	1694042
3	335564	559872	122143	169635	506854	1694069
4	335350	559470	122105	169083	506649	1692658
5	336047	560191	122213	169727	507142	1695320
6	337085	560397	122261	169990	507663	1697396
7	337355	558808	121977	169783	507432	1695355
8	335826	559922	122159	169692	506992	1694592
9	335181	558727	121952	169101	506280	1691240
10	318961	502712	108711	155438	488619	1574442

Table 21. Deposition of oxidized nitrogen in 13 sub-regions of OSPAR Region II (Greater North Sea) in the year 2000 after 25 % reduction of NO_x emissions in each of the 10 emission sectors. Unit: t N a^{-1}.

Sec.	Sub-regions of OSPAR Region II – Greater North Sea												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	21229	8536	16421	10687	19569	27659	9688	17807	33427	41840	37342	30548	29378
2	22166	8916	17096	11101	20077	28290	9972	18296	34651	43279	38439	31349	29884
3	21904	8816	16899	10992	19901	28053	9878	18119	34284	42823	38069	31050	29694
4	22373	9001	17265	11203	20231	28470	10057	18431	34957	43698	38761	31619	30058
5	22418	9016	17297	11221	20263	28526	10079	18472	35041	43783	38836	31704	30102
6	22424	9017	17300	11223	20264	28526	10080	18473	35046	43786	38838	31706	30103
7	20569	8309	15820	10321	18727	26524	9250	17004	32059	40050	35644	28998	28218
8	20822	8351	16129	10503	19042	26635	9378	17266	32393	40915	36402	29357	27158
9	22380	9003	17275	11208	20247	28498	10067	18452	34987	43734	38795	31674	30074
10	22418	9016	17296	11220	20259	28519	10076	18467	35037	43776	38823	31695	30088

Table 22. Deposition of reduced nitrogen in 13 sub-regions of OSPAR Region II (Greater North Sea) in the year 2000 after 25 % reduction of NO_x emissions in each of the 10 emission sectors. Unit: t N a^{-1}.

Sec.	Sub-regions of OSPAR Region II – Greater North Sea												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	11013	4057	9590	9353	16991	25197	7768	21440	20261	25261	24398	28868	38875
2	11029	4063	9602	9359	16984	25182	7763	21411	20278	25273	24393	28868	38873
3	11022	4061	9596	9355	16982	25189	7764	21424	20268	25265	24392	28865	38869
4	11039	4066	9607	9360	16981	25174	7763	21403	20289	25282	24391	28877	38849
5	11041	4067	9609	9360	16982	25170	7763	21398	20293	25286	24391	28878	38847
6	11041	4067	9609	9360	16982	25170	7763	21398	20293	25286	24391	28878	38848
7	10937	4035	9537	9332	17007	25282	7758	21543	20147	25155	24384	28805	38987
8	10971	4044	9565	9341	17002	25237	7771	21482	20234	25235	24414	28895	38971
9	11040	4067	9608	9360	16982	25172	7763	21399	20291	25284	24391	28877	38851
10	11040	4067	9608	9360	16982	25170	7763	21398	20293	25284	24390	28877	38847

Table 23. Deposition of total nitrogen in 13 sub-regions of OSPAR Region II (Greater North Sea) in the year 2000 after 25 % reduction of NO_x emissions in each of the 10 emission sectors. Unit: t N a^{-1}.

Sec.	Sub-regions of OSPAR Region II – Greater North Sea												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	32243	12593	26011	20040	36560	52856	17455	39247	53688	67102	61740	59416	68253
2	33195	12979	26697	20460	37061	53472	17735	39707	54928	68553	62831	60217	68757
3	32926	12877	26495	20347	36882	53242	17642	39543	54552	68088	62461	59916	68563
4	33412	13067	26871	20563	37212	53644	17820	39834	55246	68980	63152	60496	68908
5	33459	13084	26905	20581	37245	53696	17842	39870	55334	69069	63227	60582	68950
6	33465	13085	26908	20583	37246	53696	17843	39870	55339	69072	63228	60584	68950
7	31506	12345	25357	19653	35734	51806	17008	38547	52206	65205	60029	57802	67205
8	31794	12394	25695	19844	36044	51872	17149	38749	52627	66150	60816	58252	66129
9	33420	13070	26883	20568	37229	53670	17830	39851	55278	69018	63186	60551	68925
10	33459	13083	26904	20580	37241	53690	17839	39865	55330	69060	63213	60572	68936

Table 24. Deposition of oxidized nitrogen in 13 sub-regions of OSPAR Region II (Greater North Sea) in the year 2000 after 25 % reduction of NH_3 and VOC emissions in each of the 10 emission sectors. Unit: t N a^{-1}.

Sec.	Sub-regions of OSPAR Region II – Greater North Sea												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	22425	9018	17300	11223	20262	28525	10080	18472	35049	43790	38838	31707	30101
2	22432	9023	17305	11225	20261	28514	10074	18463	35050	43793	38830	31699	30096
3	22425	9018	17300	11222	20262	28525	10080	18472	35047	43786	38837	31706	30102
4	22445	9028	17315	11233	20281	28544	10086	18487	35073	43822	38865	31726	30117
5	22474	9044	17330	11240	20258	28513	10089	18483	35108	43833	38856	31736	30095
6	22549	9076	17375	11258	20238	28473	10094	18492	35194	43910	38872	31798	30063
7	22530	9076	17363	11249	20185	28389	10080	18440	35170	43851	38792	31755	30010
8	22441	9026	17309	11227	20255	28506	10079	18467	35065	43797	38832	31711	30089
9	22416	9015	17294	11221	20276	28535	10077	18472	35036	43783	38841	31695	30118
10	21973	8865	16993	11081	20535	29022	10017	18683	34496	43408	38986	31410	30581

Table 25. Deposition of reduced nitrogen in 13 sub-regions of OSPAR Region II (Greater North Sea) in the year 2000 after 25 % reduction of NH_3 and VOC emissions in each of the 10 emission sectors. Unit: t N a^{-1}.

Sec.	Sub-regions of OSPAR Region II – Greater North Sea												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	11036	4066	9604	9359	16981	25168	7760	21390	20285	25277	24385	28862	38846
2	11029	4061	9596	9343	16958	25161	7758	21392	20274	25252	24369	28865	38833
3	11039	4066	9606	9359	16982	25168	7762	21394	20289	25281	24386	28872	38847
4	11011	4057	9584	9343	16901	25071	7745	21334	20240	25204	24306	28821	38791
5	11040	4066	9606	9358	16987	25178	7762	21402	20289	25282	24393	28878	38850
6	11028	4063	9596	9354	16980	25182	7755	21400	20261	25255	24382	28861	38850
7	10972	4043	9547	9307	16862	25090	7727	21362	20160	25121	24273	28718	38697
8	11039	4067	9606	9359	16985	25178	7762	21400	20288	25280	24391	28875	38851
9	10985	4045	9557	9311	16843	25036	7738	21349	20207	25136	24254	28812	38634
10	8789	3273	7538	7183	12980	18983	5975	15980	15980	19743	18868	22084	29252

Table 26. Deposition of total nitrogen in 13 sub-regions of OSPAR Region II (Greater North Sea in the year) 2000 after 25 % reduction of NH_3 and VOC emissions in each of the 10 emission sectors. Unit: t N a^{-1}.

Sec.	Sub-regions of OSPAR Region II – Greater North Sea												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	33462	13084	26904	20582	37243	53693	17840	39863	55335	69066	63223	60569	68947
2	33461	13083	26901	20569	37219	53675	17833	39854	55324	69046	63200	60564	68929
3	33464	13084	26906	20582	37244	53693	17842	39866	55336	69067	63224	60578	68949
4	33456	13085	26900	20577	37182	53615	17831	39821	55314	69026	63171	60548	68908
5	33514	13111	26936	20598	37245	53691	17852	39885	55397	69116	63249	60613	68945
6	33576	13138	26971	20612	37218	53654	17849	39892	55455	69164	63255	60659	68913
7	33502	13119	26910	20556	37047	53479	17807	39802	55330	68972	63065	60472	68707
8	33480	13092	26915	20586	37240	53684	17841	39867	55353	69077	63224	60586	68939
9	33402	13059	26851	20532	37119	53572	17816	39821	55242	68920	63095	60508	68752
10	30762	12138	24531	18264	33515	48005	15992	34663	50476	63150	57854	53494	59833