OSPAR COMMISSION

Atmospheric Deposition of Nitrogen to the OSPAR Maritime Area in the period 1990-2021

Hazardous Substances and Eutrophication Series

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EMEP MSC-W Report for OSPAR

Nitrogen Depositions to the OSPAR Maritime Area in the period 1990-2021

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OSPAR Convention

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. The Contracting Parties are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom

Convention OSPAR

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. Les Parties contractantes sont l´Allemagne, la Belgique, le Danemark, l´Espagne, 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, la Suisse et l´Union Européenne.

Acknowledgements

The authors are indebted to the scientific teams at EMEP MSC-W and EMEP CEIP for their help in providing the necessary input data for the model runs and analyses conducted for this report. The OSPAR Commission is acknowledged for supporting the work presented in this report.

Contents

Executive Summary

Airborne nitrogen depositions to the OSPAR Maritime Area for the 32-year period 1990-2021 have been calculated with the EMEP MSC-W Chemistry Transport Model at a horizontal resolution of 0.1°longitude x 0.1°latitude, based on emission data updated in 2023 by the EMEP Centre on Emission Inventories and Projections. The 1990-2021 period is the longest period for which EMEP MSC-W has done this type of calculation for OSPAR until now.

Results for actual and normalized nitrogen depositions, as well as source-receptor relationships, are presented in this report and in the accompanying data sheets for the 5 OSPAR Regions, the 24 Exclusive Economic Zones (EEZs) within the OSPAR Maritime Area, the 25 so-called 'partial EEZs' (EEZs divided up into different OSPAR regions), and the 64 COMP4 (Fourth Common Procedure) Assessment Units. Normalization ("weather-averaging") was done using meteorological data from the 2016-2021 period.

According to our model results, *actual* (i.e. non-normalized) depositions of *oxidized* nitrogen were clearly lower in 2021 than in 1990 in all OSPAR Regions, EEZs, partial EEZs, and COMP4 Assessment Units. In the case of *reduced* nitrogen depositions, there are both increases and decreases, depending on the receptor area under consideration. This is mainly due to the much less significant (or even absent) downward trends seen in the emissions of *reduced* nitrogen in many countries. However, total (oxidized+reduced) nitrogen depositions were lower in 2021 than in 1990 in all OSPAR Regions, EEZs, partial EEZs, and COMP4 Assessment Units.

A trend analysis for depositions over the 32-year period from 1990 to 2021, using the Mann-Kendall test, shows statistically significant downward trends in all receptor areas for *oxidized* nitrogen, while for *reduced* nitrogen there are far less areas with significant downward trends; indeed some of them show *increases*. In general, trends in normalized depositions are more significant than those in actual depositions because the interannual variability in meteorology is filtered out.

In general, receptor areas are most influenced by the countries adjacent to them, but large emitters can make important contributions even if they are far away, mainly as oxidized nitrogen deposition. The largest contribution to nitrogen deposition in OSPAR Regions II and III is made by the United Kingdom, while OSPAR Region IV receives the single-largest contribution from Spain; the more remote Regions I and V are strongly influenced by the boundary condition (i.e. sources outside the EMEP model domain).

Récapitulatif

Les dépôts atmosphériques d'azote dans la zone maritime OSPAR pour la période de 1990 à 2021 ont été calculés avec le modèle de transport de la chimie du MSC-W de l'EMEP à une résolution horizontale de 0,1° de longitude x 0,1° de latitude, sur la base des données d'émission mises à jour en 2023 par le Centre des inventaires et des projections des émissions de l'EMEP. La période 1990-2021 est la plus longue période pour laquelle le MSC-W de l'EMEP a effectué ce type de calcul pour OSPAR jusqu'à présent.

Les résultats des dépôts d'azote réels et normalisés, ainsi que les relations source-récepteur, sont présentés dans ce rapport et dans les fiches de données qui l'accompagnent pour les 5 Régions OSPAR, les 24 zones économiques exclusives (ZEE) de la zone maritime OSPAR, les 25 ZEE dites « partielles » (ZEE divisées en différentes Régions OSPAR) et les 64 unités d'évaluation COMP4 (Quatrième procédure commune). La normalisation ("weather-averaging") a été effectuée à l'aide des données météorologiques de la période 2016-2021.

D'après les résultats de notre modèle, les dépôts réels (c'est-à-dire non normalisés) d'azote oxydé sont nettement plus faibles en 2021 qu'en 1990 dans toutes les Régions OSPAR, les ZEE, les ZEE partielles et les unités d'évaluation COMP4. Dans le cas des dépôts d'azote réduit, on observe à la fois des augmentations et des diminutions, selon la zone réceptrice considérée. Ceci est principalement dû aux tendances à la baisse beaucoup moins significatives (voire absentes) observées dans les émissions d'azote réduit dans de nombreux pays. Cependant, les dépôts d'azote total (oxydé+réduit) étaient plus faibles en 2021 qu'en 1990 dans toutes les Régions OSPAR, ZEE, ZEE partielles et unités d'évaluation COMP4.

Une analyse des tendances des dépôts sur la période de 32 ans allant de 1990 à 2021, utilisant le test de Mann-Kendall, montre des tendances à la baisse statistiquement significatives dans toutes les zones réceptrices pour l'azote oxydé, alors que pour l'azote réduit, il y a beaucoup moins de zones avec des tendances à la baisse significatives ; en effet, certaines d'entre elles montrent des augmentations. En général, les tendances des dépôts normalisés sont plus significatives que celles des dépôts réels car la variabilité interannuelle de la météorologie est filtrée.

En général, les zones réceptrices sont le plus influencées par les pays qui leur sont adjacents, mais les grands émetteurs peuvent apporter des contributions importantes même s'ils sont éloignés, principalement sous forme de dépôts d'azote oxydé. La plus grande contribution aux dépôts d'azote dans les Régions OSPAR II et III est apportée par le Royaume-Uni, tandis que la Région OSPAR IV reçoit la plus grande contribution de l'Espagne ; les Régions I et V, plus éloignées, sont fortement influencées par les sources situées en dehors du domaine du modèle EMEP.

1 Introduction

Nitrogen deposition to OSPAR Convention Waters has been a subject of cooperation between EMEP MSC-W (Meteorological Synthesizing Centre – West) and OSPAR since 2003, starting with the first EMEP report for OSPAR delivered by Bartnicki and Fagerli (2003). This cooperation has been continued and documented in numerous reports until the present day.

This report covers results for the 2023 contract between OSPAR and EMEP MSC-W, entitled "CONTRACT FOR EMEP-W products on actual and normalized airborne deposition of nitrogen to each OSPAR region and to each EEZ, to each partial EEZ and the 40 largest COMP4 units with source-receptor analyses". The following product (deliverable) was requested:

- Actual and normalized airborne deposition of nitrogen to each OSPAR Region and to each EEZ, to each partial EEZ and the 40 largest COMP4 units including reports, figures, and tables and source receptor analysis.

The term "Partial EEZs" in this context refers to the different parts of EEZs falling within more than one OSPAR Region. This is the case for 9 of the 24 EEZs considered by EMEP MSC-W. EEZs can fall within up to five OSPAR Regions. In total, 25 partial EEZs are considered.

The term "COMP4 units" refers to the sixty-four COMP4 Assessment Units as defined in a shape file provided by OSPAR to EMEP MSC-W in August 2022[1]. All of these units have been implemented in the EMEP MSC-W analysis routines for nitrogen deposition, although only 40 of them were required by the contract (as the smallest and thinnest Units are only poorly resolved by the EMEP model grid).

Calculations have been done for the entire 1990-2021 period. As usual, and as required by the contract, results are provided in this report and the accompanying Excel file both for *actual* deposition (best representation of real depositions in each year) and for *normalized* deposition (based on emissions in each year but on 'average' meteorology).

For the normalization procedure we have used meteorological data for the years 2016 to 2021.

After the description of the model setup in Chapter 2, we present the emission data used in the model calculations (Chapter 3) and the definitions of receptor areas considered for OSPAR (Chapter 4). The model results are presented in Chapters 5 and 6, while Chapter 7 lists the main conclusions. Chapter 8 briefly introduces the Excel and ASCII files that have been submitted to OSPAR along with this report.

[1] The only change since the August 2022 version of the COMP4 definitions was the name of the 'GBC' assessment unit – its long name was updated from *German Bight (deep)* to *German Bight Central*.

2 Modeling

2.1 The EMEP MSC-W model

The EMEP MSC-W model, a multi-pollutant 3D Eulerian Chemical Transport Model, has been used for all nitrogen computations presented here. The model takes into account processes of emissions, advection, turbulent diffusion, chemical transformations, wet and dry depositions and inflow/outflow of pollutants into/out of the model domain. It was documented in detail in Simpson et al. (2012) and in the annual chapters on model updates in subsequent EMEP status reports (Simpson et al., 2021; 2022; 2023; and references therein).

The model is regularly evaluated against measurements from the EMEP network under the LRTAP Convention, with results available to the scientific community online at the AeroVal evaluation web pages (https://aeroval.met.no/evaluation.php?project=emep), but also in a large number of international research projects and operational services (e.g. the Copernicus Atmosphere Modelling Service, where the EMEP MSC-W model is participating).

A detailed evaluation of this year's EMEP MSC-W model simulation (for 2021) can be viewed at https://aeroval.met.no/evaluation.php?project=emep&exp_name=2023-reporting

As in every model, deviations between model and observations do occur and are highly variable both in space and time, and these are subject to continuous investigation and model development. Nevertheless, the performance of the EMEP MSC-W model can be considered as state-of-the-art over a large range of both gaseous species and particulate matter, and thereby is among the best air quality models available today. The transparency of the EMEP MSC-W model results and activities is further ensured by the availability of the model code as Open Source at https://github.com/metno/emep-ctm. In this way, the scientific community as well as advanced policy users can check and apply the model themselves, both as a research tool and for underpinning of air quality legislation.

2.2 Experimental setup

Meteorological data, needed as input to the EMEP MSC-W model, have been generated by the ECMWF IFS numerical weather prediction model, version cy40r1, for the period 1990 to 2017 and version cy46r1 for the period 2018 to 2021 (see ECMWF model documentation). The version change to cy46r1 was inevitable because cy40r1 is not supported by ECMWF anymore. However, changes in the weather prediction model have a relatively small effect on the chemistry transport model results (changes in the chemistry transport model itself and in the emission data are more important).

Emission data for 1990-2021 were obtained in June 2023 from the EMEP Centre CEIP (EMEP, 2023, their Chapter 3) and were used in the model runs covering that same 32-year period. More details about the emission data used in our model calculations are given in the next Chapter.

EMEP MSC-W model version rv5.0, documented and evaluated in the EMEP Status report 1/2023 (EMEP, 2023) was run for the entire 1990-2021 period, using the meteorological and emission data described above, on 0.1°lon × 0.1°lat resolution and within the longitude-latitude domain outlined shown in Figure 1.

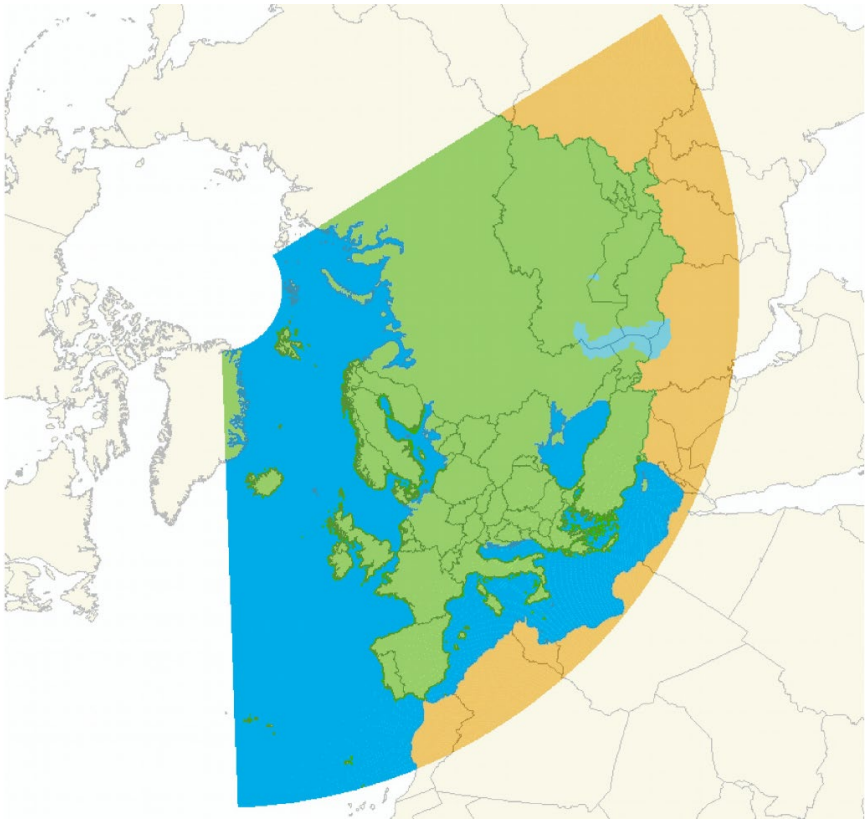


Figure 1: Domain used in the EMEP model calculations.

3 Emission data by Contracting Parties

In this chapter we present the emission data used for modelling at EMEP MSC-W. They are provided on an annual basis by the EMEP Centre on Emission Inventories and Projects (CEIP) and are publicly available (*WebDab Emission database* at https://ceip.at, see "Emissions as used in EMEP models").

Annual emissions of oxidized nitrogen (NOx) and reduced nitrogen (ammonia/NH_3) are listed in Tables 1 and 2, respectively, for the 1990-2021 period and the OSPAR Contracting Parties[2]. Emissions from international shipping in the North Sea and North-East Atlantic areas (see Figure 2), and all other sources combined, are listed as well. Figure 3 visualizes the evolution of emissions for the same period.

Data for the European Union (EU) are not tabulated because the number of members has changed several times during the considered period. The emissions of other sources (labelled 'Other' in the Figure and the Tables) may appear large, but it has to be noted that these sources are far away from the OSPAR maritime area and thus are not very important for nitrogen deposition in the OSPAR receptor areas that are considered in this report. However, for accurate modelling they must always be included in the EMEP MSC-W model simulations.

As discussed in earlier reports, emissions of oxidized nitrogen have been considerably reduced over the years, while ammonia emissions do not show very clear reductions during the later years. This is reflected also in the results for deposition of nitrogen, to be presented in Chapter 5.

For completeness, emissions of *total* nitrogen (oxidized+reduced) are listed in Table 3.

[2] Belgium (BE), Denmark (DK), Finland (FI), France (FR), Germany (DE), Iceland (IS), Ireland (IE), Luxembourg (LU), The Netherlands (NL), Norway (NO), Portugal (PT), Spain (ES), Sweden (SE), Switzerland (CH) and the United Kingdom (GB).

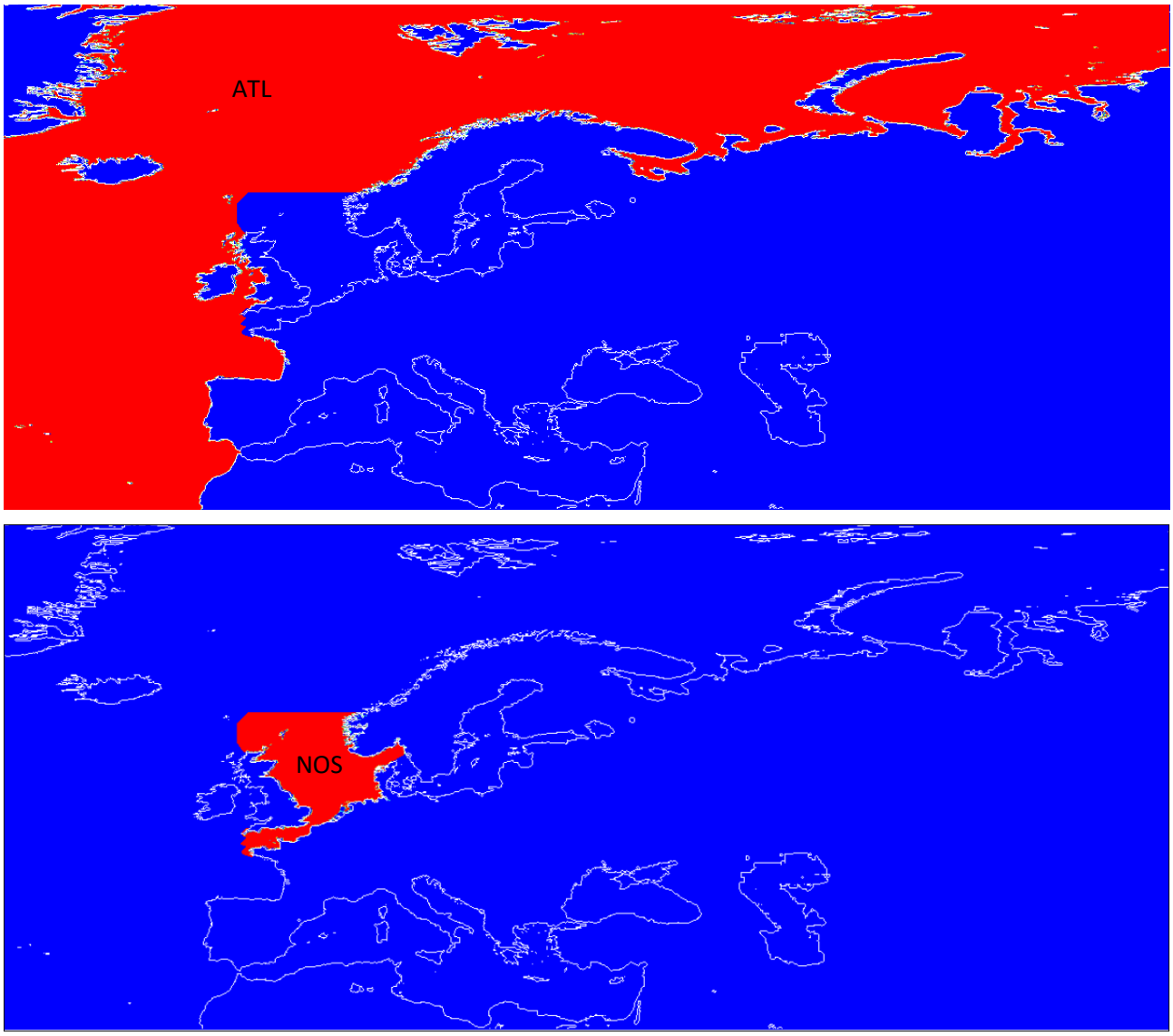


Figure 2: Visualization of the ATL and NOS shipping emission regions in the EMEP model domain. NOS: North Sea shipping, ATL: North-East Atlantic shipping except North Sea.

Table 1. Annual emissions of oxidized nitrogen from OSPAR Contracting Parties in the period 1990 – 2021, as used in the EMEP MSC-W model calculations of nitrogen deposition. Unit: ktonnes(N)/year. Country abbreviations according to ISO 3166-1 alpha-2. NOS: North Sea shipping (see Figure 2); ATL: North East Atlantic shipping (see Figure 2); OSPAR: sum of the 15 OSPAR contracting parties included in this table; Other: all other areas within the EMEP model domain (this also includes international shipping, e.g. from the Baltic and Mediterranean Seas). The table continues on the next page.

	BE	DK	FI	FR	DE	IS	IE	LU	NL
1990	129	90	93	664	865	9	51	12	207
1991	128	105	92	678	796	8	52	14	203
1992	129	91	88	673	750	9	55	14	199
1993	127	91	89	639	718	10	52	14	194
1994	127	92	90	615	678	9	52	13	181
1995	125	86	83	603	660	10	52	11	177
1996	120	96	84	595	635	10	53	11	173
1997	116	82	83	575	612	10	51	11	165
1998	117	76	78	582	603	10	54	11	159
1999	109	70	77	571	592	10	55	12	157
2000	109	66	73	553	568	9	55	13	151
2001	106	65	74	541	551	8	55	13	147
2002	103	65	74	527	533	9	53	13	142
2003	102	67	76	512	520	9	52	14	140
2004	105	63	72	498	506	9	53	17	137
2005	100	60	63	483	492	8	53	17	134
2006	96	60	68	456	496	8	52	16	132
2007	93	56	64	435	482	9	51	14	127
2008	85	52	59	411	466	8	46	13	124
2009	76	46	54	390	438	8	39	12	112
2010	76	44	57	376	444	7	37	12	110
2011	71	42	52	359	438	7	33	12	106
2012	67	39	49	351	436	7	33	12	99
2013	64	37	48	345	437	6	34	11	95
2014	61	34	46	322	424	6	34	10	87
2015	61	33	42	315	416	7	35	9	86
2016	57	33	41	300	406	6	35	8	81
2017	54	33	40	291	389	6	34	7	79
2018	52	31	39	274	363	6	34	6	77
2019	48	29	37	258	337	6	32	6	73
2020	42	27	32	224	297	5	29	5	66
2021	43	27	32	230	295	6	30	4	64

Table 1. Continued.

	NO	PT	ES	CH	SE	GB[3]	OSPAR	NOS	ATL	Other
1990	60	79	399	44	88	928	3718	182	235	6917
1991	58	84	411	43	89	904	3666	190	245	6554
1992	59	90	417	41	85	891	3591	204	264	6342
1993	61	87	398	37	81	848	3446	200	257	6026
1994	62	87	400	37	82	831	3355	205	264	5771
1995	66	90	402	35	78	791	3269	212	273	5603
1996	68	85	397	34	77	767	3206	216	278	5551
1997	71	86	404	32	73	712	3082	221	285	5465
1998	71	90	403	32	71	688	3044	228	293	5368
1999	69	93	404	32	69	654	2971	239	308	5261
2000	65	91	406	31	68	628	2888	251	321	5284
2001	65	91	396	30	65	611	2818	246	313	5292
2002	63	92	403	29	62	582	2750	241	306	5295
2003	64	85	405	29	61	571	2707	237	300	5334
2004	63	86	410	28	60	554	2661	233	295	5362
2005	63	86	402	29	59	546	2597	228	287	5412
2006	63	80	393	28	58	527	2534	223	280	5377
2007	64	77	394	28	57	504	2454	219	273	5357
2008	62	71	336	28	54	451	2266	197	238	5226
2009	59	67	301	26	50	394	2071	197	239	5164
2010	61	62	285	26	52	386	2034	195	231	5152
2011	60	57	285	24	50	359	1954	197	242	5199
2012	59	53	268	24	48	366	1911	193	235	5189
2013	58	52	247	25	46	347	1853	187	227	5164
2014	57	51	242	23	46	324	1767	191	234	5141
2015	55	52	247	22	45	311	1736	196	246	5149
2016	52	49	232	22	44	284	1651	189	234	5147
2017	50	50	230	21	42	272	1597	191	239	5176
2018	50	49	226	20	41	259	1526	190	244	5150
2019	47	47	207	19	38	241	1424	183	238	5177
2020	44	41	182	16	36	208	1255	172	208	4973
2021	43	42	189	16	35	208	1264	171	212	5267

[3] Here and elsewhere in this report, the abbreviation 'GB' is used for the United Kingdom of Great Britain and Northern Ireland. This is because EMEP MSC-W under the UN LRTAP Convention is required to use ISO 3166-1 alpha-2 codes.

Table 2. Annual emissions of ammonia (reduced nitrogen) from OSPAR Contracting Parties in the period 1990 – 2021, as used in the EMEP MSC-W model calculations of nitrogen deposition. Unit: ktonnes(N)/year. Country abbreviations according to ISO 3166-1 alpha-2. OSPAR: sum of the 15 OSPAR contracting parties included in this table; Other: all other areas within the EMEP model domain. (No significant emissions of ammonia from international shipping, thus NOS and ATL are not included in this table.) The table continues on the next page.

	BE	DK	FI	FR	DE	IS	IE	LU	NL
1990	87	116	30	556	597	4	91	5	284
1991	87	112	28	554	535	4	93	5	295
1992	87	109	27	548	533	4	95	5	243
1993	87	106	28	542	528	4	95	5	242
1994	87	103	29	535	510	4	96	5	210
1995	87	97	29	540	511	4	96	5	180
1996	85	93	30	544	518	4	100	5	183
1997	84	92	31	541	512	4	102	5	175
1998	82	92	31	540	519	4	106	5	162
1999	80	88	32	539	518	4	104	5	161
2000	78	86	30	551	521	4	99	5	143
2001	77	83	30	546	525	4	100	5	138
2002	74	81	31	535	515	4	100	5	132
2003	71	80	32	521	512	4	100	5	129
2004	67	79	32	516	498	4	98	5	129
2005	66	77	33	516	504	4	99	5	127
2006	65	74	32	505	500	4	100	5	129
2007	63	73	32	504	507	4	95	5	126
2008	61	73	31	516	509	4	96	5	116
2009	61	69	31	508	512	4	97	5	112
2010	62	70	31	499	515	4	95	5	110
2011	61	67	31	502	517	4	92	5	109
2012	61	66	31	498	522	4	97	5	104
2013	60	64	30	489	527	4	97	5	102
2014	59	64	31	494	533	4	94	5	105
2015	59	65	30	496	530	4	99	5	106
2016	59	65	29	497	525	4	103	5	107
2017	58	67	28	496	510	4	107	5	109
2018	57	66	28	493	487	4	112	5	107
2019	56	63	27	478	470	4	104	5	103
2020	56	65	26	461	436	4	102	5	102
2021	56	58	26	450	425	4	103	5	100

Table 2. Continued.

	NO	PT	ES	CH	SE	GB	OSPAR	Other
1990	26	60	402	57	50	252	2617	7120
1991	26	60	401	56	48	255	2557	6881
1992	26	59	404	55	49	244	2490	6794
1993	25	58	388	55	50	241	2453	6464
1994	24	58	407	54	51	245	2417	6288
1995	24	58	405	54	50	241	2380	6152
1996	25	59	443	53	50	246	2438	6098
1997	24	58	440	51	51	255	2425	6019
1998	25	56	463	51	51	254	2442	5979
1999	25	58	453	51	50	249	2418	5928
2000	25	60	472	51	49	244	2419	5852
2001	25	58	473	51	49	241	2404	5854
2002	25	56	466	50	48	237	2360	5914
2003	26	53	471	49	48	233	2335	5992
2004	26	54	448	49	48	237	2292	6073
2005	26	51	419	49	47	232	2254	6142
2006	26	50	415	50	47	228	2231	6170
2007	26	51	420	50	46	226	2228	6180
2008	26	49	379	50	47	212	2174	6143
2009	26	48	376	48	44	214	2157	6122
2010	26	47	376	48	45	215	2148	6078
2011	26	47	368	47	44	215	2135	6115
2012	26	46	366	46	44	214	2128	6190
2013	26	45	368	46	44	210	2117	6215
2014	26	47	384	46	44	220	2156	6229
2015	26	47	387	45	44	222	2167	6275
2016	26	48	388	45	43	223	2167	6341
2017	26	49	402	45	43	226	2174	6429
2018	27	49	399	45	43	222	2145	6453
2019	25	50	393	44	43	222	2086	6653
2020	25	50	404	44	43	214	2037	6757
2021	25	51	394	44	42	218	2001	7028

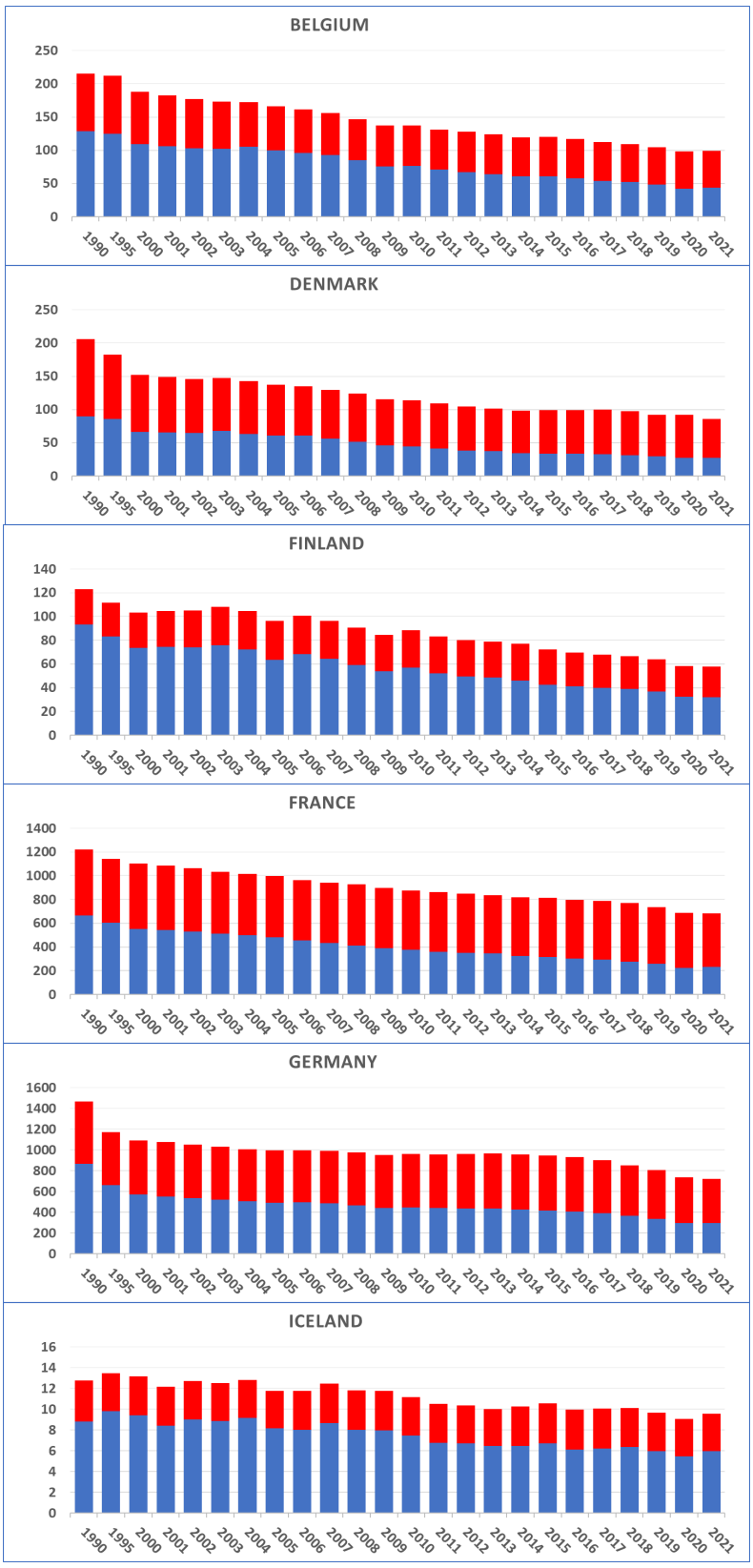


Figure 3: Change in emissions during the 1990-2021 period, as provided by the EMEP Centre CEIP for modelling, based on official data submissions by Contracting Parties (listed in Tables 1 and 2). Blue: Oxidized nitrogen (NOx); red: reduced nitrogen (NH_3). Unit: ktonnes(N)/year. (Figure continues on the next two pages.)

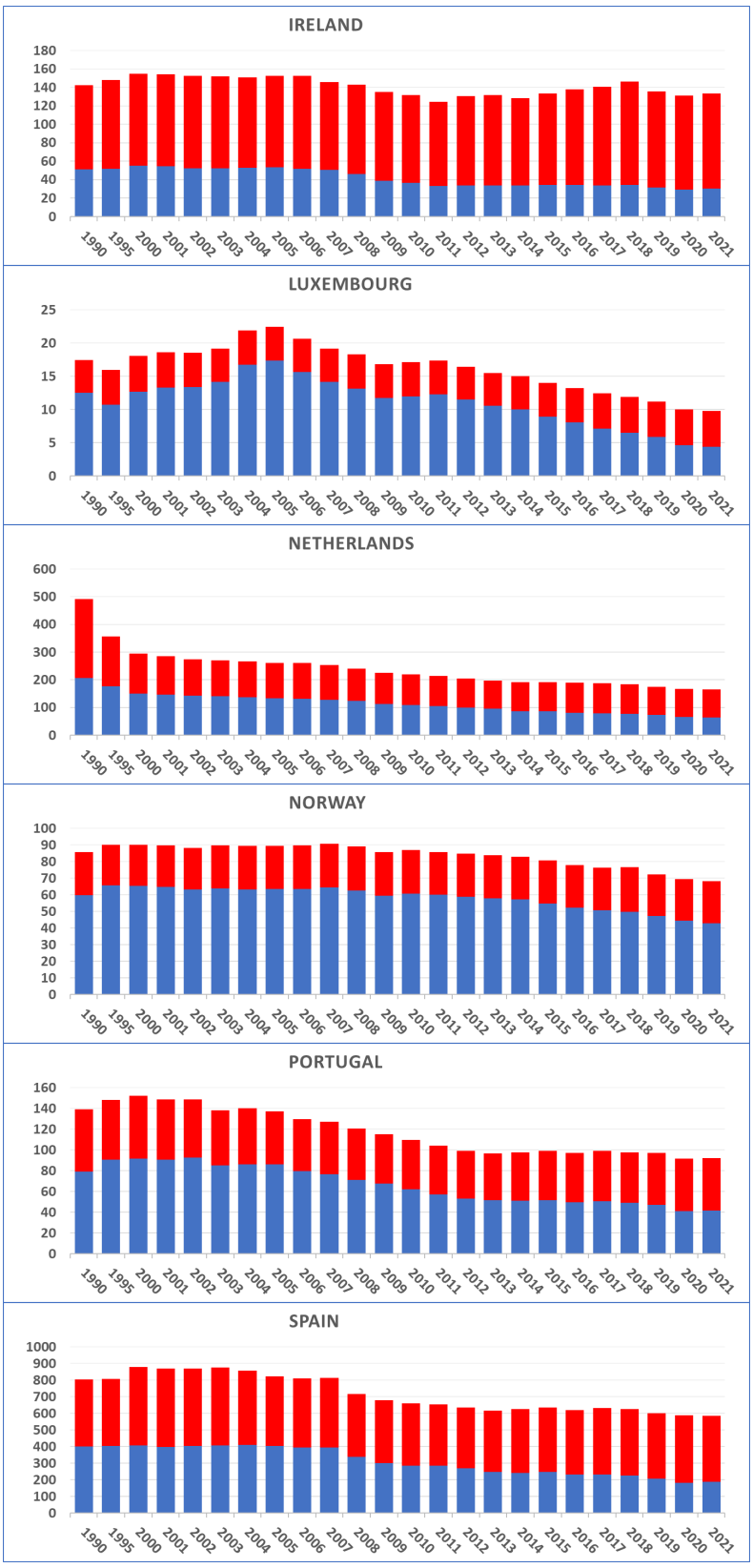


Figure 3: Continued.

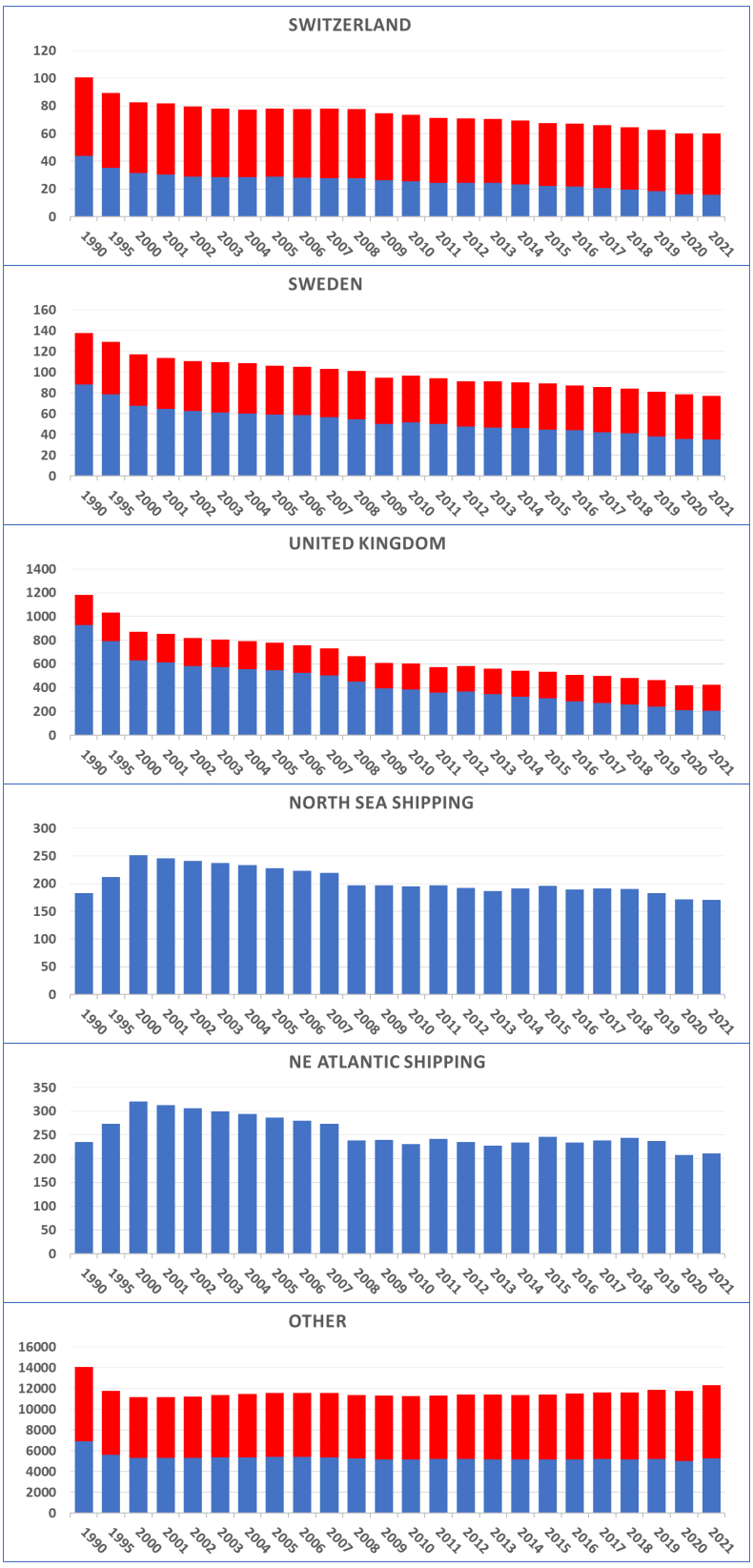


Figure 3: Continued.

Table 3. National annual emissions of total nitrogen (oxidized+reduced) from OSPAR Contracting Parties in the period 1990 – 2021, as used in the EMEP MSC-W model calculations of nitrogen deposition. Unit: ktonnes(N)/year. Country abbreviations according to ISO 3166-1 alpha-2. NOS: North Sea shipping (see Figure 2); ATL: North East Atlantic shipping (see Figure 2); OSPAR: sum of the 15 OSPAR contracting parties included in this table; Other: all other areas within the EMEP model domain. The table continues on the next page.

	BE	DK	FI	FR	DE	IS	IE	LU	NL
1990	215	206	123	1220	1463	13	143	17	491
1991	215	217	121	1231	1331	12	145	19	498
1992	216	200	115	1222	1284	13	150	19	442
1993	214	197	117	1181	1246	13	147	19	436
1994	214	194	118	1150	1189	13	148	18	391
1995	212	183	112	1143	1171	13	148	16	357
1996	206	189	114	1140	1153	14	153	16	356
1997	200	174	113	1116	1124	14	154	16	340
1998	199	168	109	1123	1122	13	160	16	321
1999	189	158	109	1110	1110	13	159	17	318
2000	188	152	103	1103	1089	13	155	18	294
2001	182	149	105	1087	1076	12	154	19	285
2002	177	146	105	1062	1047	13	152	19	273
2003	173	147	108	1033	1032	12	152	19	270
2004	172	142	105	1014	1005	13	151	22	266
2005	166	137	96	999	996	12	152	22	261
2006	161	134	100	961	996	12	152	21	261
2007	156	130	96	939	989	12	146	19	253
2008	146	124	90	927	975	12	143	18	239
2009	137	115	85	898	950	12	135	17	224
2010	138	114	88	875	959	11	131	17	220
2011	131	109	83	861	955	10	125	17	214
2012	128	104	80	849	958	10	130	16	204
2013	124	101	79	834	964	10	131	15	197
2014	120	98	77	816	957	10	128	15	192
2015	120	99	72	812	947	11	133	14	192
2016	117	99	70	797	931	10	138	13	188
2017	112	100	68	787	899	10	141	12	187
2018	109	97	67	768	850	10	146	12	184
2019	105	92	64	736	807	10	136	11	175
2020	98	92	58	685	733	9	131	10	167
2021	99	85	58	680	720	10	133	10	165

Table 3. Continued.

	NO	PT	ES	CH	SE	GB	OSPAR	NOS	ATL	Other
1990	86	139	802	101	138	1180	6335	182	235	14037
1991	83	144	812	99	137	1159	6224	190	245	13435
1992	85	149	821	96	134	1135	6081	204	264	13136
1993	85	145	786	92	131	1089	5899	200	257	12490
1994	86	145	806	91	133	1076	5772	205	264	12059
1995	90	148	807	89	129	1032	5650	212	273	11755
1996	93	143	840	87	127	1013	5645	216	278	11649
1997	95	143	843	84	125	966	5508	221	285	11484
1998	96	146	866	83	121	942	5485	228	293	11347
1999	95	151	857	83	118	902	5389	239	308	11189
2000	90	152	878	83	117	872	5307	251	321	11136
2001	90	149	869	82	113	853	5223	246	313	11145
2002	88	149	869	79	111	820	5110	241	306	11209
2003	90	138	876	78	109	805	5043	237	300	11326
2004	89	140	857	77	108	791	4953	233	295	11435
2005	90	137	821	78	106	778	4851	228	287	11554
2006	90	130	808	78	105	755	4765	223	280	11547
2007	91	127	814	78	103	729	4682	219	273	11538
2008	89	121	715	77	101	663	4441	197	238	11369
2009	86	115	677	74	94	609	4228	197	239	11286
2010	87	109	661	73	96	602	4182	195	231	11230
2011	86	104	653	71	94	574	4088	197	242	11314
2012	85	99	634	71	91	580	4039	193	235	11379
2013	84	97	616	70	91	558	3970	187	227	11379
2014	83	98	626	70	90	544	3923	191	234	11370
2015	80	99	635	68	89	533	3903	196	246	11423
2016	78	97	620	67	87	507	3818	189	234	11488
2017	76	99	631	66	86	498	3771	191	239	11605
2018	76	97	624	64	84	481	3671	190	244	11603
2019	72	97	600	63	81	462	3510	183	238	11831
2020	69	92	586	60	78	422	3292	172	208	11730
2021	68	92	583	60	77	426	3265	171	212	12295

4 OSPAR receptor areas

In this chapter we describe the receptor areas considered in the model calculations done by EMEP MSC-W for OSPAR. The term 'receptor areas' in this context means the regions for which nitrogen depositions are diagnosed, and contributions to which are calculated by the EMEP MSC-W model. We consider 118 receptor areas for OSPAR: 1) the five OSPAR Regions, 2) the twenty-four Exclusive Economic Zones (EEZs) in the OSPAR Maritime Area, 3) the twenty-five 'partial EEZs' (pieces of EEZs belonging to different OSPAR Regions), and 4) the sixty-four COMP4 Assessment Units.

4.1 OSPAR Regions

All five OSPAR Regions cover a certain number of grid cells in the EMEP grid system, either in full or in part. We have calculated this percentage for each EMEP grid square covered by each OSPAR Region. The results are illustrated in Figure 4 a-e for OSPAR Region I-V at a resolution of 0.1°longitude x 0.1°latitude grid. Table 4 lists the OSPAR Regions and their areas within the EMEP model domain, calculated on the 0.1°longitude × 0.1°latitude grid.

Table 4. The five OSPAR Regions as implemented in the EMEP MSC-W analysis in the 0.1°lon × 0.1°lat grid. OSPAR Regions I and V are not fully covered by the EMEP model domain/grid (actual areas as in the shape files from OSPAR are shown in parentheses).

Region	Area included in the EMEP model domain
OSPAR Region I	4 311 747 km^2 (of 5.53 million km^2)
OSPAR Region II	748 583 km^2 (fully covered)
OSPAR Region III	381 860 km^2 (fully covered)
OSPAR Region IV	538 119 km^2 (fully covered)
OSPAR Region V	4 080 366 km^2 (of 6.35 million km^2)

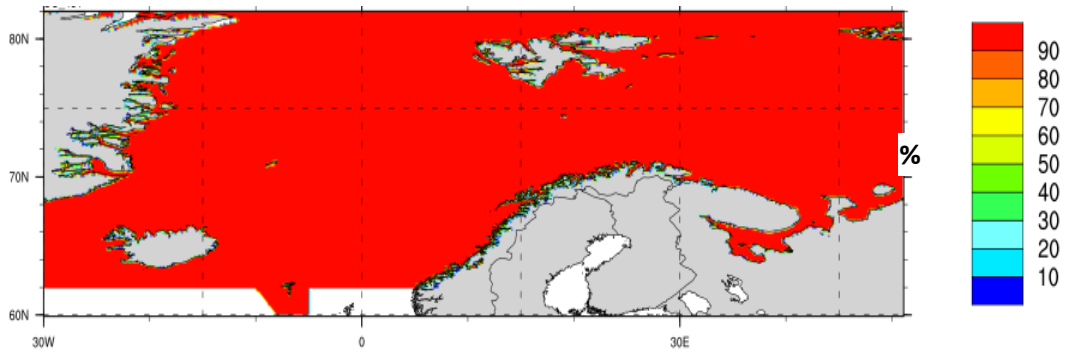


Figure 4a: Visualization of OSPAR Region I in the EMEP grid. The plot colours indicate the percentage (%) of each EMEP model grid cell area that is covered within OSPAR Region I. EMEP model grid cells cover only 0.1°lon × 0.1°lat pixels, and thus appear very small in this plot. Red colour indicates that the model grid cell is entirely (100 %) within OSPAR Region I. Other colours indicate that the grid cell is only partially covered within OSPAR Region I. OSPAR Region I is not fully included in the EMEP model domain - it is cut at 30°W, which is the western boundary of the EMEP model domain (and of this plot) and at 82°N, which is the northern boundary of the EMEP model domain (and of this plot).

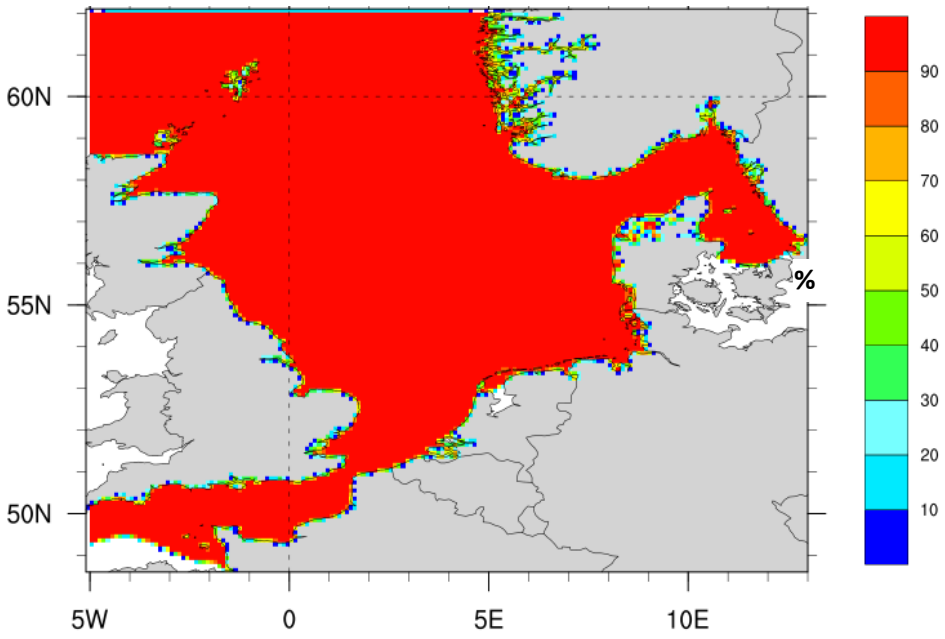


Figure 4b: As Figure 4a, but for OSPAR Region II.

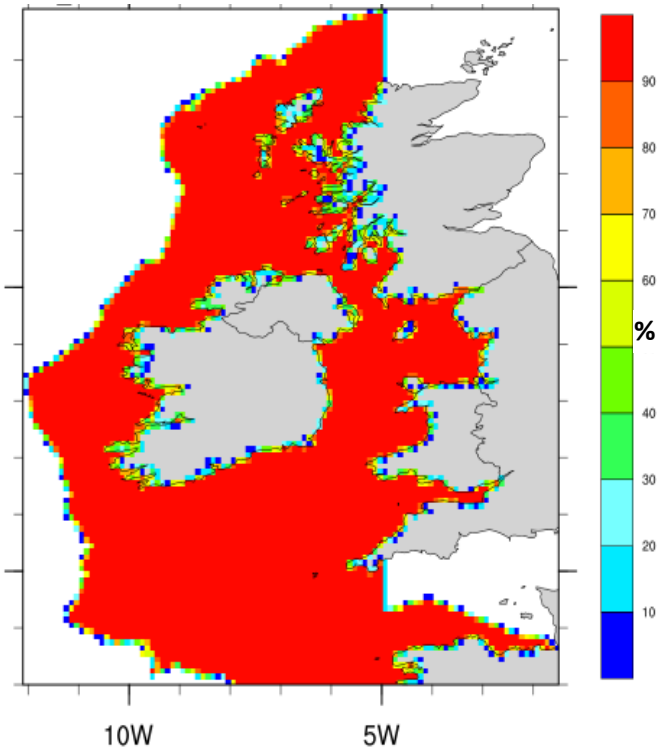


Figure 4c: As Figure 4b, but for OSPAR Region III.

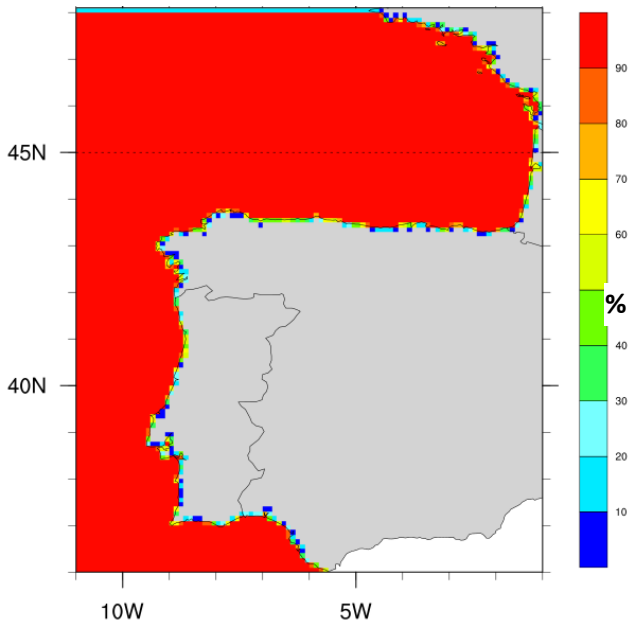


Figure 4d: As Figure 4a, but for OSPAR Region IV.

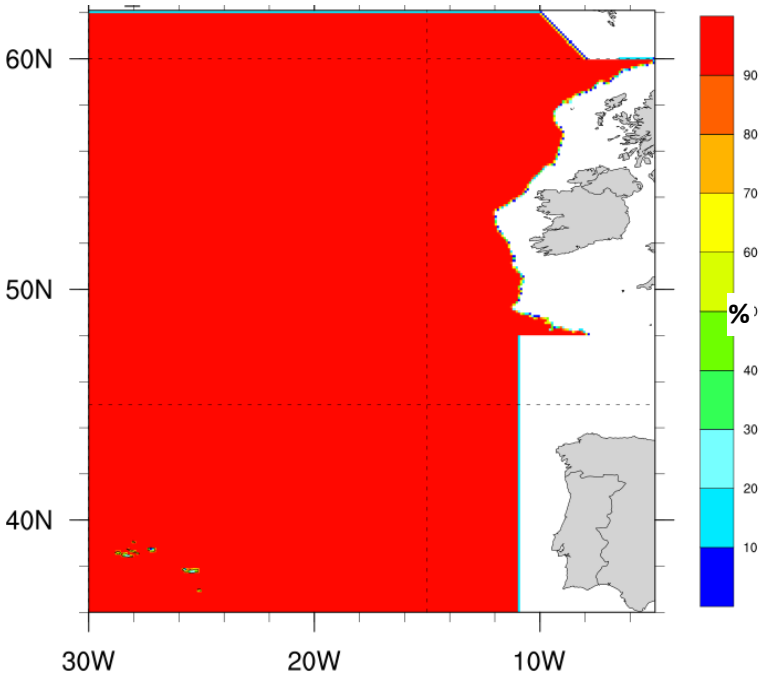


Figure 4e: As Figure 4a, but for OSPAR Region V.

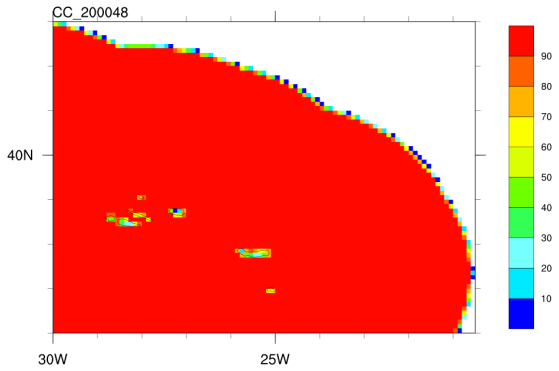
4.2 Exclusive Economic Zones

National EEZs of OSPAR Contracting Parties were implemented in the EMEP 0.1°×0.1° grid system in 2019 according to the specification suggested by OSPAR (www.marineregions.org). In some cases (e.g. Sweden) only those parts of EEZs that belong to the OSPAR Maritime Area were implemented in the EMEP grid. Table 5 lists the regions and their areas within the EMEP model domain, calculated on the 0.1°lon × 0.1°lat grid. The percentages of EMEP grid cells covered by each EEZ are shown in Figure 5.

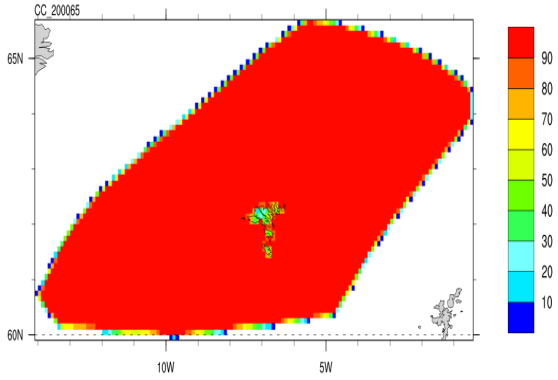
Table 5. The twenty-four Exclusive Economic Zones (EEZs) implemented in the EMEP MSC-W analysis in the 0.1°lon × 0.1°lat grid. Areas listed here include only the parts that are located within the OSPAR Convention area (i.e. within OSPAR regions). For example, those parts of the French and Spanish EEZs, which are located in the Mediterranean Sea are not included in this analysis. However, hyperlinks to marineregions.org are given in the table (last accessed 05 Jan 2024), showing the entire EEZs' definitions.

Number EEZ	Name	Area in the EMEP MSC-W model domain (km^2)
EEZ 48	Portuguese Exclusive Economic Zone (Azores)	487 910
EEZ 65	Faeroe Exclusive Economic Zone	262 572
EEZ 71	Icelandic Exclusive Economic Zone	750 705
EEZ 91	Portuguese Exclusive Economic Zone	269 184
EEZ 99	Joint regime area Spain / France	2 857
EEZ 100	Joint regime area UK / Denmark (Faeroe Islands)	7 895
EEZ 108	Irish Exclusive Economic Zone	425 135
EEZ 109	Guernsey Exclusive Economic Zone	6 504
EEZ 110	Jersey Exclusive Economic Zone	2 284
EEZ 119	Joint regime area Iceland / Denmark (Faeroe)	1 264
EEZ 123	Joint regime area Iceland / Norway (Jan Mayen)	45 105
EEZ 185	Swedish Exclusive Economic Zone	13 424
EEZ 187	Joint regime area Sweden / Norway	141
EEZ 188	Belgian Exclusive Economic Zone	3 470
EEZ 189	Dutch Exclusive Economic Zone	62 043
EEZ 190	German Exclusive Economic Zone	40 658
EEZ 191	Danish Exclusive Economic Zone	74 638
EEZ 209	French Exclusive Economic Zone	255 780
EEZ 212	Greenlandic Exclusive Economic Zone	634 585
EEZ 213	United Kingdom Exclusive Economic Zone	728 809
EEZ 215	Svalbard Exclusive Economic Zone	700 964
EEZ 216	Norwegian Exclusive Economic Zone	926 079
EEZ 224	Jan Mayen Exclusive Economic Zone	289 545
EEZ 273	Spanish Exclusive Economic Zone	298 494

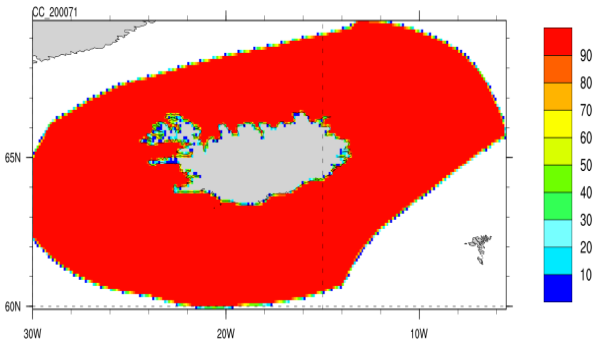
EEZ 48: Portuguese EEZ (Azores)



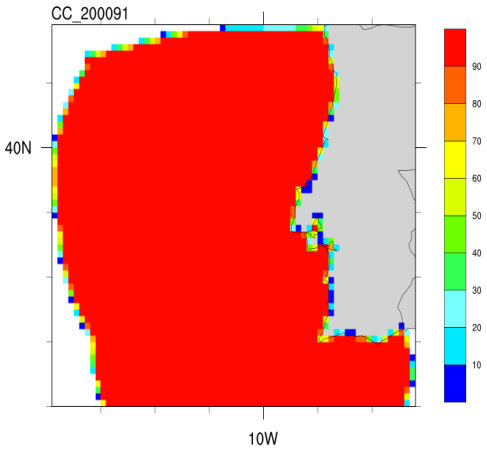
EEZ 65: Faeroe EEZ



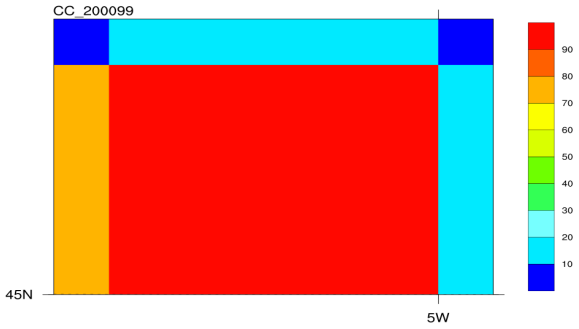
EEZ 71: Icelandic EEZ



EEZ 91: Portuguese EEZ



EEZ 99: Joint regime area Spain / France



EEZ 100: Joint regime area UK / Denmark (Faeroe)

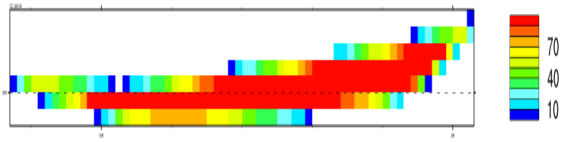
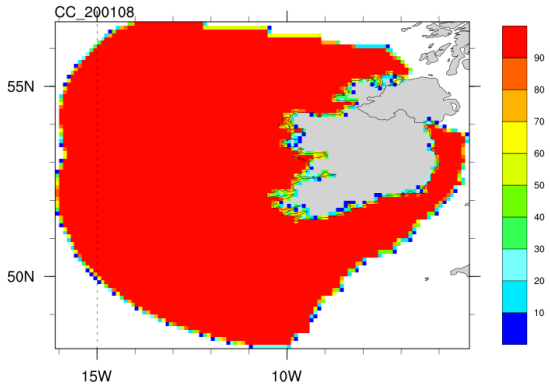
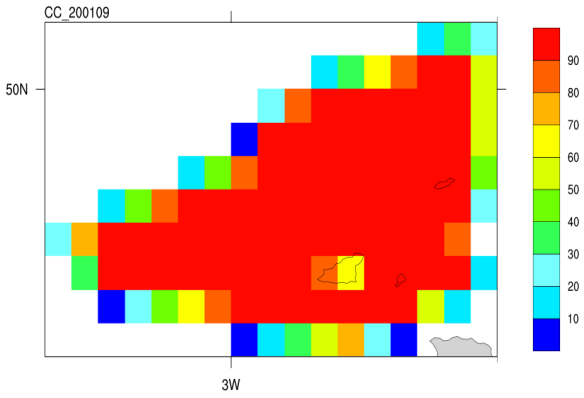


Figure 5: Visualization of EEZs in the EMEP grid (created in the same way as Figure 4 which is for the OSPAR regions). The plots show how large a percentage of each EMEP model grid cell lies within the respective EEZ. EMEP model grid cells cover 0.1°lon × 0.1°lat pixels and thus appear very small in some of the plots. Red colour indicates that the model grid cell is entirely covered (100 %) within the EEZ. Other colours indicate that the grid cell is only partly within the EEZ. Some EEZs are not fully covered by the EMEP model domain, e.g. EEZ 48 (PT/Azores) is cut at 30W°, which is the western boundary of the EMEP model domain. Parts of EEZs outside the OSPAR regions are not included in the plots (and the analysis). The figure continues on the next 3 pages.

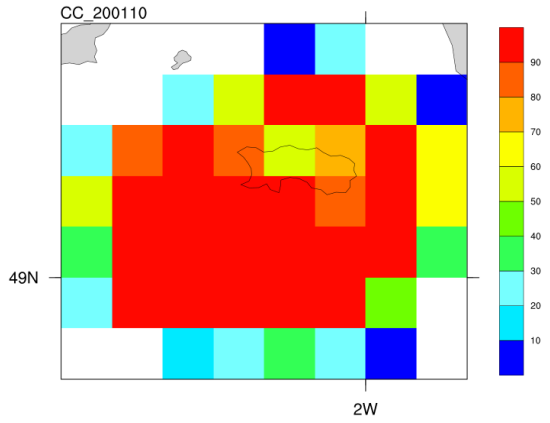
EEZ 108: Irish EEZ



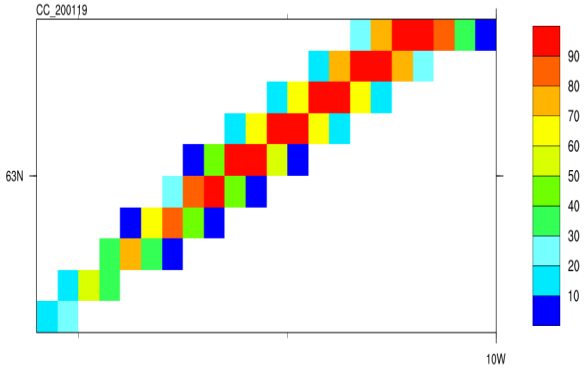
EEZ 109: Guernsey EEZ



EEZ 110: Jersey EEZ



EEZ 119: Joint regime area Iceland / Denmark (Faeroe Islands)



EEZ 123: Joint regime area Iceland/ Norway (Jan Mayen)

EEZ 185: Swedish EEZ

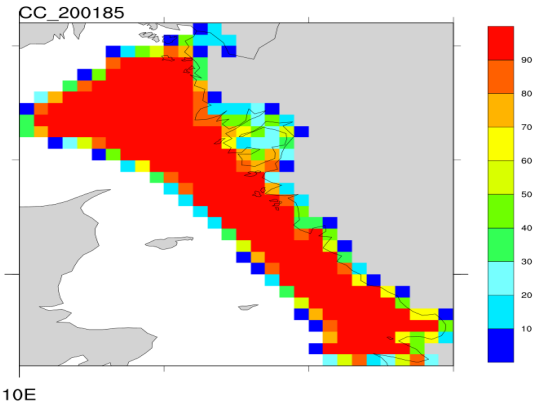
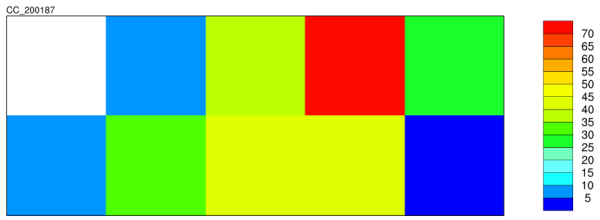
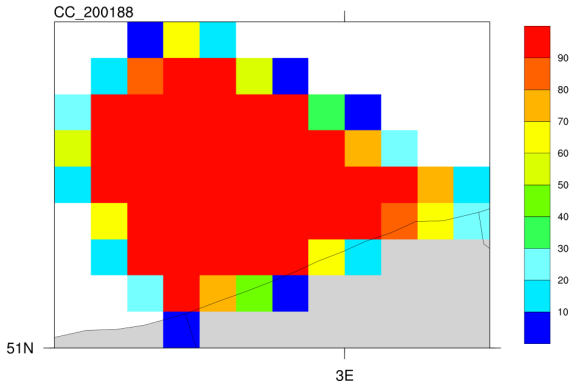


Figure 5: Continued.

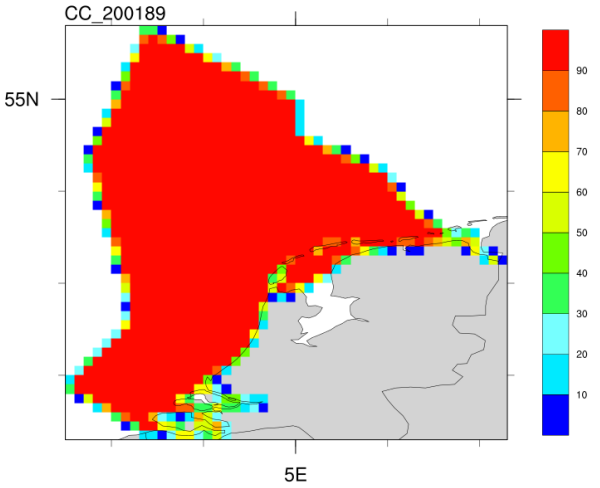
EEZ 187: Joint regime area Sweden / Norway



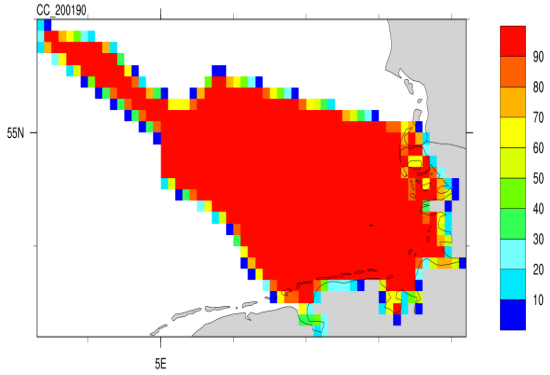
EEZ 188: Belgian EEZ



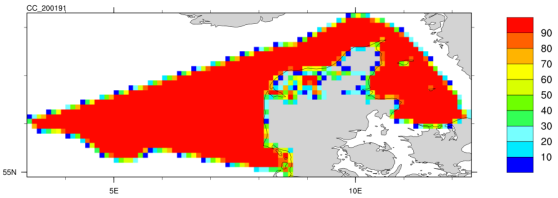
EEZ 189: Dutch EEZ



EEZ 190: German EEZ



EEZ 191: Danish EEZ



EEZ 209: French EEZ

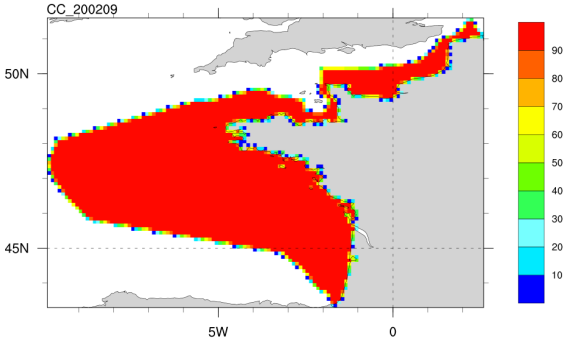
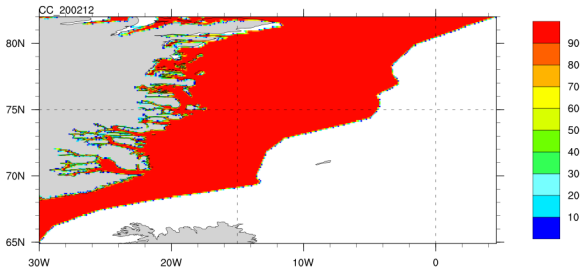
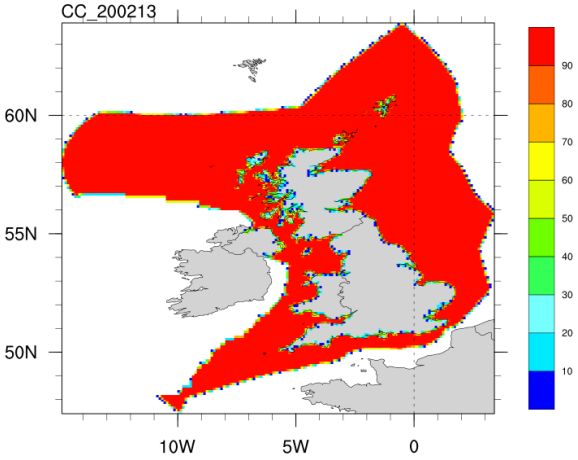


Figure 5: Continued.

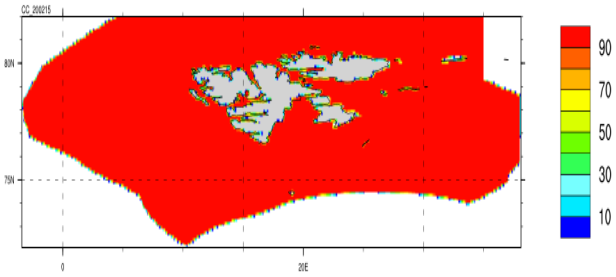
EEZ 212: Greenlandic EEZ



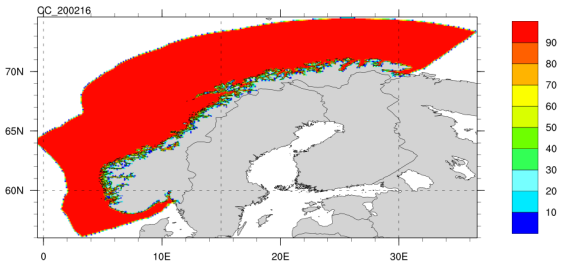
EEZ 213: United Kingdom EEZ



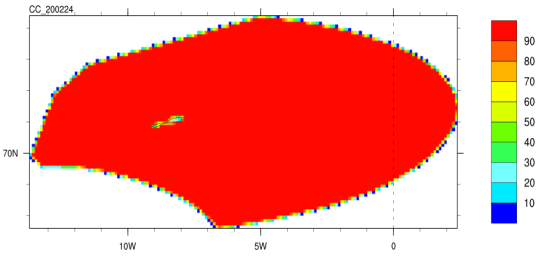
EEZ 215: Svalbard EEZ



EEZ 216: Norwegian EEZ



EEZ 224: Jan Mayen EEZ



EEZ 273: Spanish EEZ

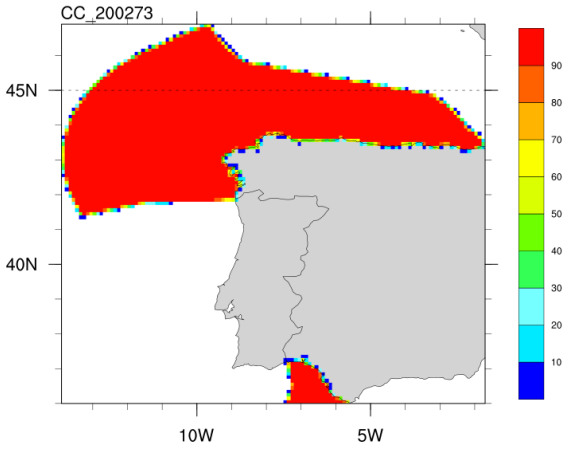


Figure 5: Continued.

4.3 Partial EEZs

Nine of the EEZs described in the previous section fall within more than one OSPAR region. We refer to the parts in different OSPAR regions as "partial EEZs". For example, the French EEZ covers parts of OSPAR regions II, III, IV and V (i.e. it is divided into four partial EEZs), while the UK EEZ covers parts of all five OSPAR regions (i.e. it is divided into five partial EEZs). The exemplary division into partial EEZs is visualized for EEZ 65 (Faeroe Exclusive Economic Zone) in Figure 6. In total, 25 partial EEZs are considered (see Table 6).
Fifteen of the EEZs addressed in this report are entirely located within one OSPAR Region (e.g. the German EEZ lies entirely in Region II), so that no partial EEZs had to be defined in these cases.

Table 6. The twenty-five partial EEZs implemented in the EMEP MSC-W analysis routines. Areas listed in the right column refer to what is covered by the OSPAR Convention area (i.e. within the five OSPAR Regions).

Number of EEZ	Name	Located in:	Area in the EMEP MSC-W model domain (km^2)
EEZ_I_065	Faeroe Exclusive Economic Zone	OSPAR Region I	200 166
EEZ_II_065	Faeroe Exclusive Economic Zone	OSPAR Region II	10 350
EEZ_V_065	Faeroe Exclusive Economic Zone	OSPAR Region V	52 057
EEZ_I_071	Icelandic Exclusive Economic Zone	OSPAR Region I	601 407
EEZ_V_071	Icelandic Exclusive Economic Zone	OSPAR Region V	149 298
EEZ_IV_091	Portuguese Exclusive Economic Zone	OSPAR Region IV	132 790
EEZ_V_091	Portuguese Exclusive Economic Zone	OSPAR Region V	136 394
EEZ_I_100	Joint regime area United Kingdom / Denmark (Faeroe Islands)	OSPAR Region I	3 628
EEZ_II_100	Joint regime area United Kingdom / Denmark (Faeroe Islands)	OSPAR Region II	74
EEZ_V_100	Joint regime area United Kingdom / Denmark (Faeroe Islands)	OSPAR Region V	4 192
EEZ_III_108	Irish Exclusive Economic Zone	OSPAR Region III	145 815
EEZ_V_108	Irish Exclusive Economic Zone	OSPAR Region V	279 321
EEZ_II_209	French Exclusive Economic Zone	OSPAR Region II	25 520
EEZ_III_209	French Exclusive Economic Zone	OSPAR Region III	40 882
EEZ_IV_209	French Exclusive Economic Zone	OSPAR Region IV	186 716
EEZ_V_209	French Exclusive Economic Zone	OSPAR Region V	2 662
EEZ_I_213	United Kingdom Exclusive Economic Zone	OSPAR Region I	28 902
EEZ_II_213	United Kingdom Exclusive Economic Zone	OSPAR Region II	352 278
EEZ_III_213	United Kingdom Exclusive Economic Zone	OSPAR Region III	193 924
EEZ_IV_213	United Kingdom Exclusive Economic Zone	OSPAR Region IV	2 418
EEZ_V_213	United Kingdom Exclusive Economic Zone	OSPAR Region V	151 287
EEZ_I_216	Norwegian Exclusive Economic Zone	OSPAR Region I	771 086
EEZ_II_216	Norwegian Exclusive Economic Zone	OSPAR Region II	154 993
EEZ_IV_273	Spanish Exclusive Economic Zone	OSPAR Region IV	203 697
EEZ_V_273	Spanish Exclusive Economic Zone	OSPAR Region V	94 797

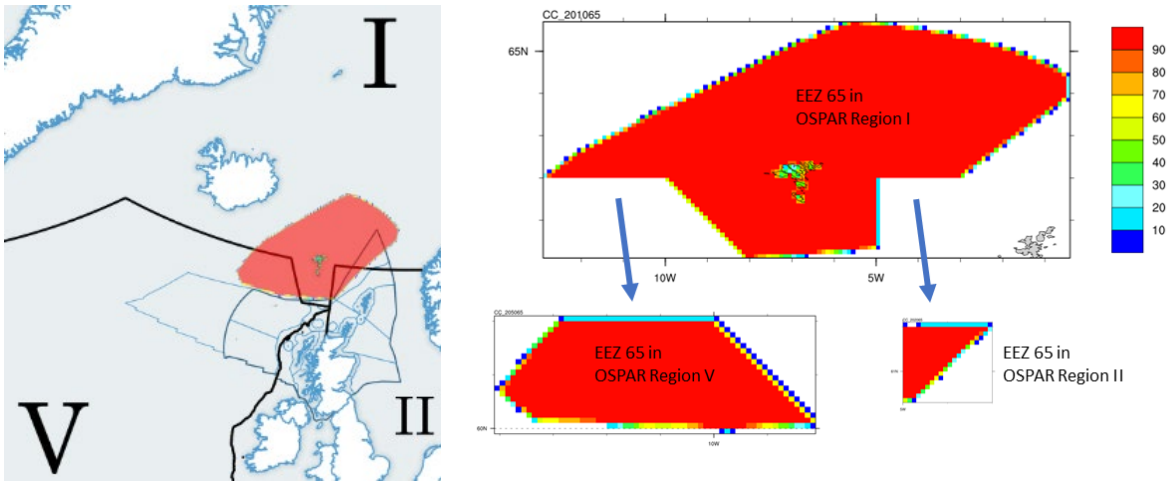


Figure 6: Left panel: OSPAR regions I, II and V, and EEZ 65 (Faeroe Exclusive Economic Zone) indicated in light red colour. Right panels: Division of EEZ 65 into three separate parts, belonging to OSPAR Regions I, II, and V, respectively. These three partial EEZs are listed in the first 3 rows of Table 6.

4.4 COMP4 Assessment Units

Updated definitions of the 64 COMP4 Assessment Units were provided as shape files to EMEP MSC-W in 2022 and implemented in the EMEP 0.1°×0.1° grid and the tools to analyse nitrogen deposition. We used the shape file which was sent to us by OSPAR as an e-mail attachment on 30 August 2022. The only change since the 2022 version of the COMP4 definitions was the name of the 'GBC' unit – its long name was updated from *German Bight Deep* to *German Bight Central*.

The COMP4 Assessment Units are listed in Table 7, while Figure 7 shows the percentages of EMEP grid cells covered by each COMP4 Assessment Unit (only for those areas that are larger than 10 000 km^2).

According to the contract, EMEP MSC-W had to calculate nitrogen deposition for the 40 largest COMP4 Assessment Units. These are listed in black font in Table 7 (remaining units are grey). The rationale behind this choice is that the smallest and thinnest units cannot be resolved well enough by the EMEP model grid to allow for accurate source-receptor calculations. These, however, are needed in the normalization routine only. The results for *actual* depositions can thus be considered as reasonably accurate for all COMP4 units, while normalized deposition should only be used for the 40 largest COMP4 units. The smallest of those units has an area of about 2 600 km^2. In 2021, we had recommended to use only results for receptor areas larger than 10 000 km^2, which was a more conservative limit because in the 2021 contract, contributions from individual countries had to be reported, rather than only the *total* normalized deposition (i.e. the sum of contributions from all countries), which is a more robust result.

Table 7. The sixty-four COMP4 Assessment Units as implemented in the EMEP MSC-W analysis in the 0.1°lon × 0.1°lat grid. Units not belonging to the 40 largest units are marked in grey font. The table continues on the next page.

Abbreviation	Long name	Area in the EMEP MSC-W model domain (km^2)	Contracting Parties involved[4]
CFR	Coastal FR channel	7 146	FR, UK
CCTI	Channel coastal shelf tidal influenced	5 064	FR, UK
ATL	Atlantic	924 824	ES, FR, IE, UK, NO
SHPM	Shannon plume	379	IE
CNOR1	Coastal NOR 1	8 635	NO
CNOR2	Coastal NOR 2	2 606	NO
CNOR3	Coastal NOR 3	1 723	NO
DB	Dogger Bank	14 660	NL, DE, DK, UK
KD	Kattegat Deep	4 922	DK, SE
NT	Norwegian Trench	58 801	NO, SE, DK
SNS	Southern North Sea	61 520	FR, BE, NL, UK
GBC	German Bight Central	4 525	DE
ADPM	Adour plume	285	FR
GBSW	Gulf of Biscay shelf waters	20 936	FR
SPM	Seine plume	1 108	FR
GDPM	Gironde plume	2 816	FR
CUKC	Coastal UK channel	6 272	UK
CWMTI	Channel well mixed tidal influenced	20 570	FR, UK
SCHPM1	Scheldt plume 1	579	BE, NL
ELPM	Elbe plume	7 808	DE
SCHPM2	Scheldt plume 2	93	NL
MPM	Meuse plume	205	NL
RHPM	Rhine plume	2 271	NL
EMPM	Ems plume	1 451	DE
THPM	Thames plume	5 495	UK
HPM	Humber plume	1 366	UK
ECPM1	East Coast (permanently mixed) 1	3 509	UK
ECPM2	East Coast (permanently mixed) 2	1 443	UK
IS2	Intermittently Stratified 2	26 373	IE, UK
OC	Outer Coastal DEDK	18 460	DE, DK
ENS	Eastern North Sea	60 319	NL, DE, DK
CWCC	Coastal Waters CC (D5)	2 018	PT

Table 7. Continued.

[4] In this column, 'UK' is used as abbreviation for the United Kingdom of Great Britain and Northern Ireland, as it is based on a table provided by the OSPAR Secretariat and not on EMEP data.

Abbreviation	Long name	Area in the EMEP MSC-W model domain (km^2)	Approximate location
OWCO	Ocean Waters CO (D5)	18 859	PT
OWAO	Ocean Waters AO (D5)	97 884	PT
OWBO	Ocean Waters BO (D5)	182 696	PT
ASS	Atlantic Seasonally Stratified	216 452	FR, IE, UK
CIRL	Coastal IRL 3	9 546	IE
CUK1	Coastal UK 1	10 644	UK
IS1	Intermittently Stratified 1	73 074	UK
IRS	Irish Sea	32 543	IE, UK
KC	Kattegat Coastal	9 597	DK, SE
NNS	Northern North Sea	262 706	UK, DK, SE, NO
CWM	Channel well mixed	41 855	FR, UK
LBPM	Liverpool Bay plume	1 350	UK
SK	Skagerak	5 739	DK, SE
SS	Scottish Sea	52 961	UK
CWBC	Coastal Waters BC (D5)	4 222	PT
CWAC	Coastal Waters AC (D5)	7 349	PT
LPM	Loire plume	1 490	FR
GBCW	Gulf of Biscay coastal waters	10 803	FR
NAAP2	Noratlantic Area NOR-NorP2(D5)	8 293	ES
NAAO1	Noratlantic Area NOR-NorO1(D5)	261 130	ES
NAAPF	Noratlantic Area NOR-Plataforma	36 992	ES
NAAC3	Noratlantic Area NOR-NorC3(D5)	2 635	ES
NAAC2	Noratlantic Area NOR-NorC2(D5)	1 640	ES
NAAC1A	Noratlantic Area NOR-NorC1(D5)A	546	ES
NAAC1B	Noratlantic Area NOR-NorC1(D5)B	84	ES
NAAC1C	Noratlantic Area NOR-NorC1(D5)C	26	ES
NAAC1D	Noratlantic Area NOR-NorC1(D5)D	13	ES
SAAP2	Sudatlantic Area SUD-P2(D5)	925	ES
SAAOC	Sudatlantic Area SUD-OCEAN(D5)	10 077	ES
SAAP1	Sudatlantic Area SUD-P1(D5)	2 458	ES
SAAC1	Sudatlantic Area SUD-C1(D5)	399	ES
SAAC2	Sudatlantic Area SUD-C2(D5)	271	ES

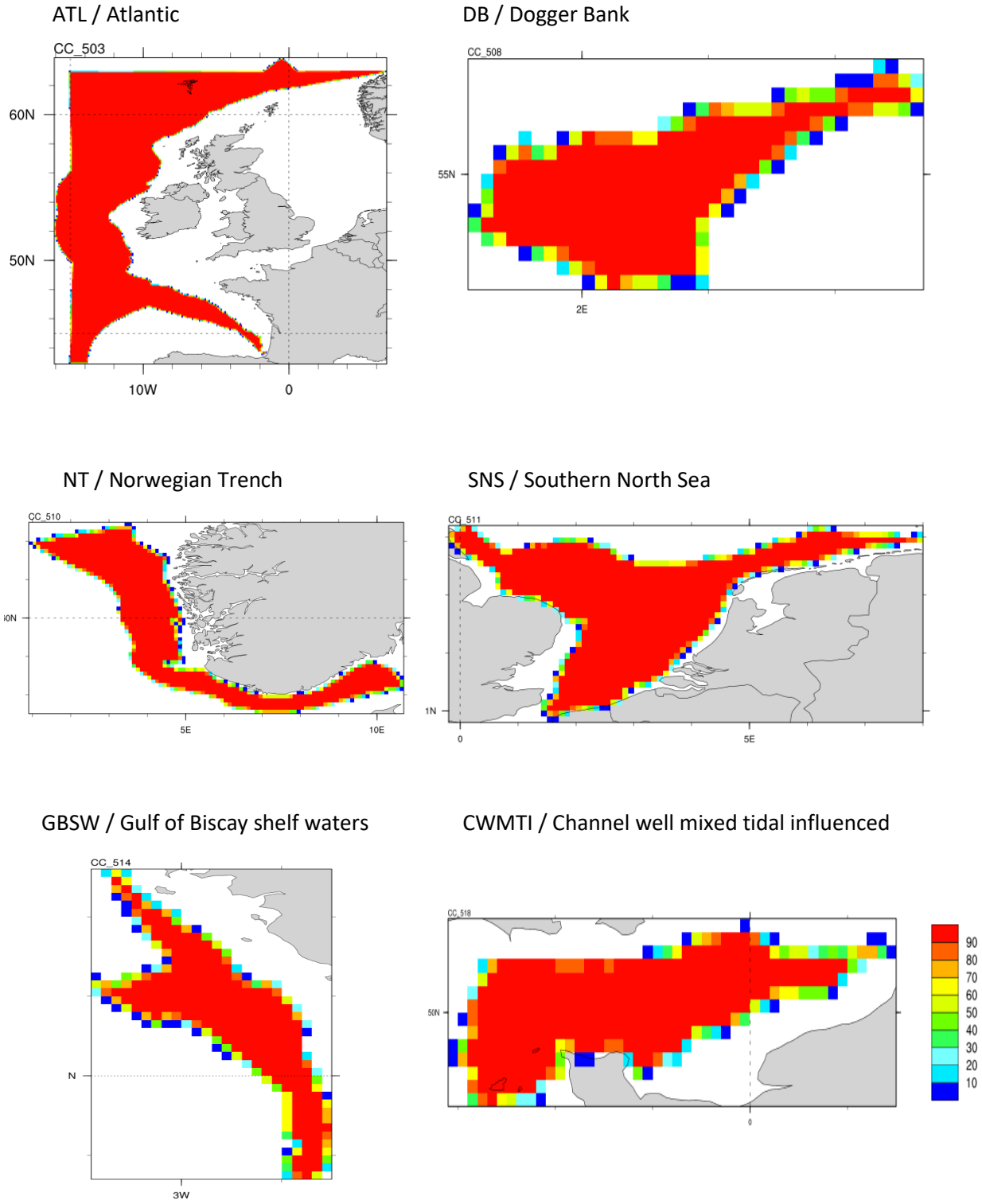
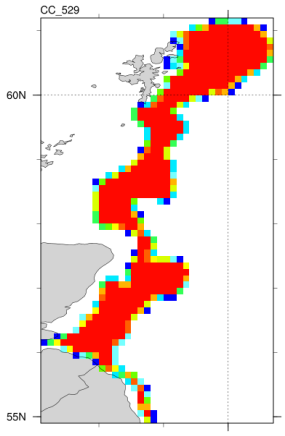
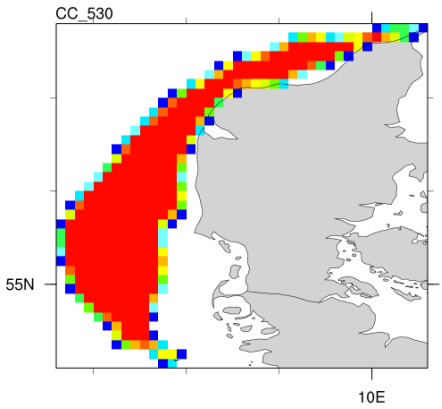


Figure 7: Visualization of COMP4 Assessment Units in the EMEP grid. The plots show the percentage (%) of each EMEP model grid cell that is covered by the respective COMP4 Assessment Unit. EMEP model grid cells cover 0.1°lon × 0.1°lat pixels and thus appear very small in some of the plots. Red colour indicates that the model grid cell is entirely (100 %) within the COMP4 Assessment Unit. The remaining colours indicate that the grid cell is only partly within in the COMP4 Assessment Unit. Only those COMP4 Assessment Units covering more than 10 000 km^2 are shown. The figure continues on the next 3 pages. The legend in the lower right panel applies to all panels in this Figure.

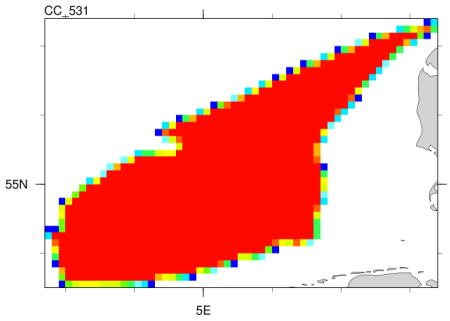
IS2 / Intermittently Stratified 2



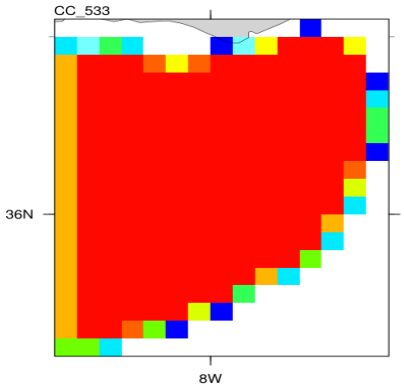
CO / Coastal Offshore



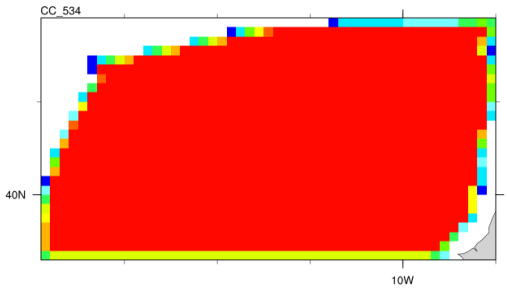
ENS / Eastern North Sea



OWCO / Ocean Waters CO (D5)



OWAO / Ocean Waters AO (D5)



OWBO / Ocean Waters BO (D5)

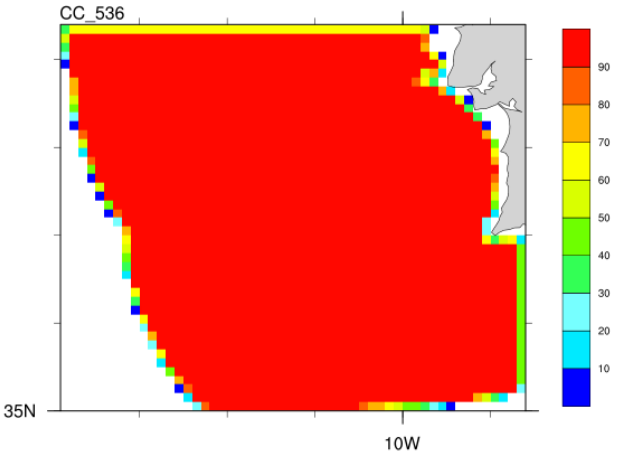
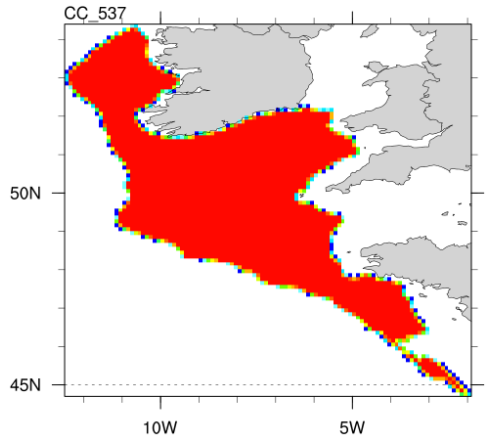
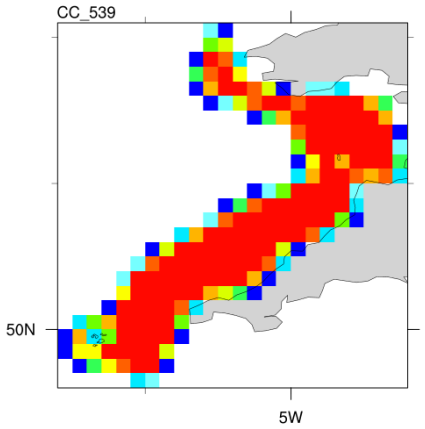


Figure 7: Continued.

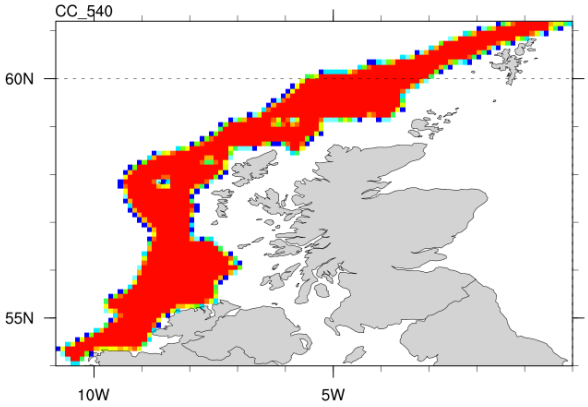
ASS / Atlantic Seasonally Stratified



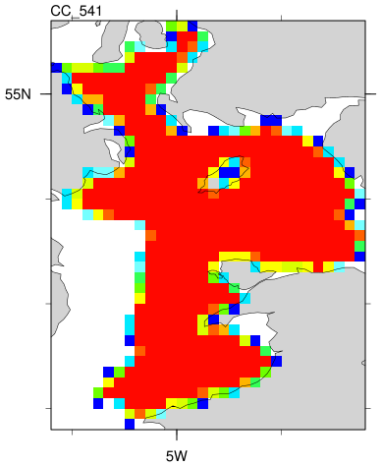
CUK1 / Coastal UK 1



IS1 / Intermittently Stratified 1



IRS / Irish Sea



NNS / Northern North Sea

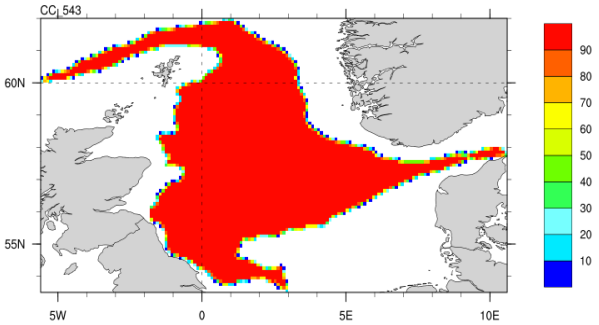
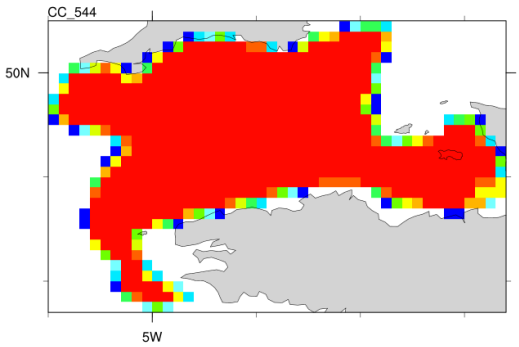
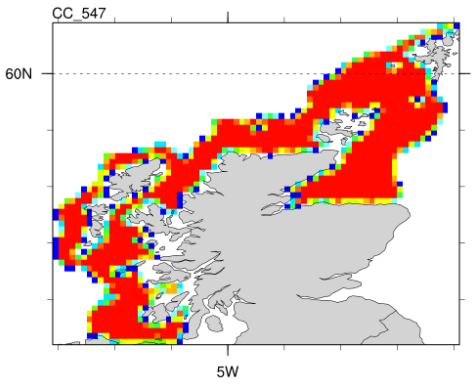


Figure 7: Continued.

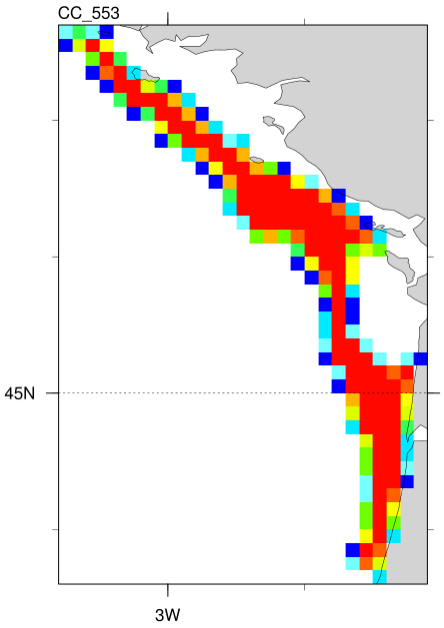
CWM / Channel well mixed



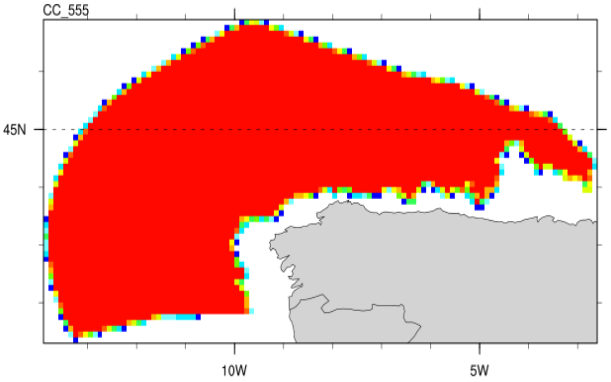
SS / Scottish Sea



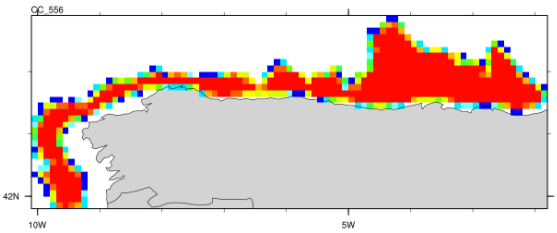
GBCW / Gulf of Biscay coastal waters



NAAO1 / Noratlantic Area NOR-NorO1(D5)



NAAPF / Noratlantic Area NOR-Plataforma



SAAOC / Sudatlantic Area SUD-OCEAN(D5)

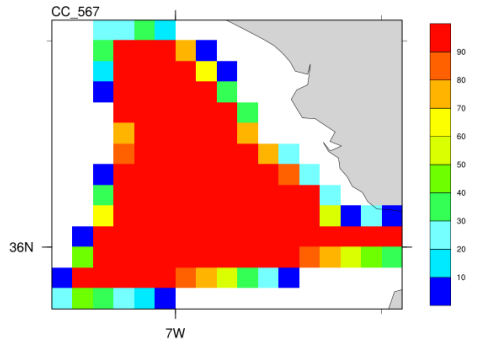


Figure 7: Continued.

5 Actual and normalized depositions of nitrogen

Actual and *normalized* depositions of nitrogen have been computed for the five OSPAR Regions, the twenty-four EEZs, the twenty-five partial EEZs, and the sixty-four COMP4 Assessment Units, for each year of the period 1990-2021.

Normalized ("weather-averaged") depositions follow the year-to-year changes in emissions more closely than actual depositions, because they are not affected by meteorological variability and thus better reflect the effect of policy measures on nitrogen emissions. In this report for OSPAR, the years 2016-2021 have been used for normalization.

In reports issued before 2021, more meteorological years (starting from 1995) had been used for the normalization process, relying on transfer coefficients calculated in the past in the old 50km × 50km polar-stereographic model grid. Transfer coefficients tell us how much of one country's emission (source) is transported and deposited to a receptor area (e.g. an OSPAR region). They are needed for the normalization procedure used by EMEP. However, the 50km × 50km polar-stereographic model grid is too coarse for many of the small COMP4 units to be assessed for OSPAR since 2021. We thus use only transfer coefficients that have been calculated in the finer 0.3°lon × 0.2°lat grid. These have been available only for the year 2016 and later. Another reason to choose the period 2016-2021, specifically for OSPAR, is that some of the receptors considered here (e.g. EEZ048) are not fully covered by the EMEP model domain (see Sections 4.1 and 4.2 and in particular Figures 4 and 5). When the EMEP model domain was changed in 2017 (for reporting the status of 2015), the parts included in the domain changed for these receptors, both in shape and in area. This would lead to artificial changes in the transfer coefficients from earlier years before the grid change to the later years in the period.

5.1 OSPAR Regions

Figure 8 shows actual (non-normalized) oxidized and reduced nitrogen depositions from 1990 to 2021 for all OSPAR Regions. The actual depositions of oxidized nitrogen have clearly decreased since the 1990s in all five OSPAR regions, while for reduced nitrogen the decreases are much smaller. Nevertheless, the trends in *total* (oxidized+reduced) nitrogen deposition are decreasing in all OSPAR Regions and are statistically significant at the 95% confidence level.

Figure 9 shows normalized results. The normalization is based on 6 years of meteorological data (period 2016 to 2021). Normalized annual values of deposition of oxidized and reduced nitrogen were lower in 2021 compared to 1990 in all OSPAR Regions.

Table 8 lists actual *and* normalized depositions in the 5 OSPAR regions for the year 2021, i.e. the most recent year for which model calculations have been made.

Tables 9 and 10 give all statistically significant trends based on a linear model (at the 95% confidence level) for actual and normalized nitrogen deposition, respectively. Considering the entire 32-year period, downward trends for (actual) oxidized and total nitrogen deposition are statistically significant in all five OSPAR regions, while for reduced nitrogen deposition a statistically significant downward trend could only be detected in OSPAR Regions I, II and V. Considering the last decade (2011 to 2021), total nitrogen deposition has declined significantly only in OSPAR Regions I and III. When looking at normalized trends (filtering out interannual variability in meteorology), downward trends are significant in all OSPAR Regions for oxidized, reduced and total nitrogen over the 32-year period. However, in the latest decade (2011-2021), no statistically significant downward trend could be identified for reduced nitrogen deposition.

Table 11 contains the entire 1990-2021 timeseries of normalized total nitrogen depositions for the five OSPAR Regions. Separate results for, respectively, oxidized and reduced nitrogen can be found in the accompanying data sheet (Chapter 8).

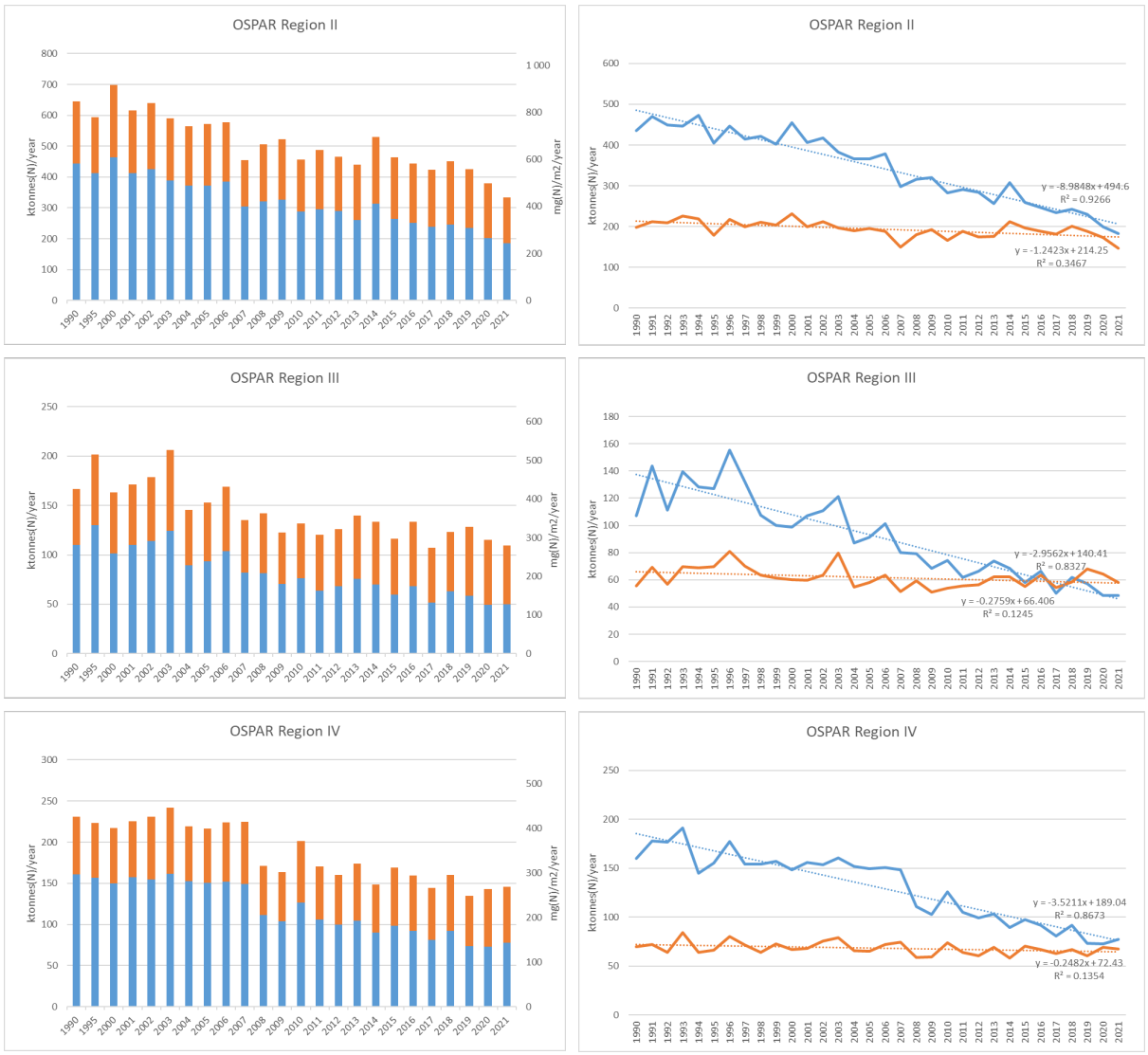


Figure 8a: Left panels: Time series of the actual (non-normalized) depositions of oxidized (blue), reduced (red) and total nitrogen (entire bar height as the sum of the blue and red bar) to OSPAR Regions II, III and IV (i.e. the regions that are fully included in the EMEP model domain), as calculated by the EMEP MSC-W model for the period 1990-2021. Unit: ktonnes(N)/year (left axis) or mg(N)/m^2/year (right axis). Right panels: Linear regression for oxidized (blue) and reduced (red) nitrogen deposition, with regression line (dashed line), the respective equations and coefficients of determination (R^2) indicated in the figure.

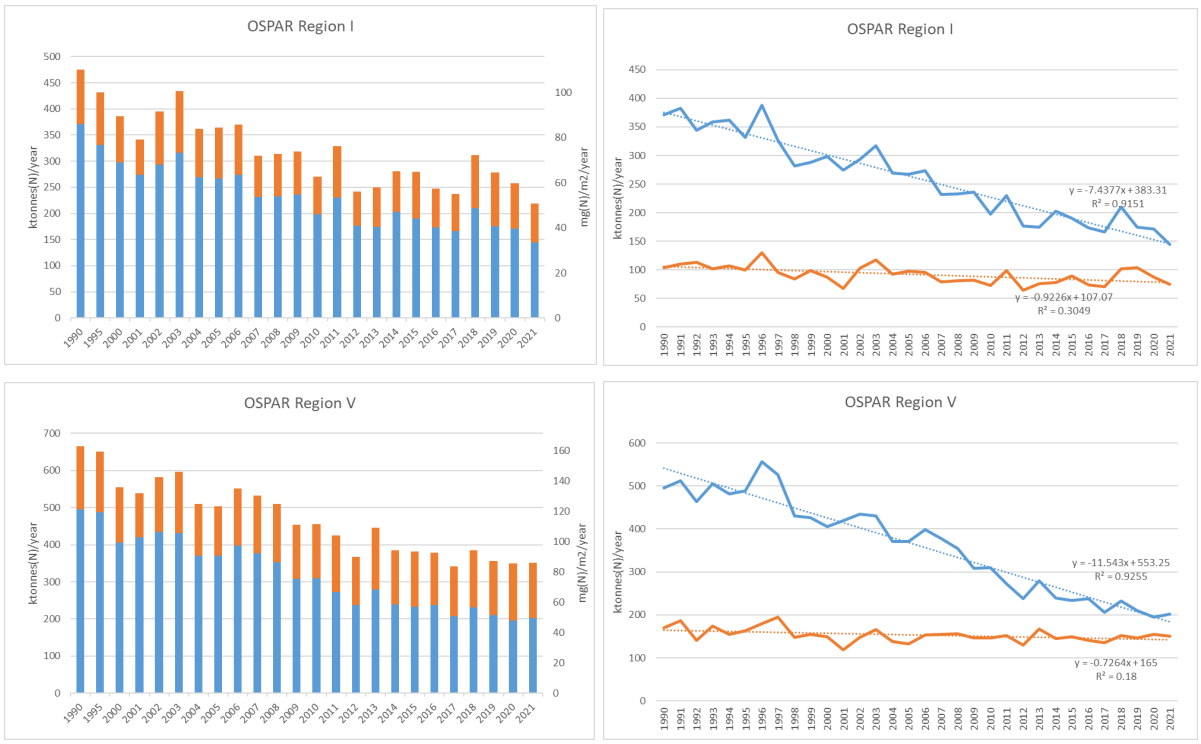


Figure 8b: As Figure 8a, but for OSPAR Regions I and V (which are not fully covered by the EMEP domain).

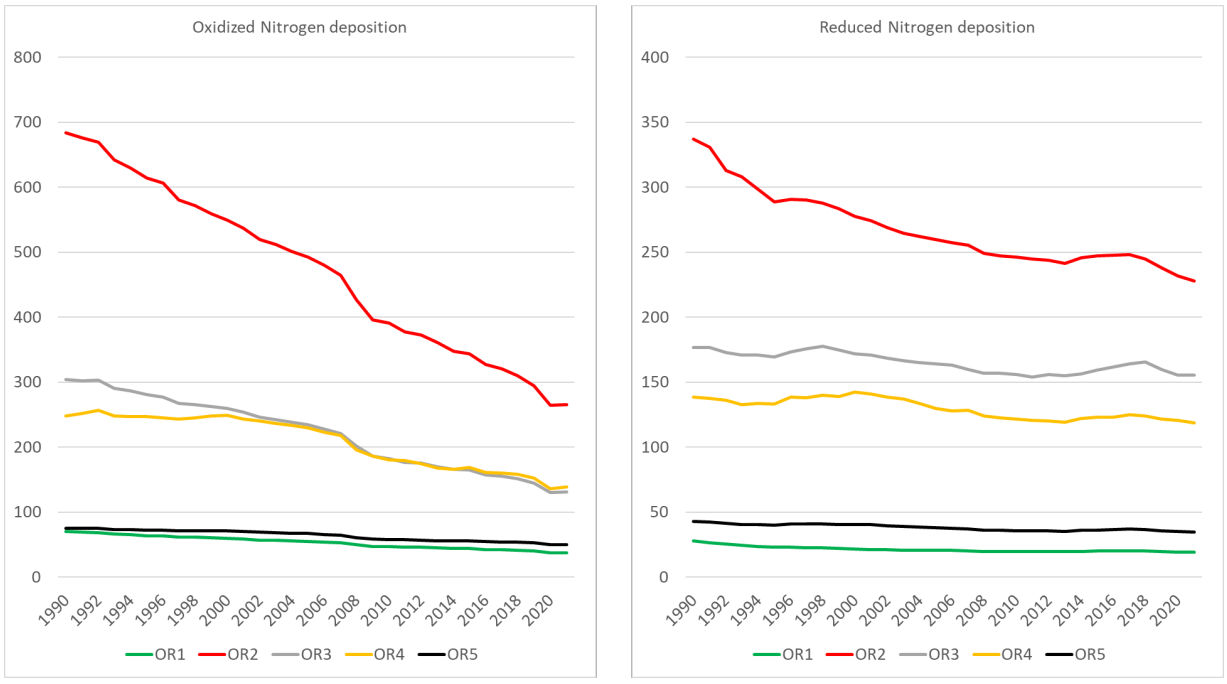


Figure 9: Normalized deposition of oxidized (left panel) and reduced (right panel) nitrogen to the five OSPAR Regions ('OR1'= OSPAR Region I, etc.). Unit: mg(N)/m^2/year.

Table 8. Deposition of oxidized, reduced and total nitrogen, in the five OSPAR Regions in 2021. Both the actual (based on 2021 meteorology) and normalized (based on meteorological data of 2016-2021) values are given. Results for other years are provided separately in Excel format (see Chapter 8). Unit: ktonnes(N)/year.

OSPAR Region	Oxidized N		Reduced N		Total N	
	Actual	Normalized	Actual	Normalized	Actual	Normalized
I	144	162	74	83	219	246
II	182	199	146	171	329	369
III	49	50	58	59	107	110
IV	77	75	68	64	145	139
V	202	205	150	142	352	347

Table 9. Trends in **actual** (non-normalized) depositions of oxidized, reduced, and total nitrogen to the five OSPAR Regions. The values correspond to the slopes of a linear regression line, given in %/decade, calculated for the entire 32-year period (1990 – 2021), for the 1990s, and for the most recent decade 2011-2021. Missing values, indicated by hyphens, mean that there is no significant trend at the 95% confidence level (i.e. the Mann-Kendall test yields a p-value larger > 0.05).

OSPAR Region	Oxidized Nitrogen			Reduced Nitrogen			Total Nitrogen		
	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021
I	-20	-20	-37	-9	-16	-	-17	-19	-
II	-19	-	-37	-8	-	-	-16	-	-31
III	-18	-	-21	-	-	-	-11	-	-
IV	-17	-	-27	-	-	-	-12	-	-14
V	-19	-	-26	-4	-	-	-15	-	-17

Table 10. Trends in **normalized** depositions of oxidized, reduced, and total nitrogen to the five OSPAR Regions. The values correspond to the slopes of a linear regression line, given in %/decade, calculated for the whole 32-year period (1990 – 2021), for the 1990s and for the most recent decade. Missing values, indicated by hyphens, mean that there is no significant trend at the 95% confidence level (i.e. the Mann-Kendall test yields a p-value > 0.05).

OSPAR Region	Oxidized Nitrogen			Reduced Nitrogen			Total Nitrogen		
	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021
I	-15	-16	-19	-10	-22	-	-14	-18	-13
II	-20	-20	-30	-10	-18	-	-17	-19	-21
III	-18	-15	-26	-4	-	-	-13	-10	-13
IV	-14	-	-22	-5	-	-	-11	-	-14
V	-11	-5	-13	-6	-	-	-9	-5	-9

5.2 Exclusive Economic Zones

Actual (non-normalized) atmospheric nitrogen depositions to each of the twenty-four Exclusive Economic Zones during the period 1990-2021 are shown in Figure 10. There is a clear decline in the deposition of oxidized nitrogen between 1990 and 2021 in all EEZs. The deposition of reduced nitrogen was larger in 2021 than in 1990 in four of the EEZs. Again, one must keep in mind that the inter-annual variability in these depositions is large due to meteorological conditions. Nevertheless, it is clear that, overall, the downward trend of reduced nitrogen deposition is much smaller than that of oxidized nitrogen deposition.

Table 12 lists actual *and* normalized depositions to the 24 EEZs for the year 2021, i.e. the most recent year for which model calculations have been made.

Table 13 and 14 give all statistically significant trends (at the 95% confidence level) for actual and normalized nitrogen deposition, respectively.

Table 15 contains the entire 1990-2021 time series of normalized total nitrogen depositions to the 24 EEZs.

Table 11. Normalized deposition of total nitrogen to the 5 OSPAR Regions in the period 1990 to 2021. Unit: ktonnes(N)/year.

	Region I	Region II	Region III	Region IV	Region V
1990	424	765	184	208	479
1991	415	754	183	210	478
1992	405	735	182	212	476
1993	392	712	176	205	466
1994	383	695	175	205	462
1995	374	676	172	205	459
1996	373	672	172	206	461
1997	365	652	169	205	457
1998	361	643	169	208	458
1999	355	631	167	208	457
2000	349	619	165	211	456
2001	344	607	162	207	451
2002	337	590	158	204	444
2003	335	582	156	201	438
2004	331	572	154	198	434
2005	326	563	152	193	428
2006	322	552	149	189	421
2007	316	539	145	186	416
2008	301	506	137	172	398
2009	290	481	131	166	388
2010	287	477	129	162	384
2011	284	466	126	161	381
2012	282	462	127	158	378
2013	277	451	124	154	373
2014	275	444	123	155	373
2015	275	443	124	157	376
2016	270	431	122	153	371
2017	268	426	122	154	372
2018	265	416	121	152	370
2019	258	398	116	147	361
2020	245	372	109	138	346
2021	246	369	110	139	347

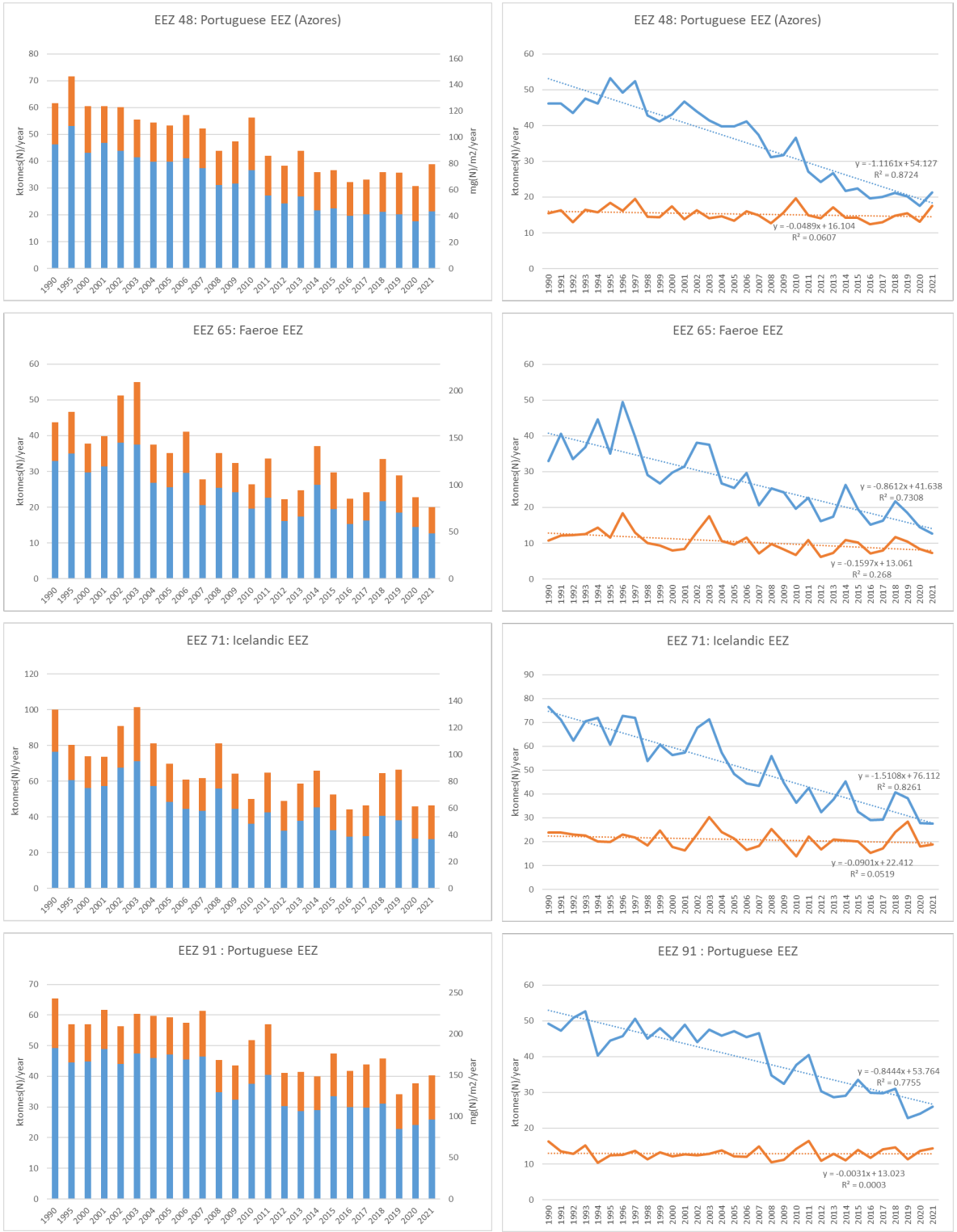
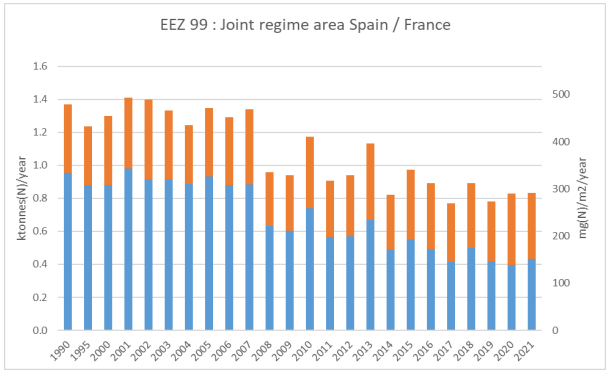
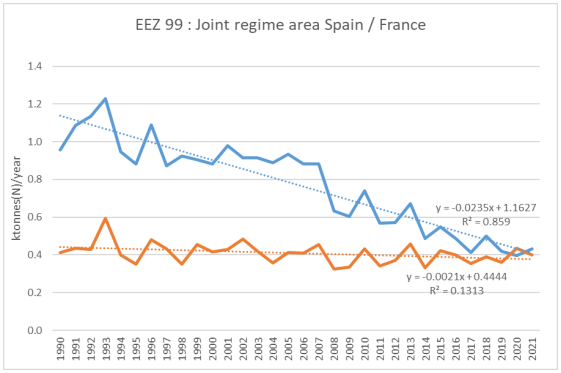
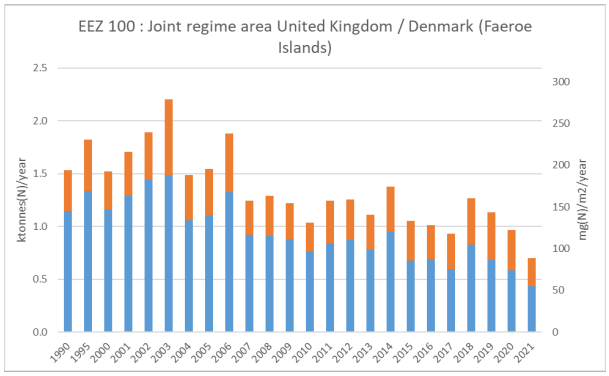
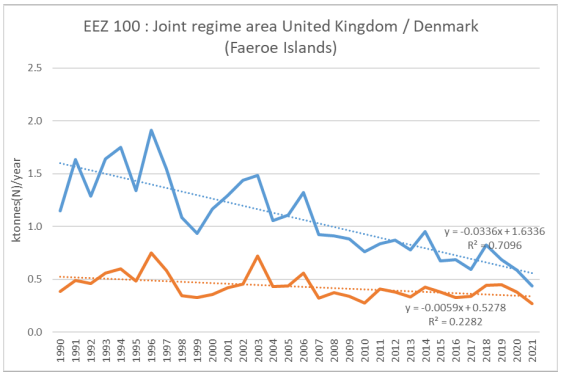


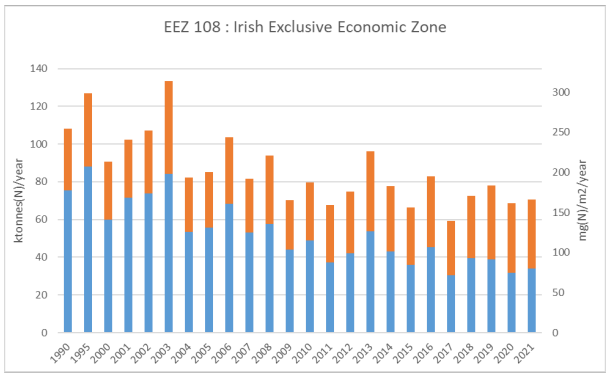
Figure 10: Left panels: Time series of actual (non-normalized) depositions of oxidized (blue), reduced (red) and total nitrogen (entire bar height is the sum of the oxidized and reduced nitrogen) to selected EEZs, as calculated by the EMEP MSC-W model for the period 1990-2021. Unit: ktonnes(N)/year (left axis) or mg(N)/m^2/year (right axis). Right panel: Linear regression for oxidized (blue) and reduced (red) nitrogen deposition, with regression line (dashed line), the equation and coefficients of determination (R^2) indicated in the figure. The figure continues on the next pages.

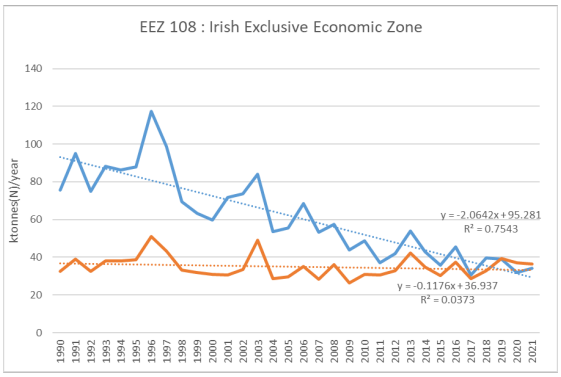


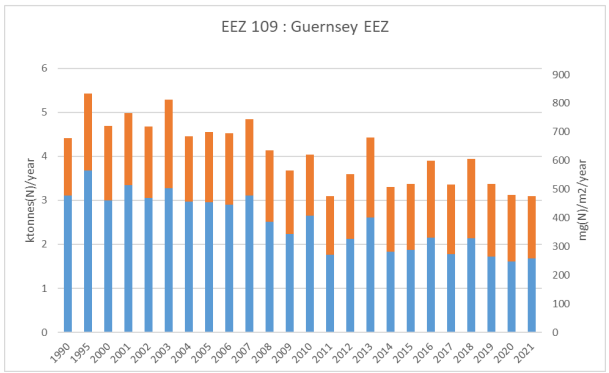


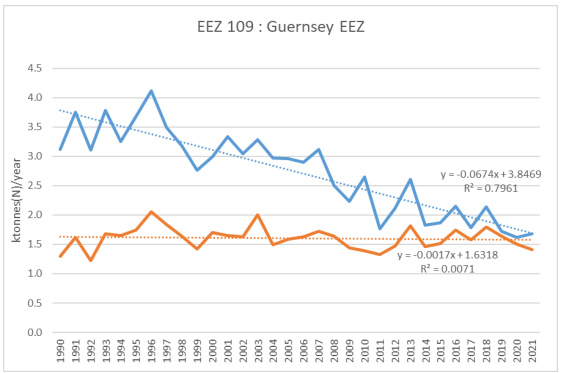












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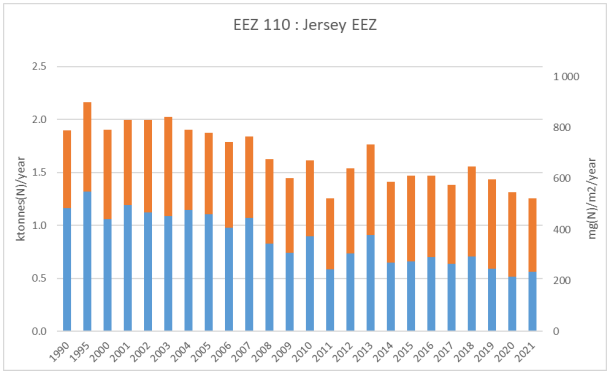

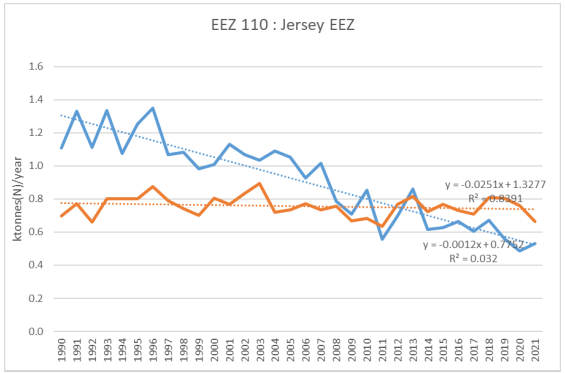

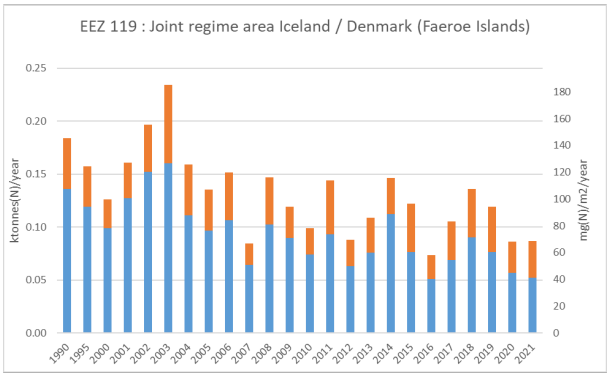

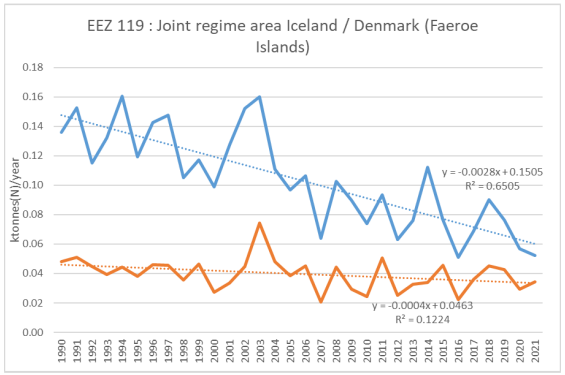

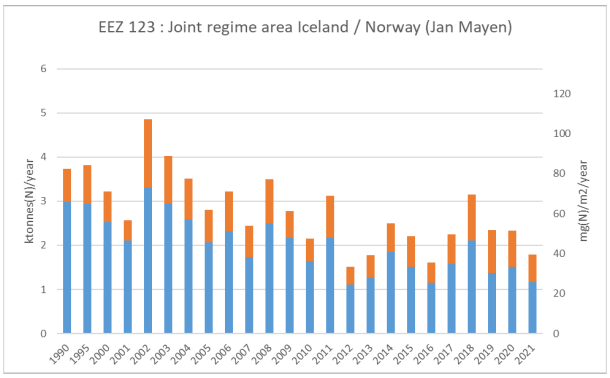

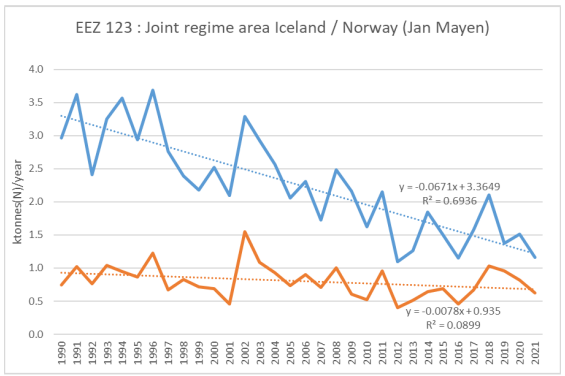

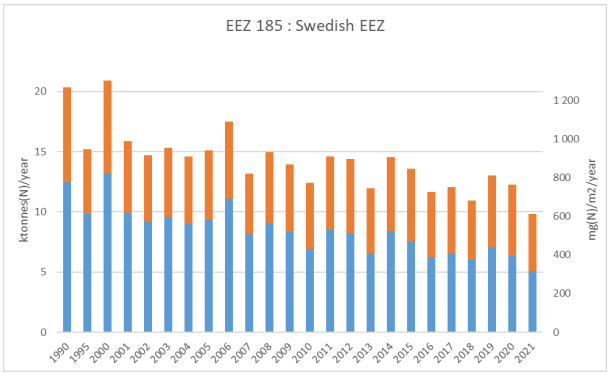

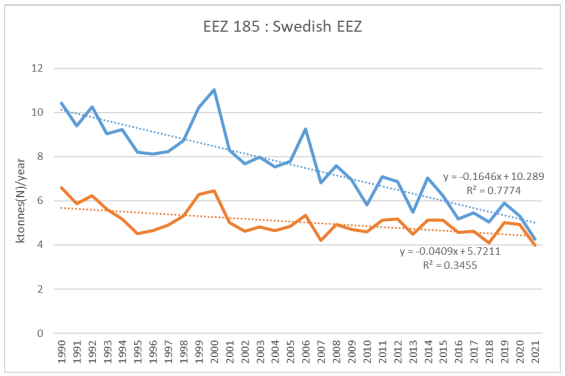

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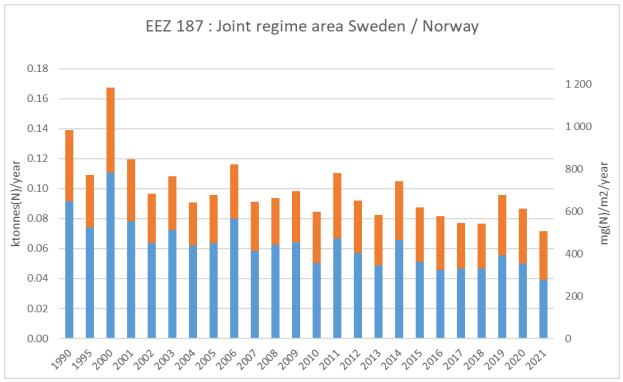

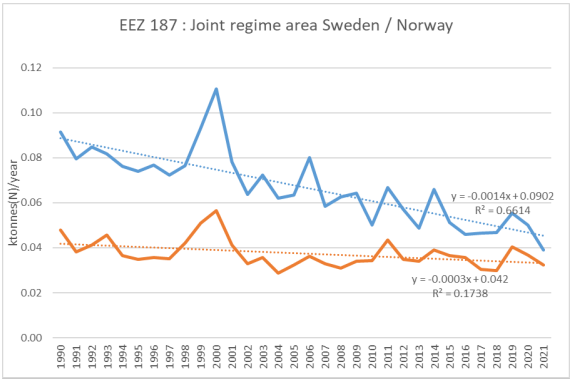

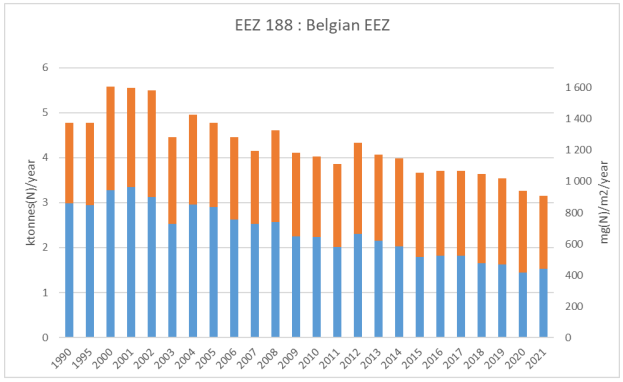

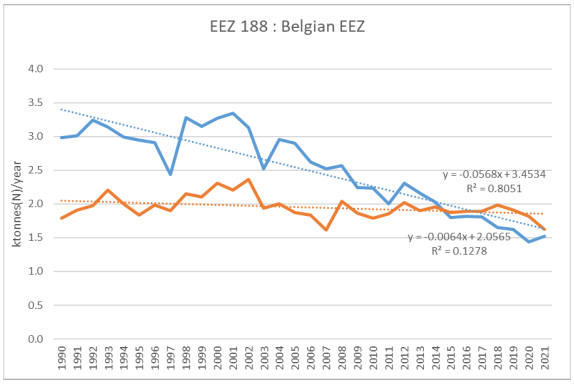

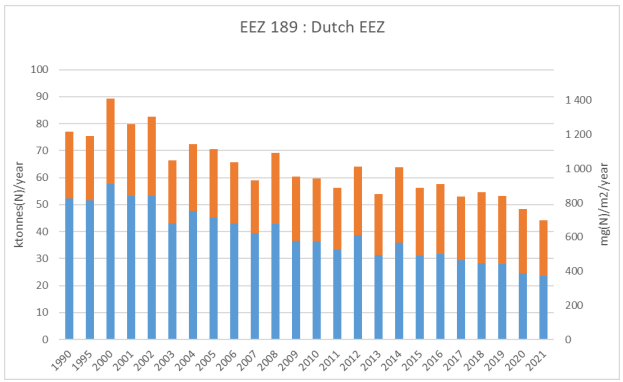

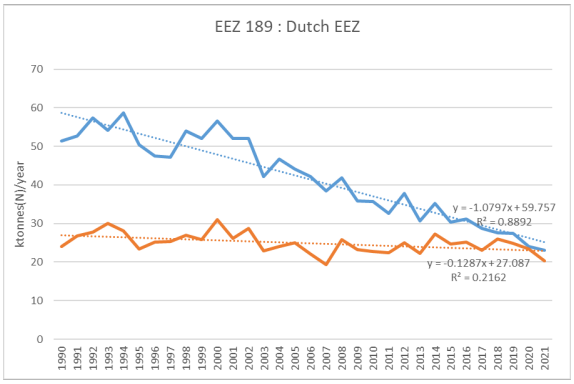

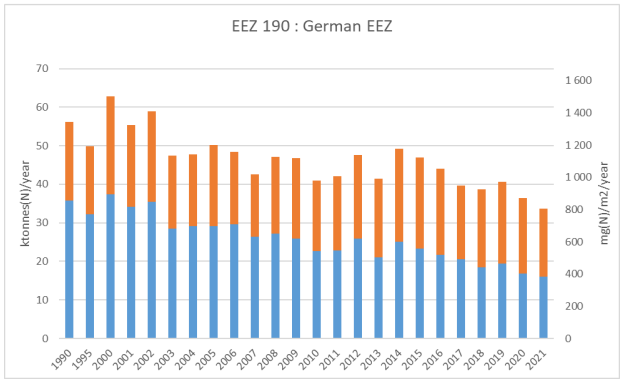

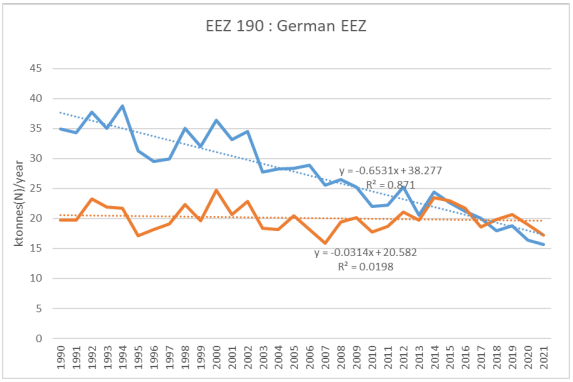

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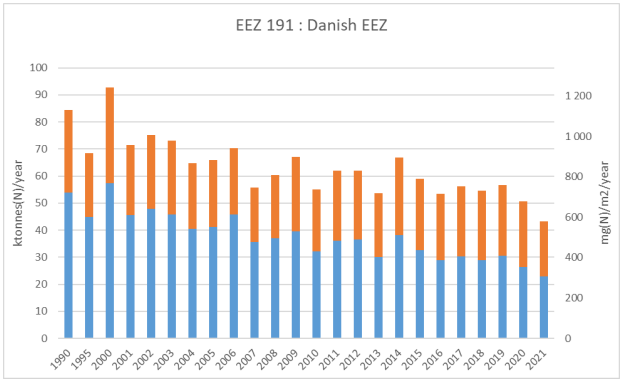

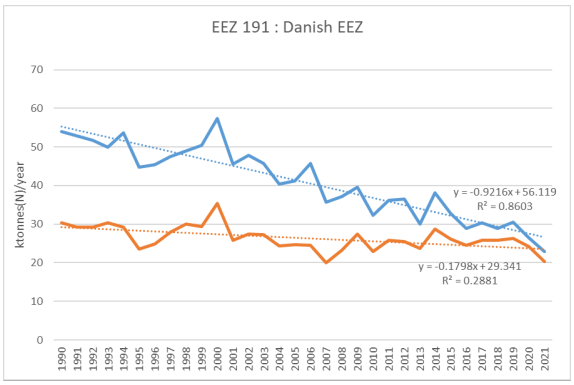

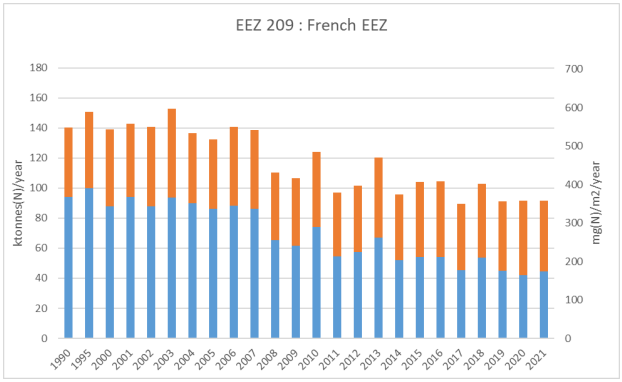

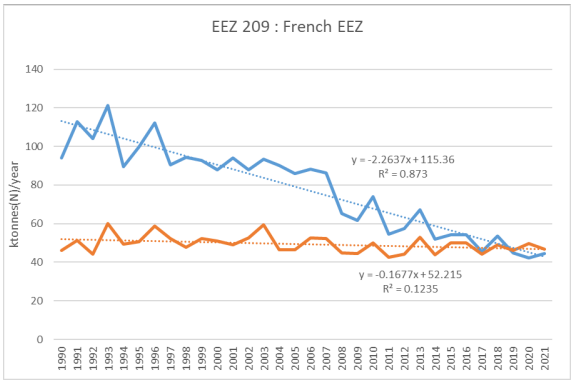

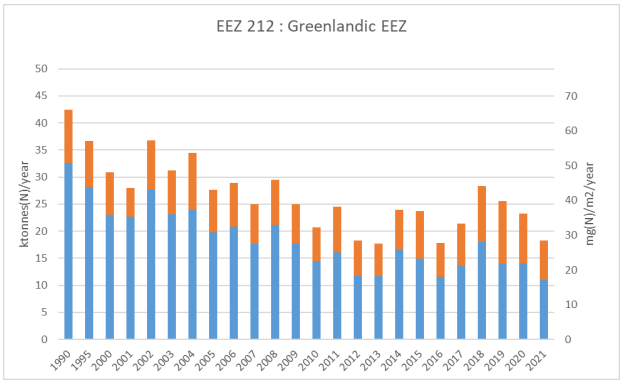

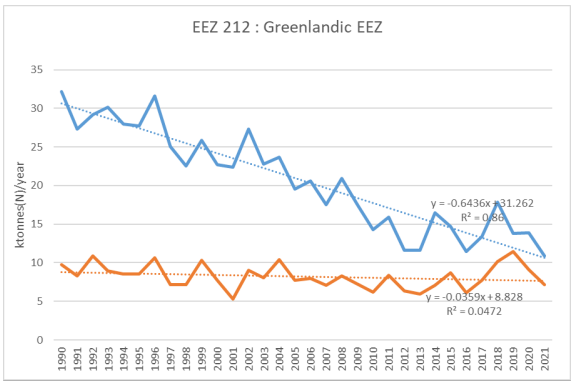

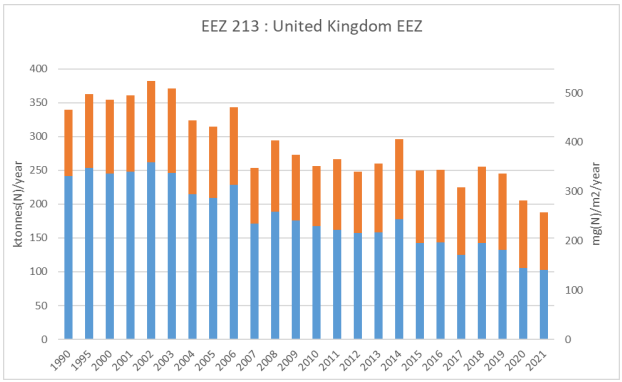

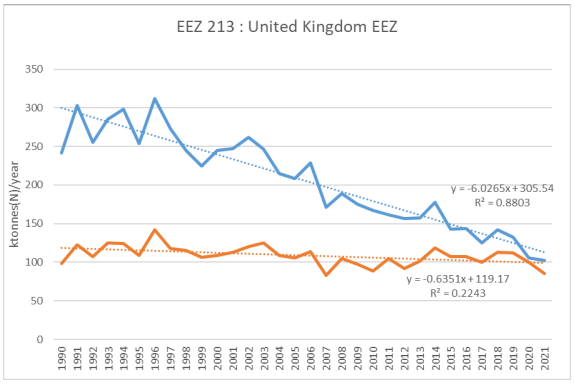

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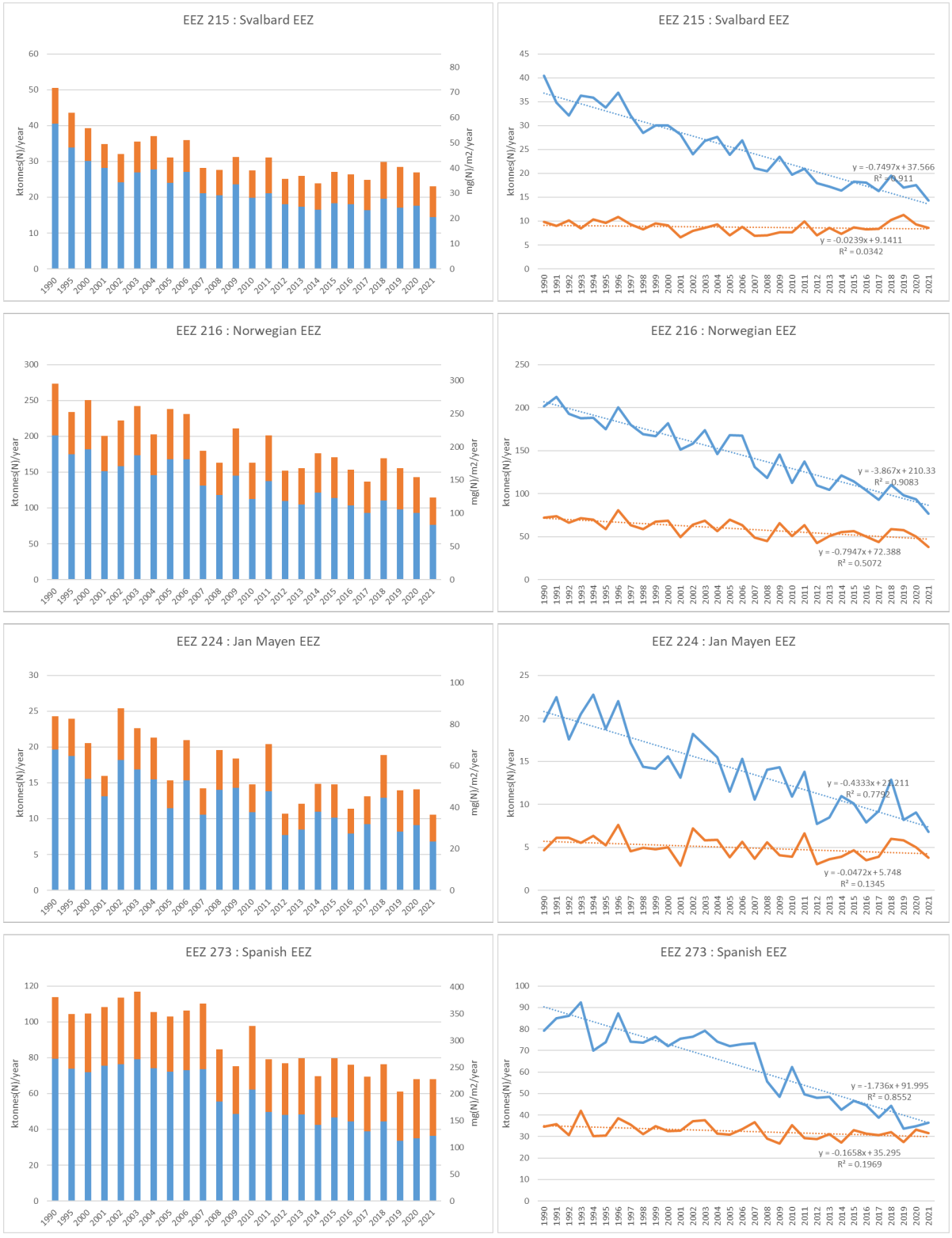

Figure 10: Continued.

Table 12. Deposition of oxidized, reduced and total nitrogen, to the twenty-four EEZs in 2021. Both the actual (based on 2021 meteorology) and normalized (based on meteorological data of 2016-2021) values are given. Results for other years are provided separately in Excel format (see Chapter 8). Unit: tonnes(N)/year.

EEZ	Oxidized N		Reduced N		Total N	
	Actual	Normalized	Actual	Normalized	Actual	Normalized
EEZ048	21 298	19 584	17 542	14 350	38 840	33 934
EEZ065	12 729	15 030	7 251	8 468	19 980	23 498
EEZ071	27 621	30 252	18 841	19 480	46 463	49 732
EEZ091	25 954	25 568	14 408	13 262	40 362	38 829
EEZ099	432	404	402	378	834	781
EEZ100	434	575	268	354	702	929
EEZ108	34 110	33 811	36 316	34 172	70 426	67 983
EEZ109	1 682	1 670	1 415	1 540	3 097	3 210
EEZ110	532	528	664	709	1 196	1 238
EEZ119	52	61	34	34	87	94
EEZ123	1 160	1 373	629	733	1 789	2 106
EEZ185	4 252	4 721	3 972	4 252	8 224	8 972
EEZ187	39	43	32	32	71	75
EEZ188	1 523	1 472	1 621	1 780	3 145	3 252
EEZ189	23 057	24 030	20 249	22 653	43 305	46 683
EEZ190	15 629	16 337	17 193	18 132	32 822	34 469
EEZ191	22 970	25 134	20 329	22 852	43 299	47 986
EEZ209	44 661	43 140	46 893	45 604	91 554	88 744
EEZ212	10 913	12 911	7 157	8 301	18 070	21 212
EEZ213	102 696	112 187	85 218	99 440	187 913	211 627
EEZ215	14 329	16 408	8 567	9 197	22 896	25 605
EEZ216	76 593	86 961	37 618	47 356	114 211	134 318
EEZ224	6 794	8 372	3 777	4 491	10 571	12 863
EEZ273	36 358	35 782	31 510	30 200	67 868	65 982

Table 13. Trends in **actual** (non-normalized) depositions of oxidized, reduced, and total nitrogen to the twenty-four EEZs within the OSPAR Maritime Area. The values correspond to the slopes of a linear regression line, given in %/decade, calculated for the whole 32-year period (1990 – 2021), for the 1990s and for the most recent decade. Missing values, indicated by hyphens, mean that there is no statistically significant trend at the 95% confidence level (i.e. the Mann-Kendall test yields a p-value > 0.05).

EEZ	Oxidized Nitrogen			Reduced Nitrogen			Total Nitrogen		
	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021
EEZ 48	-17	-	-21	-	-	-	-12	-	-
EEZ 65	-20	-	-	-11	-	-	-18	-	-
EEZ 71	-21	-	-	-	-	-	-17	-26	-
EEZ 91	-15	-	-	-	-	-	-12	-	-
EEZ 99	-18	-	-24	-	-	-	-13	-	-
EEZ 100	-20	-	-48	-10	-	-	-18	-	-
EEZ 108	-18	-	-	-	-	-	-11	-	-
EEZ 109	-15	-	-	-	-	-	-10	-	-
EEZ 110	-17	-	-	-	-	-	-11	-	-
EEZ 119	-20	-	-	-9	-	-	-17	-	-
EEZ 123	-20	-	-	-	-	-	-17	-	-
EEZ 185	-19	-	-40	-13	-	-	-17	-	-33
EEZ 187	-18	-	-	-10	-	-	-16	-	-35
EEZ 188	-16	-	-24	-	-	-	-11	-	-19
EEZ 189	-18	-	-29	-5	-	-	-14	-	-21
EEZ 190	-18	-	-30	-	-	-	-13	-	-20
EEZ 191	-19	-	-36	-11	-	-	-16	-	-30
EEZ 209	-17	-	-18	-	-	-	-11	-	-
EEZ 212	-21	-29	-	-	-	-	-18	-27	-
EEZ 213	-19	-	-37	-4	-	-	-14	-	-30
EEZ 215	-21	-26	-	-	-	-	-18	-22	-
EEZ 216	-20	-10	-44	-15	-	-	-19	-8	-
EEZ 224	-21	-21	-	-	-	-	-18	-	-
EEZ 273	-17	-	-27	-	-	-	-13	-	-14

Table 14. Trends in **normalized** depositions of oxidized, reduced, and total nitrogen to the twenty-four EEZs within the OSPAR Maritime Area. The values correspond to the slopes of a linear regression line, given in %/decade, calculated for the whole 32-year period (1990 – 2021), for the 1990s and for the most recent decade. Missing values, indicated by hyphens, mean that there is no significant trend at the 95% confidence level (i.e. the Mann-Kendall test yields a p-value > 0.05).

EEZ	Oxidized Nitrogen			Reduced Nitrogen			Total Nitrogen		
	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021
EEZ 48	-4	4	-6	-5	-	3	-4	-	-
EEZ 65	-18	-17	-25	-8	-12	-	-16	-16	-18
EEZ 71	-14	-12	-18	-8	-13	-	-12	-13	-13
EEZ 91	-10	13	-17	-3	5	4	-8	11	-11
EEZ 99	-16	-5	-25	-5	-	-	-12	-	-16
EEZ 100	-19	-18	-26	-7	-10	-	-16	-16	-18
EEZ 108	-17	-13	-23	-3	-	-	-12	-9	-12
EEZ 109	-18	-12	-26	-7	-6	-	-14	-10	-18
EEZ 110	-18	-12	-27	-6	-	-	-13	-8	-17
EEZ 119	-17	-16	-24	-8	-12	-	-15	-15	-17
EEZ 123	-16	-15	-22	-8	-15	-	-14	-15	-16
EEZ 185	-18	-19	-27	-12	-21	-	-16	-20	-20
EEZ 187	-18	-19	-27	-12	-21	-	-16	-20	-20
EEZ 188	-19	-17	-30	-11	-15	-7	-16	-16	-19
EEZ 189	-20	-20	-30	-13	-25	-	-17	-22	-21
EEZ 190	-20	-20	-30	-13	-24	-11	-17	-22	-21
EEZ 191	-19	-20	-29	-13	-22	-	-17	-21	-21
EEZ 209	-17	-9	-26	-6	-	-	-13	-6	-17
EEZ 212	-12	-12	-14	-10	-21	-	-11	-15	-10
EEZ 213	-20	-19	-29	-7	-9	-	-16	-16	-18
EEZ 215	-11	-13	-12	-11	-28	-	-11	-18	-8
EEZ 216	-18	-16	-26	-9	-17	-	-16	-17	-20
EEZ 224	-15	-14	-20	-9	-15	-	-14	-15	-15
EEZ 273	-14	-	-22	-4	-	-	-11	-	-14

Table 15. Normalized deposition of total nitrogen to the twenty-four EEZs in the OSPAR Maritime Area in the period 1990 to 2021. In the headers, only the numbers of the EEZs are given. For example, '065' means EEZ065 (Faeroe Exclusive Economic Zone). Unit: ktonnes(N)/year. The table continues on the next page.

	048	065	071	091	099	100	108	109	110	119	123	185
1990	39.3	45.3	80.3	51.6	1.25	1.82	110	5.67	2.08	0.17	3.75	17.8
1991	39.5	44.7	79.1	52.6	1.25	1.80	109	5.64	2.07	0.17	3.69	17.4
1992	39.5	44.0	78.1	54.1	1.26	1.78	109	5.61	2.06	0.17	3.63	16.9
1993	39.0	42.7	76.3	52.6	1.22	1.72	106	5.44	2.00	0.17	3.53	16.4
1994	38.9	42.0	75.2	53.0	1.21	1.69	105	5.36	1.97	0.16	3.47	16.0
1995	39.0	41.1	74.0	53.6	1.20	1.65	103	5.29	1.95	0.16	3.40	15.5
1996	39.4	40.9	74.0	54.0	1.21	1.64	103	5.28	1.95	0.16	3.40	15.5
1997	39.3	39.8	72.6	54.3	1.20	1.60	102	5.18	1.92	0.15	3.32	15.0
1998	39.3	39.4	72.1	55.2	1.21	1.58	102	5.17	1.91	0.15	3.29	14.8
1999	39.7	38.7	71.2	56.2	1.20	1.55	101	5.12	1.90	0.15	3.23	14.5
2000	40.3	38.1	70.2	57.4	1.21	1.53	99.2	5.11	1.90	0.15	3.18	14.2
2001	39.7	37.4	69.0	56.3	1.19	1.50	97.7	5.02	1.87	0.15	3.13	14.0
2002	39.2	36.4	67.8	55.8	1.17	1.46	95.7	4.89	1.83	0.14	3.06	13.6
2003	38.4	35.9	67.0	54.6	1.16	1.44	94.4	4.80	1.79	0.14	3.02	13.5
2004	38.3	35.4	66.4	54.1	1.14	1.42	93.1	4.73	1.76	0.14	2.99	13.3
2005	37.4	34.9	65.3	52.7	1.11	1.40	92.1	4.66	1.74	0.14	2.94	13.1
2006	37.0	34.3	64.5	51.4	1.09	1.37	90.7	4.55	1.70	0.13	2.90	12.9
2007	36.9	33.5	63.7	50.8	1.07	1.34	88.2	4.45	1.67	0.13	2.85	12.6
2008	35.6	31.4	60.8	46.3	1.00	1.25	83.7	4.19	1.59	0.12	2.70	12.0
2009	35.2	29.8	58.8	45.0	0.96	1.18	80.3	4.03	1.53	0.12	2.58	11.4
2010	34.8	29.5	58.2	43.7	0.94	1.17	79.0	3.97	1.51	0.12	2.56	11.4
2011	34.8	28.8	57.2	43.7	0.93	1.14	77.3	3.91	1.49	0.11	2.51	11.2
2012	34.4	28.7	56.8	42.5	0.91	1.14	77.6	3.87	1.48	0.11	2.49	11.0
2013	34.0	28.0	55.9	41.5	0.89	1.11	76.3	3.78	1.44	0.11	2.45	10.8
2014	34.4	27.7	55.6	41.8	0.89	1.09	75.3	3.75	1.43	0.11	2.42	10.6
2015	34.8	27.6	55.7	42.8	0.90	1.09	76.1	3.76	1.44	0.11	2.42	10.6
2016	34.6	26.8	54.7	41.6	0.88	1.06	75.1	3.66	1.41	0.11	2.36	10.4
2017	34.8	26.6	54.4	42.1	0.88	1.05	75.2	3.64	1.40	0.11	2.34	10.3
2018	34.8	26.1	53.8	42.0	0.87	1.04	75.0	3.58	1.38	0.10	2.31	10.1
2019	34.6	25.1	52.1	41.1	0.83	0.99	71.7	3.44	1.33	0.10	2.23	9.7
2020	33.9	23.5	49.6	38.1	0.78	0.93	67.7	3.22	1.25	0.09	2.11	9.1
2021	33.9	23.5	49.7	38.8	0.78	0.93	68.0	3.21	1.24	0.09	2.11	9.0

Table 15. Continued.

	187	188	189	190	191	209	212	213	215	216	224	273
1990	0.15	6.39	102	71.9	100	147	32.7	415	39.4	260	22.2	98.3
1991	0.15	6.37	101	70.2	98	146	32.0	410	38.3	255	21.8	98.9
1992	0.14	6.23	97	67.7	95.4	146	31.3	404	37.2	251	21.4	99.8
1993	0.14	6.07	94.3	65.8	92.4	142	30.5	391	36.1	243	20.8	96.6
1994	0.13	5.93	91.1	63.4	89.8	140	29.9	385	35.2	238	20.5	96.6
1995	0.13	5.79	87.7	61.4	87.0	139	29.3	376	34.3	233	20.1	96.5
1996	0.13	5.74	87.2	61.1	86.4	140	29.3	374	34.1	233	20.1	97.7
1997	0.13	5.59	84.4	59.3	83.7	138	28.8	365	33.6	227	19.7	97.1
1998	0.12	5.53	83.0	58.4	82.6	138	28.5	361	33.2	224	19.5	98.3
1999	0.12	5.44	81.5	57.5	80.8	137	28.1	354	32.7	220	19.2	98.4
2000	0.12	5.35	79.6	56.4	79.3	138	27.7	348	32.1	216	18.9	99.6
2001	0.12	5.24	77.9	55.4	77.7	135	27.3	342	31.8	213	18.6	98.0
2002	0.11	5.09	75.5	53.8	75.7	132	26.9	332	31.4	207	18.2	96.7
2003	0.11	4.98	74.3	53.0	74.7	130	26.7	327	31.2	205	18.0	95.5
2004	0.11	4.88	73.0	52.1	73.4	128	26.4	322	30.9	202	17.8	94.0
2005	0.11	4.79	71.8	51.4	72.2	126	26.1	318	30.6	199	17.6	91.7
2006	0.11	4.70	70.5	50.6	70.9	123	25.9	311	30.3	196	17.3	89.7
2007	0.11	4.57	68.7	49.6	69.4	121	25.6	303	29.9	192	17.0	88.6
2008	0.10	4.31	64.3	47.0	65.7	114	24.7	283	28.9	181	16.2	81.6
2009	0.10	4.14	61.1	45.0	62.5	110	24.1	269	28.1	172	15.5	78.7
2010	0.10	4.09	60.4	44.7	62.2	108	23.9	266	27.9	171	15.4	76.9
2011	0.09	4.01	59.0	43.8	60.8	106	23.6	259	27.8	168	15.2	76.5
2012	0.09	3.97	58.4	43.4	59.9	105	23.5	258	27.7	166	15.1	75.0
2013	0.09	3.88	56.9	42.6	58.6	103	23.2	252	27.4	162	14.8	73.2
2014	0.09	3.82	56.2	42.1	57.7	102.1	23.2	249	27.4	160	14.7	73.4
2015	0.09	3.82	56.0	41.9	57.6	103	23.2	249	27.4	159	14.6	74.3
2016	0.09	3.73	54.5	40.9	56.3	100.3	22.9	242	27.1	155	14.3	72.5
2017	0.09	3.68	53.8	40.3	55.8	100.0	22.8	240	27.1	153	14.2	72.8
2018	0.08	3.61	52.5	39.1	54.3	98.7	22.6	236	26.9	150	14.0	72.2
2019	0.08	3.47	50.3	37.4	52.0	95.0	22.0	227	26.4	144	13.6	69.8
2020	0.08	3.26	46.9	34.8	48.9	88.9	21.3	211	25.6	135	12.9	65.6
2021	0.08	3.25	46.7	34.5	48.0	88.7	21.2	212	25.6	134	12.9	66.0

5.3 Partial EEZs

Actual (non-normalized) atmospheric nitrogen depositions have been computed for each of the twenty-five partial Exclusive Economic Zones (listed in Table 6), for each year of the period 1990-2021.

Normalized results are listed for total nitrogen in Table 16. Both actual and normalized results for oxidized and reduced nitrogen are listed in the accompanying Excel file (see Chapter 8). The results are qualitatively consistent with those for the EEZs (previous section), with clear downward trends in many areas for oxidized nitrogen, but much less pronounced for reduced nitrogen. Depositions of oxidized and total nitrogen were lower in 2021 than in 1990 in all the twenty-five partial Exclusive Economic Zones, while for reduced nitrogen deposition, small *increases* were detected in five of them.

Table 16. Normalized deposition of total nitrogen to *partial EEZs*. In the headers, only the numbers of the EEZs are given. For example, 'II_065' means the part of EEZ065 (Faeroe Exclusive Economic Zone) that falls within OSPAR Region II. Unit: ktonnes(N)/year. The table continues on the next page.

	I_065	II_065	V_065	I_071	V_071	IV_091	V_091	I_100	II_100	V_100	III_108	V_108
1990	34.3	2.59	8.34	64.1	16.1	32.9	18.7	0.90	0.02	0.90	54.9	54.8
1991	33.9	2.55	8.25	63.1	15.9	33.6	19.0	0.89	0.02	0.89	54.8	54.4
1992	33.4	2.51	8.14	62.3	15.7	34.7	19.4	0.88	0.02	0.88	54.7	54.1
1993	32.3	2.43	7.90	60.9	15.4	33.7	18.8	0.85	0.02	0.85	53.2	52.6
1994	31.8	2.39	7.79	60.0	15.2	34.1	18.9	0.84	0.02	0.84	52.7	51.9
1995	31.1	2.34	7.63	59.0	14.9	34.6	19.0	0.82	0.02	0.82	52.0	51.1
1996	31.0	2.32	7.60	59.0	14.9	34.8	19.2	0.81	0.02	0.82	52.2	51.1
1997	30.1	2.25	7.41	57.8	14.7	35.0	19.3	0.79	0.02	0.79	51.5	50.2
1998	29.8	2.23	7.35	57.4	14.7	35.6	19.5	0.78	0.02	0.79	51.7	50.1
1999	29.3	2.18	7.23	56.6	14.5	36.5	19.8	0.76	0.02	0.77	51.0	49.5
2000	28.8	2.14	7.11	55.9	14.3	37.3	20.1	0.75	0.02	0.76	50.2	49.0
2001	28.3	2.10	6.99	54.9	14.1	36.6	19.8	0.74	0.02	0.75	49.5	48.3
2002	27.6	2.04	6.82	53.9	13.9	36.3	19.6	0.72	0.02	0.73	48.5	47.2
2003	27.2	2.02	6.73	53.3	13.7	35.4	19.3	0.71	0.02	0.72	47.9	46.6
2004	26.8	1.98	6.64	52.8	13.6	35.1	19.0	0.70	0.02	0.71	47.2	45.9
2005	26.4	1.96	6.55	51.9	13.4	34.2	18.6	0.69	0.02	0.70	46.8	45.3
2006	25.9	1.92	6.43	51.2	13.3	33.2	18.2	0.67	0.02	0.68	46.1	44.5
2007	25.3	1.87	6.29	50.6	13.1	32.8	17.9	0.66	0.02	0.67	44.8	43.5
2008	23.7	1.75	5.92	48.2	12.5	29.9	16.4	0.61	0.01	0.62	42.6	41.2
2009	22.5	1.65	5.63	46.6	12.2	29.0	16.0	0.58	0.01	0.59	40.8	39.5
2010	22.3	1.64	5.57	46.1	12.1	28.1	15.5	0.57	0.01	0.58	40.2	38.9
2011	21.8	1.60	5.44	45.3	11.9	28.1	15.6	0.56	0.01	0.57	39.2	38.2
2012	21.7	1.59	5.42	45.0	11.8	27.3	15.2	0.56	0.01	0.57	39.5	38.1
2013	21.2	1.55	5.31	44.2	11.7	26.6	14.9	0.54	0.01	0.55	38.9	37.4
2014	20.9	1.52	5.24	44.0	11.6	26.9	14.9	0.53	0.01	0.55	38.3	37.1
2015	20.8	1.52	5.25	44.1	11.7	27.6	15.2	0.53	0.01	0.55	38.8	37.3
2016	20.2	1.47	5.12	43.2	11.5	26.8	14.8	0.52	0.01	0.53	38.5	36.6
2017	20.1	1.46	5.09	43.0	11.5	27.1	14.9	0.51	0.01	0.53	38.7	36.5
2018	19.7	1.43	5.02	42.4	11.4	27.1	14.9	0.50	0.01	0.52	38.8	36.2
2019	18.9	1.37	4.83	41.1	11.0	26.6	14.5	0.48	0.01	0.50	36.9	34.8
2020	17.7	1.28	4.54	39.1	10.6	24.6	13.5	0.45	0.01	0.47	34.9	32.8
2021	17.7	1.27	4.55	39.2	10.6	25.1	13.7	0.45	0.01	0.47	35.1	32.9

Table 16. Continued.

	II_209	III_209	IV_209	V_209	I_213	II_213	III_213	IV_213	V_213	I_216	II_216	IV_273	V_273
1990	32.8	22.7	90.1	0.80	7.89	272	105	0.64	29.8	111	148	81.8	16.5
1991	32.7	22.6	90.3	0.80	7.77	268	104	0.63	29.5	109	146	82.4	16.5
1992	32.3	22.6	90.4	0.79	7.66	263	103	0.63	29.2	108	142	83.2	16.6
1993	31.4	22.0	87.6	0.77	7.41	255	100	0.61	28.3	104	138	80.4	16.1
1994	30.9	21.7	86.8	0.76	7.29	250	99	0.61	27.9	103	135	80.6	16.0
1995	30.5	21.5	86.4	0.75	7.13	244	97.4	0.60	27.4	101	131	80.5	16.0
1996	30.4	21.5	86.8	0.75	7.09	242	97.4	0.60	27.3	101	131	81.6	16.1
1997	29.8	21.2	85.7	0.74	6.89	235	95.6	0.59	26.6	100	127	81.2	15.9
1998	29.6	21.2	86.2	0.74	6.81	232	95.4	0.59	26.5	99	125	82.3	16.0
1999	29.3	21.1	85.9	0.74	6.67	227	93.8	0.59	26.0	97	123	82.3	16.1
2000	29.2	21.2	86.3	0.74	6.55	223	92.4	0.59	25.6	96	120	83.4	16.2
2001	28.7	20.8	85.0	0.72	6.43	219	90.9	0.58	25.2	94	118	82.1	15.9
2002	28.0	20.3	83.4	0.71	6.25	212	88.6	0.56	24.6	92.2	115	81.0	15.7
2003	27.4	20.0	82.1	0.70	6.17	209	87.3	0.56	24.3	91.4	113	80.1	15.4
2004	27.0	19.7	80.8	0.69	6.07	206	86.3	0.55	23.9	90.1	112	78.8	15.2
2005	26.6	19.4	79.2	0.67	5.98	202	85.1	0.54	23.6	88.9	110	76.7	14.9
2006	26.0	18.9	77.3	0.66	5.87	198	83.5	0.53	23.2	87.7	108	75.0	14.6
2007	25.5	18.6	76.1	0.65	5.73	193	81.3	0.52	22.7	86.2	106	74.2	14.4
2008	24.3	17.5	71.5	0.60	5.36	180	76.1	0.48	21.3	81.4	99	68.2	13.4
2009	23.3	16.9	68.8	0.58	5.07	170	72.7	0.47	20.3	78.0	94.0	65.7	13.0
2010	23.0	16.6	67.4	0.57	5.02	168	71.7	0.46	20.1	77.5	93.3	64.2	12.7
2011	22.6	16.4	66.8	0.56	4.90	164	70.0	0.45	19.6	76.4	91.1	63.8	12.7
2012	22.4	16.2	65.8	0.56	4.86	163	70.1	0.45	19.6	75.6	90.2	62.5	12.5
2013	21.9	15.8	64.3	0.55	4.75	159	68.7	0.44	19.2	74.2	88.1	61.0	12.2
2014	21.7	15.8	64.1	0.54	4.67	157	68.1	0.43	18.9	73.4	86.6	61.2	12.2
2015	21.7	15.9	64.5	0.55	4.64	156	68.5	0.44	19.0	73.0	86.1	62.0	12.3
2016	21.2	15.5	63.0	0.53	4.49	151	67.3	0.43	18.6	71.1	83.6	60.5	12.0
2017	21.1	15.5	62.9	0.53	4.44	150	67.2	0.43	18.5	70.5	82.6	60.8	12.0
2018	20.7	15.3	62.2	0.53	4.35	146	66.6	0.42	18.3	69.5	80.7	60.3	11.9
2019	19.9	14.7	59.9	0.51	4.17	140	63.9	0.41	17.6	67.0	77.2	58.3	11.6
2020	18.7	13.7	56.1	0.47	3.88	130	59.9	0.38	16.5	62.9	72.0	54.8	10.8
2021	18.6	13.7	56.0	0.47	3.88	131	60.3	0.38	16.5	62.8	71.5	55.1	10.9

5.4 COMP4 Assessment Units

Airborne nitrogen depositions have been calculated for the sixty-four COMP4 Assessment Units. Some of these areas are very small and/or have a rather thin and elongated shape, so that they are poorly resolved by the EMEP model grid.

A detailed uncertainty analysis was beyond the scope of this contract, but as a rule of thumb, areas should extend over at least 3 model grid cells (both in east-west and in south-east direction) to give numerically stable results in *source-receptor* calculations. Since source-receptor calculations are used to calculate transfer coefficients, and transfer coefficients are needed for our normalization procedure, the resolution of our source-receptor calculations (i.e. 0.3°lon × 0.2°lat) is a limiting factor. A 3×3 array of grid cells (fulfilling the above-mentioned criterion for numerical stability) in this resolution has sizes between about 1000 and 6000 km^2, depending on the latitude within the OSPAR Maritime Area.

Independently of these uncertainty considerations, normalized and actual atmospheric nitrogen depositions have been computed in this contract for all the sixty-four COMP4 Assessment Units (as defined in a table provided by OSPAR in August 2022), and for each year of the period 1990-2021. All results have been provided to OSPAR in a separate file in Excel format, together with this report (see Chapter 8).

Figure 11 shows the time series of actual (non-normalized) depositions of total nitrogen to four selected COMP4 Assessment Units.

Table 17 and 18 give all statistically significant trends (at the 95% confidence level) for actual and normalized nitrogen deposition, respectively.

Normalized results are listed for total nitrogen in Table 19. Actual and normalized results for oxidized and reduced nitrogen are listed in the accompanying Excel file (see Chapter 8). The results are qualitatively consistent with those for the EEZs, with clear downward trends in many areas for oxidized nitrogen, but much less pronounced for reduced nitrogen. Depositions of oxidized and total nitrogen were lower in 2021 than in 1990 in all twenty-four COMP4 Assessment Units, while for reduced nitrogen deposition, small increases in twenty-one of them were detected.

Actual oxidized nitrogen depositions have decreased in all COMP4 Assessment Units (and statistically significantly so), while for reduced nitrogen the trends are less significant, with more shallow slopes in the linear regression. In some of the Units, depositions have decreased while in others they have increased slightly. Trends *in total* nitrogen deposition are decreasing in all COMP4 Assessment Units and (over the whole 32-year period) are statistically significant at the 95% confidence level.

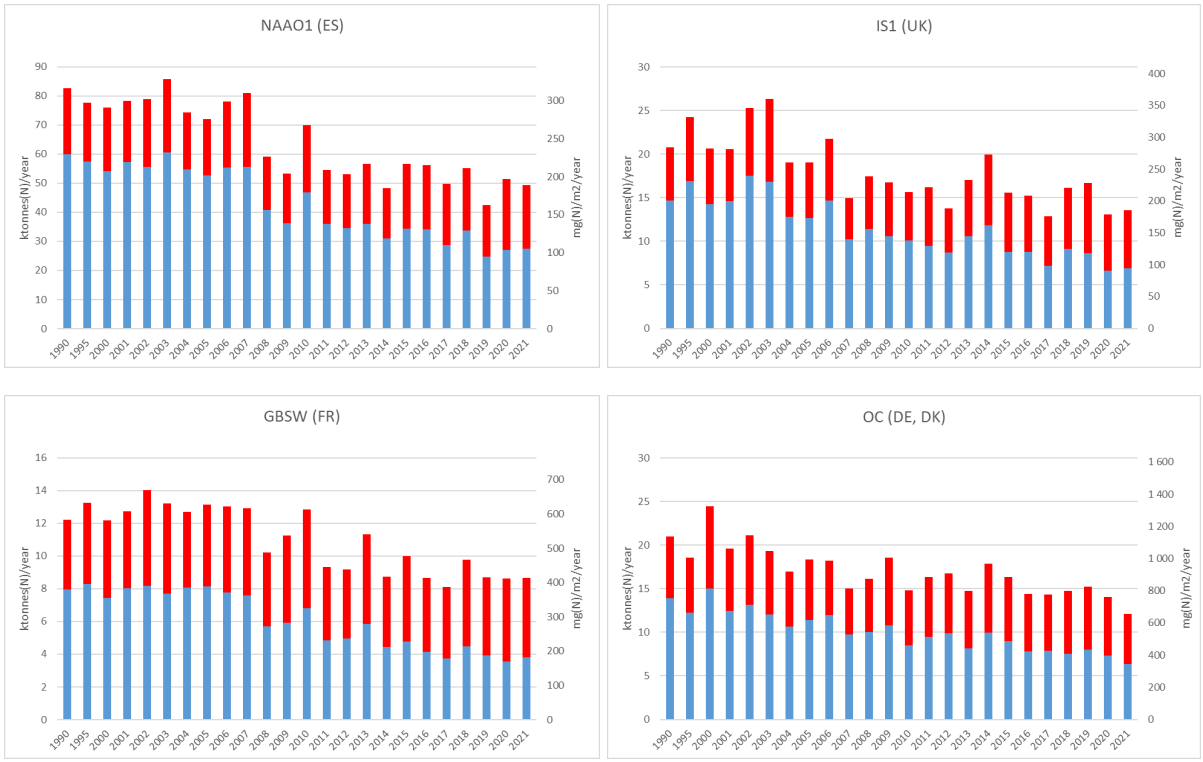

Figure 11: Time series of actual (non-normalized) depositions of total nitrogen to four selected COMP4 Assessment Units, as calculated by the EMEP MSC-W model for the period 1990-2021. Unit: ktonnes(N)/year (left axes) and mg(N)/m^2/year (right axes).

Table 17. Trends in **actual** (non-normalized) depositions of oxidized, reduced, and total nitrogen to the sixty-four COMP4 Assessment Units. The values correspond to the slopes of a linear regression line, given in %/decade, calculated for the whole 32-year period (1990 – 2021), for the 1990s and for the most recent decade. Missing values, indicated by hyphens, mean that there is no trend that is significant at the 95% confidence level (i.e. the Mann-Kendall test yields a p-value > 0.05). Units not belonging to the 40 largest units are marked in grey font. See Section 4.4 for further explanations. (Table continues on the next page.)

COMP4 Unit	Oxidized Nitrogen			Reduced Nitrogen			Total Nitrogen		
	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021
CFR	-15	-	-16	-	-	-	-8	-	-9
CCTI	-14	-	-16	-	-	-	-7	-	-
ATL	-19	-	-26	-5	-	-	-15	-	-
SHPM	-19	-	-	-	-	-	-8	-	-
CNOR1	-21	-22	-	-19	-	-	-21	-23	-
CNOR2	-21	-	-53	-14	-	-	-19	-	-49
CNOR3	-19	-	-	-14	-	-	-17	-	-37
DB	-21	-	-43	-10	-	-	-18	-	-38
KD	-19	-	-38	-13	-	-	-17	-	-29
NT	-20	-	-47	-16	-	-	-19	-	-
SNS	-17	-	-29	-	-	-	-12	-	-19
GBC	-16	-	-24	-	-	-	-11	-	-13
ADPM	-19	-	-37	-7	-	-15	-14	-	-26
GBSW	-17	-	-22	-	-	-	-9	-	-
SPM	-16	-	-	-	-	-	-9	-	-8
GDPM	-17	-	-24	-	-	-	-10	-	-10
CUKC	-15	-	-20	-	-	-	-9	-	-
CWMTI	-14	-	-	-	-	-	-9	-	-
SCHPM1	-16	-	-22	-5	-	-	-11	-	-15
ELPM	-18	-	-28	-	-	-	-12	-	-15
SCHPM2	-16	-	-22	-4	-	-	-12	-	-13
MPM	-16	-	-22	-4	-	-	-11	-	-14
RHPM	-17	-	-25	-5	-	-	-12	-	-15
EMPM	-19	-	-30	-	-	-	-13	-	-17
THPM	-15	-	-23	-	-	-	-8	-	-
HPM	-18	-	-31	11	-	-	-10	-	-
ECPM1	-19	-	-53	-6	-	-	-15	-	-46
ECPM2	-19	-	-41	-	-	-	-12	-	-27
IS2	-19	-	-48	-10	-	-	-17	-	-
OC	-17	-	-33	-	-	-	-14	-	-26

Table 17. Continued.

COMP4 Unit	Oxidized Nitrogen			Reduced Nitrogen			Total Nitrogen		
	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021
ENS	-19	-	-34	-8	-	-	-15	-	-30
CWCC	-16	-	-42	-	-	-	-13	-	-
OWCO	-12	-	-	9	-	-	-9	-	-
OWAO	-16	-	-	-	-	-	-13	-	-
OWBO	-14	-	-	-	-	-	-12	-	-
ASS	-17	-	-	-	-	-	-11	-	-
CIRL	-19	-	-35	-	-	-	-11	-	-
CUK1	-16	-	-20	-	-	-	-9	-	-
IS1	-17	-	-27	-	-	-	-11	-	-
IRS	-19	-	-39	-	-	-	-12	-	-26
KC	-18	-	-35	-12	-	-	-15	-	-27
NNS	-20	-	-43	-13	-	-	-18	-	-41
CWM	-16	-	-	-	-	-	-11	-	-
LBPM	-18	-	-34	-	-	-	-11	-	-22
SK	-18	-	-	-11	-	-	-16	-	-
SS	-18	-	-40	-3	-	-	-14	-	-
CWBC	-14	-	-34	-	-23	-	-11	-	-
CWAC	-14	-	-36	-	-	-	-9	-	-
LPM	-17	-	-23	-	-	-	-10	-	-
GBCW	-17	-	-25	-	-	-	-10	-	-11
NAAP2	-18	-	-36	-7	-	-7	-13	-	-22
NAAO1	-18	-	-24	-	-	-	-13	-	-
NAAPF	-19	-	-32	-6	-	-	-14	-	-19
NAAC3	-17	-	-35	-4	-	-8	-11	-	-21
NAAC2	-18	-	-35	-5	-	-8	-12	-	-20
NAAC1A	-16	-	-36	1	-	-	-8	-	-22
NAAC1B	-20	-10	-34	1	-	-6	-11	-	-18
NAAC1C	-20	-14	-40	-	-	-5	-13	-	-24
NAAC1D	-18	-	-25	-9	-	-7	-14	-	-15
SAAP2	-13	-	-	-	-	-	-10	-	-
SAAOC	-10	-	-	4	-	-	-8	-	-
SAAP1	-12	-	-	-	-	-	-9	-	-
SAAC1	-14	-	-	-	-	-	-11	-	-
SAAC2	-14	-	-	-	-	-	-11	-	-

Table 18. Trends in **normalized** depositions of oxidized, reduced, and total nitrogen to the sixty-four COMP4 Assessment Units. The values correspond to the slopes of a linear regression line, given in %/decade, calculated for the whole 32-year period (1990 – 2021), for the 1990s and for the most recent decade. Missing values, indicated by hyphens, mean that there is no trend that is significant at the 95% confidence level (i.e. the Mann-Kendall test yields a p-value > 0.05). Units not belonging to the 40 largest units are marked in grey font. See Section 4.4 for further explanation. (Table continues on the next page.)

COMP4 Unit	Oxidized Nitrogen			Reduced Nitrogen			Total Nitrogen		
	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021
CFR	-19	-15	-29	-7	-5	-	-14	-11	-18
CCTI	-19	-14	-28	-8	-9	-	-15	-12	-18
ATL	-17	-13	-23	-6	-	-	-14	-11	-16
SHPM	-16	-11	-21	-	4	7	-8	-4	-
CNOR1	-18	-15	-28	-8	-13	-	-16	-15	-21
CNOR2	-20	-19	-30	-8	-14	-	-16	-18	-20
CNOR3	-18	-19	-27	-12	-22	-	-16	-20	-20
DB	-21	-22	-32	-9	-15	-	-18	-20	-22
KD	-18	-19	-27	-13	-22	-	-16	-21	-20
NT	-19	-19	-29	-10	-18	-	-17	-19	-21
SNS	-20	-20	-30	-11	-20	-	-17	-20	-20
GBC	-20	-20	-30	-13	-25	-11	-17	-22	-21
ADPM	-17	-6	-28	-4	-	-	-11	-	-15
GBSW	-17	-9	-27	-5	-	-	-12	-5	-16
SPM	-19	-14	-29	-7	-	-9	-13	-9	-17
GDPM	-18	-10	-28	-5	-	-	-12	-5	-16
CUKC	-19	-15	-28	-7	-7	-	-14	-12	-17
CWMTI	-18	-14	-27	-7	-7	-	-14	-11	-18
SCHPM1	-19	-17	-30	-12	-20	-8	-16	-18	-18
ELPM	-20	-20	-30	-13	-23	-12	-17	-21	-21
SCHPM2	-20	-17	-30	-14	-27	-7	-17	-22	-19
MPM	-19	-17	-29	-14	-28	-	-17	-22	-19
RHPM	-20	-19	-30	-16	-33	-	-18	-25	-20
EMPM	-20	-20	-30	-14	-27	-12	-17	-24	-20
THPM	-20	-20	-31	-8	-12	-	-16	-17	-19
HPM	-21	-23	-32	-6	-8	-	-16	-17	-17
ECPM1	-21	-22	-31	-7	-9	-	-17	-18	-20
ECPM2	-22	-24	-33	-6	-	-	-16	-18	-17
IS2	-21	-22	-31	-7	-11	-	-17	-19	-21
OC	-19	-20	-29	-13	-22	-	-17	-21	-21

Table 18. Continued.

COMP4 Unit	Oxidized Nitrogen			Reduced Nitrogen			Total Nitrogen		
	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021
ENS	-20	-21	-30	-12	-21	-	-17	-21	-22
CWCC	-9	17	-16	-3	-	6	-7	14	-9
OWCO	-7	20	-14	-2	8	6	-6	17	-9
OWAO	-11	10	-18	-4	-	2	-9	9	-12
OWBO	-9	15	-16	-3	6	4	-7	13	-11
ASS	-17	-11	-24	-5	-	-	-13	-8	-15
CIRL	-19	-16	-26	-1	-	-	-11	-9	-
CUK1	-18	-13	-26	-5	-	-	-13	-10	-14
IS1	-19	-18	-26	-4	-	-	-15	-14	-15
IRS	-20	-18	-28	-3	-	3	-13	-12	-12
KC	-19	-20	-27	-13	-23	-11	-16	-21	-20
NNS	-20	-21	-30	-9	-16	-	-17	-20	-22
CWM	-17	-10	-25	-6	-	-	-13	-8	-17
LBPM	-21	-21	-30	-4	-	-	-14	-14	-14
SK	-18	-19	-27	-12	-22	-	-16	-20	-20
SS	-20	-20	-28	-6	-	-	-16	-16	-17
CWBC	-10	17	-19	-4	-	6	-8	13	-10
CWAC	-11	15	-20	-4	-	6	-8	11	-
LPM	-17	-9	-27	-6	-	-	-12	-5	-16
GBCW	-17	-9	-28	-5	-	-	-12	-4	-16
NAAP2	-15	-	-25	-3	-	3	-10	5	-11
NAAO1	-14	-2	-22	-5	-	-	-11	-	-15
NAAPF	-16	-3	-26	-4	-	-	-11	-	-15
NAAC3	-14	-	-24	-2	12	4	-8	8	-9
NAAC2	-15	-	-26	-2	13	5	-8	8	-9
NAAC1A	-12	10	-23	-1	15	6	-6	13	-
NAAC1B	-15	-	-27	-1	15	6	-8	10	-8
NAAC1C	-16	-	-29	-2	13	5	-10	5	-14
NAAC1D	-16	-1	-29	-2	11	3	-10	4	-13
SAAP2	-8	17	-15	-1	14	6	-6	16	-8
SAAOC	-6	20	-11	0	11	6	-5	18	-8
SAAP1	-7	18	-13	-1	13	6	-5	17	-8
SAAC1	-9	14	-17	-1	14	6	-7	14	-9
SAAC2	-10	14	-18	-1	14	7	-7	14	-9

Table 19. Deposition of oxidized, reduced and total nitrogen, to the sixty-four COMP4 Assessment Units in 2021. Both the actual numbers (based on 2021 meteorology) and normalized values (based on meteorological data of 2016-2021) are given. Results for other years are provided separately in Excel format (see Chapter 8). Units not belonging to the 40 largest units are given in grey font. See Section 4.4 for further explanation. Unit: tonnes(N)/year. (Table continues on the next page.)

COMP4 Assessment Unit	Oxidized N		Reduced N		Total N	
	Actual	Normalized	Actual	Normalized	Actual	Normalized
CFR	2 432	2 386	3 170	3 358	5 602	5 744
CCTI	1 944	1 872	1 846	1 985	3 791	3 857
ATL	64 457	67 052	47 680	47 757	112 136	114 808
SHPM	30	33	64	65	94	98
CNOR1	1 519	1 791	650	947	2 169	2 739
CNOR2	739	844	576	674	1 315	1 518
CNOR3	570	624	457	485	1 027	1 109
DB	3 421	4 152	2 192	3 095	5 613	7 247
KD	1 494	1 656	1 476	1 585	2 970	3 241
NT	14 225	16 146	8 463	10 476	22 688	26 622
SNS	22 185	22 751	20 632	23 057	42 817	45 808
GBC	1 898	1 921	2 016	2 034	3 914	3 955
ADPM	73	75	112	115	186	190
GBSW	3 798	3 576	4 856	4 623	8 653	8 199
SPM	364	359	570	591	934	950
GDPM	508	496	747	746	1 255	1 242
CUKC	1 701	1 785	1 740	1 946	3 440	3 731
CWMTI	6 069	6 082	5 403	6 061	11 472	12 144
SCHPM1	293	277	389	409	682	686
ELPM	3 073	3 155	3 651	3 655	6 724	6 810
SCHPM2	48	47	52	54	100	101
MPM	109	105	117	121	226	226
RHPM	1 131	1 097	1 262	1 311	2 393	2 408
EMPM	614	629	921	931	1 535	1 560
THPM	2 092	1 993	2 040	2 218	4 132	4 210
HPM	387	398	496	567	883	965
ECPM1	532	639	464	602	996	1 241
ECPM2	337	373	434	504	770	877
IS2	3 671	4 243	2 335	3 086	6 007	7 328
OC	6 357	6 705	5 750	6 231	12 107	12 935
ENS	19 262	21 247	13 762	16 646	33 024	37 893
CWCC	298	296	167	167	466	463

Continued.

	Oxidized N		Reduced N		Total N	

COMP4 Assessment Unit	Actual	Normalized	Actual	Normalized	Actual	Normalized
OWCO	2 827	2 852	1 078	965	3 905	3 816
OWAO	8 455	8 466	5 321	4 924	13 777	13 390
OWBO	17 069	16 587	7 568	6 808	24 637	23 395
ASS	26 212	25 894	25 447	24 188	51 660	50 082
CIRL	1 282	1 624	2 408	2 883	3 690	4 507
CUK1	1 706	1 791	1 917	2 025	3 623	3 816
IS1	6 894	7 153	6 657	6 525	13 551	13 678
IRS	5 189	6 065	8 132	9 494	13 322	15 558
KC	2 898	3 139	3 193	3 344	6 090	6 483
NNS	51 941	59 348	30 851	40 956	82 792	100 304
CWM	8 715	8 732	8 005	8 440	16 720	17 172
LBPM	320	351	481	538	802	889
SK	1 637	1 783	1 338	1 429	2 976	3 211
SS	5 681	6 307	5 259	5 682	10 940	11 989
CWBC	727	709	506	460	1 233	1 169
CWAC	1 250	1 258	1 367	1 289	2 617	2 548
LPM	242	234	364	353	606	587
GBCW	1 953	1 894	2 798	2 711	4 751	4 605
NAAP2	1 674	1 673	2 264	2 218	3 938	3 891
NAAO1	27 454	26 993	21 813	20 670	49 268	47 664
NAAPF	7 010	6 699	7 315	7 057	14 324	13 756
NAAC3	538	547	834	820	1 372	1 367
NAAC2	426	426	752	748	1 178	1 174
NAAC1A	135	138	275	281	409	419
NAAC1B	25	24	48	46	72	70
NAAC1C	10	10	13	13	23	23
NAAC1D	6	6	8	9	15	15
SAAP2	191	192	115	117	306	309
SAAOC	2 016	2 089	670	652	2 686	2 741
SAAP1	511	527	239	243	750	770
SAAC1	83	82	56	58	139	140
SAAC2	60	58	40	42	100	100

6

6 Source apportionment by Contracting Parties

Source apportionment has been calculated for OSPAR Regions, EEZs and partial EEZs. For source apportionment, normalized results are considered more relevant than actual (non-normalized) depositions because they are less influenced by meteorological year-to-year variability and thus are a better measure for the influence of the various emitters (emitting countries or areas). The next two sections are thus based on *normalized* results for 2021. The accompanying data tables provide results also for earlier years (see Chapter 8).

6.1 Source apportionment to OSPAR Regions

Contributions from OSPAR Contracting Parties (and all other sources) to oxidized and reduced nitrogen deposition in OSPAR Regions have been provided to OSPAR in a separate file in ASCII format (see Chapter 8). Figure 12 summarizes the results by showing the Top-10 contributors to total normalized nitrogen deposition in each of the 5 OSPAR Regions. The normalization has been done with meteorological data for the years 2016 to 2021.

The two largest OSPAR Regions (I and V) receive the largest contributions (19% and 33% respectively) from the boundary (abbreviated 'BIC' in EMEP MSC-W terminology, originally meaning 'Boundary and Initial Conditions'). OSPAR Regions II, III and IV receive their largest contributions from the United Kingdom (contribution 27% to Region II and 29% to Region III) and Spain (26% to Region IV). Other important contributions are made by international shipping and other large countries such as Russia, Germany, and France. The Top-10 contributions typically make up around 90% of the total, except for Region I.

A recurring question is what the results would be if we used the 1995-2021 period, i.e. including meteorological years prior to 2016 and relying on the transfer coefficients that were calculated in the past on the coarse polar-stereographic grid (mentioned in the beginning of Chapter 5). Such a calculation has been made for the relatively large OSPAR regions and the EEZs, but plots are not shown in this report in order to be consistent with the results for the partial EEZs and the COMP4 Assessment Units. Indeed, when using the 1995-2021 period for normalization, all of the statements in the previous paragraph remain valid, except that the largest contribution to OSPAR region IV is made by France (26%), slightly exceeding Spain, which then comes only in second place (23%).

Finally, table 20 lists the numbers Figure 12 is based on, but also gives hints as to how much of the contributions is due to oxidized nitrogen and how much is reduced nitrogen. As far as international shipping contributions are concerned, they are entirely oxidized as ships do not emit reduced nitrogen in any significant amounts. The sum of total nitrogen deposition is usually dominated by (the longer-lived) oxidized nitrogen species, but individual contributions *can* be dominated by (the shorter-lived) reduced nitrogen, especially if the emitting country has large emissions of agriculture and/or is close to the receptor region.

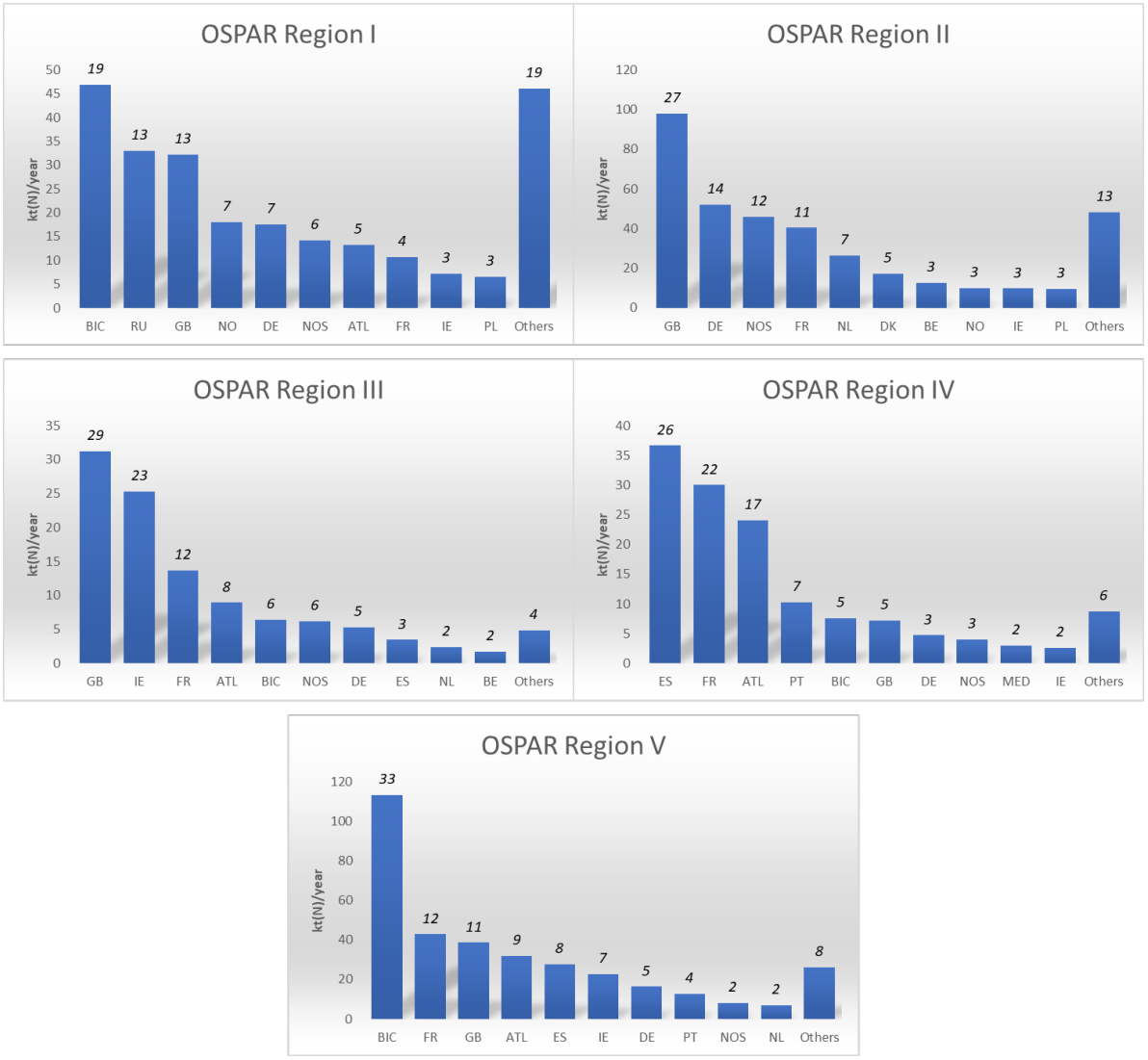

Figure 12. Top-10 contributors to normalized total nitrogen depositions in the 5 OSPAR Regions. Unit: ktonnes(N)/year. The numbers on top of each bar indicate the percentage (%) of the total deposition to the respective Region. All numbers are based on 2021 emissions and 2016-2021 average meteorology. For example, France contributes 42.8 ktonnes(N)/year to OSPAR Region V, corresponding to about 12% of the total nitrogen deposition to that Region. All numbers are listed in Table 20. ('BIC': Influence from sources outside the EMEP model domain, 'NOS': North Sea shipping, 'ATL': North Atlantic shipping except North Sea, 'Others': All contributions that are not among the Top-10.)

Table 20. Top-10 contributors to normalized total nitrogen depositions in the 5 OSPAR Regions. Unit: ktonnes(N)/year. The numbers on top of each bar indicate the percentage of the total deposition to the respective Region. All numbers are based on 2021 emissions and 2016-2021 average meteorology. ('BIC': Influence from sources outside the EMEP model domain, 'NOS': North Sea shipping, 'ATL': North Atlantic shipping except North Sea, 'Others': All contributions that are not among the Top-10.) (ox-N)% gives the percentage of oxidized nitrogen within the country's contribution, while (re-N)% gives the percentage of reduced nitrogen. For example, Norway is number 4 among the Top-10 contributors to total nitrogen deposition in OSPAR Region I, with a contribution of 18.0 ktonnes(N)/year, corresponding to about 7% of the total nitrogen deposition in that Region. 67% of Norway's contribution to OSPAR Region I is oxidized nitrogen, the rest (33%) is reduced nitrogen.

Region I	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	BIC	RU	GB	NO	DE	NOS	ATL	FR	IE	PL	Others	Sum
kt(N)/yr	46.9	33.0	32.2	18.0	17.6	14.2	13.3	10.6	7.1	6.5	46.2	245.7
%	19	13	13	7	7	6	5	4	3	3	19	100
(ox-N)%	100	55	52	67	46	100	100	32	31	45	53	66
(re-N)%	0	45	48	33	54	0	0	68	69	55	47	34
Region II	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	GB	DE	NOS	FR	NL	DK	BE	NO	IE	PL	Others	Sum
kt(N)/yr	98.1	52.1	45.8	40.3	26.4	17.2	12.5	10.0	9.7	9.4	48.0	369.5
%	27	14	12	11	7	5	3	3	3	3	13	100
(ox-N)%	52	39	100	32	37	27	43	62	38	52	73	54
(re-N)%	48	61	0	68	63	73	57	38	62	48	27	46
Region III	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	GB	IE	FR	ATL	BIC	NOS	DE	ES	NL	BE	Others	Sum
kt(N)/yr	31.3	25.3	13.7	8.9	6.5	6.2	5.3	3.5	2.4	1.7	4.8	109.6
%	29	23	12	8	6	6	5	3	2	2	4	100
(ox-N)%	39	19	24	100	100	100	47	36	50	50	57	46
(re-N)%	61	81	76	0	0	0	53	64	50	50	43	54
Region IV	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	ES	FR	ATL	PT	BIC	GB	DE	NOS	MED	IE	Others	Sum
kt(N)/yr	36.6	30.0	24.1	10.3	7.6	7.2	4.7	4.0	3.0	2.6	8.7	138.8
%	26	22	17	7	5	5	3	3	2	2	6	100
(ox-N)%	34	24	100	45	100	58	52	100	100	33	54	54
(re-N)%	66	76	0	55	0	42	48	0	0	67	46	46
Region V	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	BIC	FR	GB	ATL	ES	IE	DE	PT	NOS	NL	Others	Sum
kt(N)/yr	113.0	42.8	38.5	32.0	27.7	22.8	16.4	12.6	8.0	7.1	26.0	346.9
%	33	12	11	9	8	7	5	4	2	2	8	100
(ox-N)%	100	18	34	100	23	17	31	23	100	33	39	59
(re-N)%	0	82	66	0	77	83	69	77	0	67	61	41

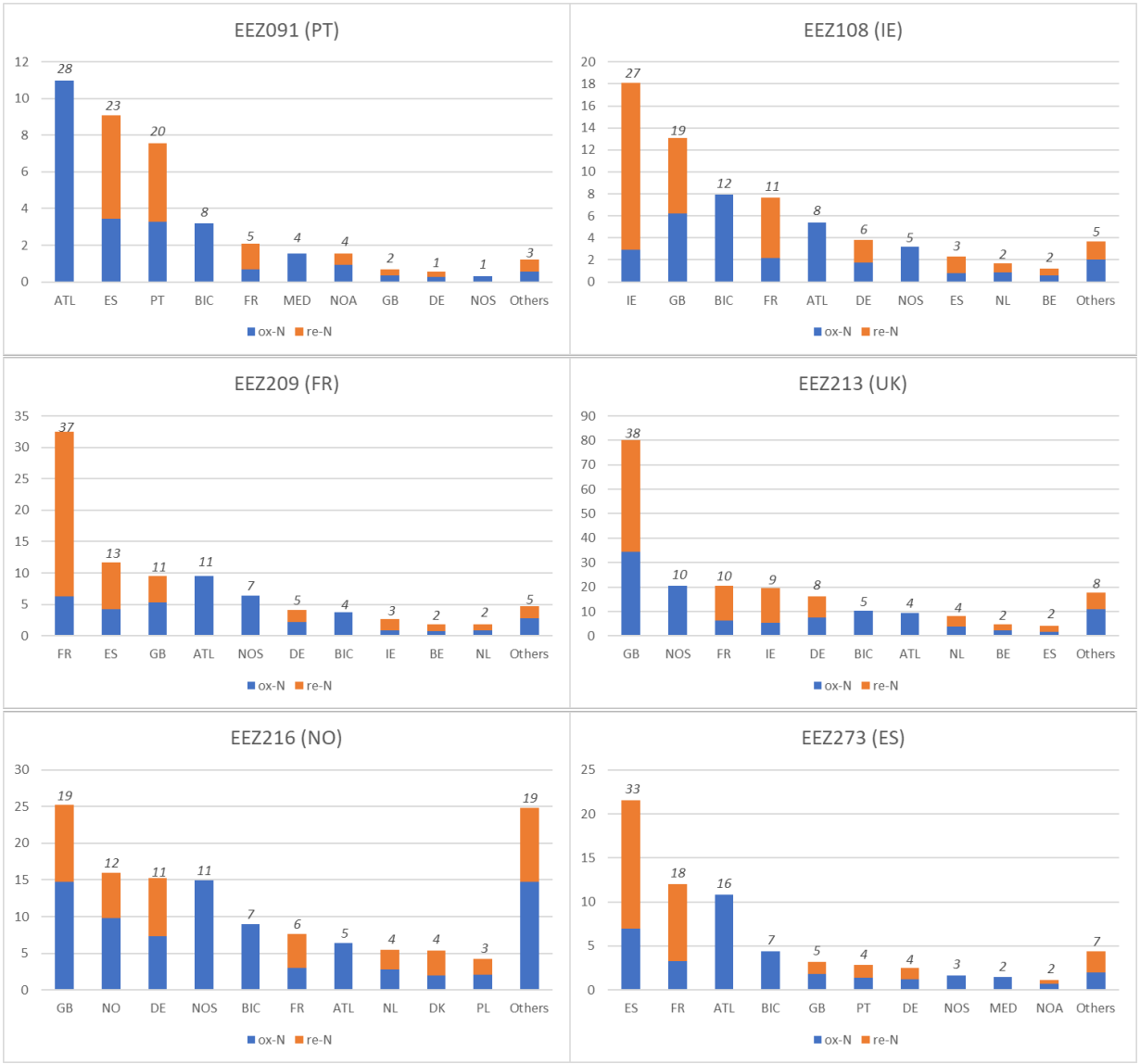

Figure 13. Top-10 contributors to normalized total nitrogen depositions in 6 of the 24 EEZs. Unit: ktonnes(N)/year. The numbers on top of each bar indicate the percentage of the total deposition to the respective Region. For example, Germany contributed 15.3 ktonnes(N)/year to EEZ216, corresponding to about 11% of the total nitrogen deposition to that EEZ. About half of this contribution is reduced nitrogen, and the other half oxidized. All numbers are based on 2021 emissions and 2016-2021 average meteorology. 'BIC': Influence from sources outside the EMEP model domain, 'NOS': North Sea shipping, 'ATL': North Atlantic shipping except North Sea, 'MED': Mediterranean shipping, 'Others': All contributions that are not among the Top-10. As reduced nitrogen emissions from shipping are considered negligible, their contributions are oxidized only (bars entirely blue). Numbers for all 24 EEZs are listed in Table 23.

6.2 Source apportionment to EEZs and partial EEZs

Contributions from OSPAR Contracting Parties (and all other sources) to oxidized and reduced nitrogen deposition in EEZs and partial EEZs have been provided to OSPAR in a separate file in ASCII format (see Chapter 8). Figure 13 summarizes the results for a selection of large EEZs by showing the Top-10 contributors to total normalized nitrogen deposition. The normalization has been done with meteorological data for the years 2016 to 2021. Table 21 lists the numbers Figure 13 is based on, but also includes all other EEZs. As far as international shipping contributions are concerned, they are entirely oxidized as ships do not emit reduced nitrogen in any significant amounts. The sum of total nitrogen deposition is usually dominated by (the longer-lived) oxidized nitrogen species, but individual contributions can be dominated by (the shorter-lived) reduced nitrogen, especially if the emitting country has large emissions of agriculture and/or is close to the receptor region.

Table 23. As Table 22, but for the 24 Exclusive Economic Zones.

EEZ048	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	BIC	PT	ATL	ES	FR	GB	DE	NOA	IE	NL	Others	Sum
kt(N)/yr	14.5	8.1	3.3	2.6	2.3	0.8	0.6	0.3	0.3	0.3	0.8	33.9
%	43	24	10	8	7	2	2	1	1	1	2	100
(ox-N)%	100	5	100	13	10	21	20	22	12	20	43	58
(re-N)%	0	95	0	87	90	79	80	78	88	80	57	42
EEZ065	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	GB	BIC	NOS	DE	IE	FR	ATL	NO	NL	DK	Others	Sum
kt(N)/yr	6.3	3.1	2.2	2.0	1.7	1.5	1.2	0.9	0.8	0.5	3.2	23.5
%	27	13	9	9	7	7	5	4	3	2	14	100
(ox-N)%	55	100	100	47	33	33	100	76	50	42	53	64
(re-N)%	45	0	0	53	67	67	0	24	50	58	47	36
EEZ071	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
source	BIC	GB	IS	DE	FR	IE	NOS	ATL	NL	NO	Others	Sum
kt(N)/yr	12.8	8.6	4.4	3.9	3.8	2.8	2.4	2.3	1.5	1.1	6.2	49.7
%	26	17	9	8	8	6	5	5	3	2	12	100
(ox-N)%	100	43	47	37	25	26	100	100	41	66	41	61
(re-N)%	0	57	53	63	75	74	0	0	59	34	59	39
EEZ091	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
source	ATL	ES	PT	BIC	FR	MED	NOA	GB	DE	NOS	Others	Sum
kt(N)/yr	11.0	9.1	7.6	3.2	2.1	1.6	1.5	0.7	0.6	0.3	1.2	38.8
%	28	23	20	8	5	4	4	2	1	1	3	100
(ox-N)%	100	38	43	100	32	100	61	54	48	100	45	66
(re-N)%	0	62	57	0	68	0	39	46	52	0	55	34
EEZ099	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
source	FR	ES	ATL	GB	BIC	DE	NOS	PT	IE	BE	Others	Sum
kt(N)/yr	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
%	28	25	14	7	5	5	4	3	2	2	6	100
(ox-N)%	25	36	100	61	100	53	100	54	33	54	57	52
(re-N)%	75	64	0	39	0	47	0	46	67	46	43	48

Table 23. Continued.

EEZ100	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
source	GB	BIC	IE	NOS	DE	FR	ATL	NL	NO	BE	Others	Sum
kt(N)/yr	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.9

%	32	12	11	9	8	6	5	3	3	2	11	100
(ox-N)%	54	100	33	100	47	34	100	48	75	53	50	62
(re-N)%	46	0	67	0	53	66	0	52	25	47	50	38
EEZ108	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
source	IE	GB	BIC	FR	ATL	DE	NOS	ES	NL	BE	Others	Sum
kt(N)/yr	18.1	13.1	8.0	7.6	5.4	3.8	3.2	2.3	1.7	1.2	3.7	68.0
%	27	19	12	11	8	6	5	3	2	2	5	100
(ox-N)%	16	47	100	28	100	46	100	34	50	50	55	50
(re-N)%	84	53	0	72	0	54	0	66	50	50	45	50
EEZ109	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
source	FR	GB	NOS	ATL	DE	ES	IE	BIC	NL	BE	Others	Sum
kt(N)/yr	1.0	0.6	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2	3.2
%	30	20	16	6	6	5	4	3	3	3	5	100
(ox-N)%	19	49	100	100	52	38	31	100	48	45	60	52
(re-N)%	81	51	0	0	48	62	69	0	52	55	40	48
EEZ110	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	FR	GB	NOS	ATL	ES	DE	IE	BIC	NL	BE	Others	Sum
kt(N)/yr	0.6	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	1.2
%	46	14	11	5	5	4	3	3	2	2	4	100
(ox-N)%	14	54	100	100	38	54	31	100	52	46	60	43
(re-N)%	86	46	0	0	63	46	69	0	48	54	40	57
EEZ119	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	GB	BIC	DE	NOS	IE	FR	ATL	NO	NL	IS	Others	Sum
kt(N)/yr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
%	24	16	8	8	8	8	6	3	3	3	13	100
(ox-N)%	55	100	50	100	29	29	100	67	50	67	50	64
(re-N)%	45	0	50	0	71	71	0	33	50	33	50	36
EEZ123	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	BIC	GB	DE	NOS	FR	IE	NO	ATL	NL	IS	Others	Sum
kt(N)/yr	0.4	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.4	2.1
%	20	20	8	7	7	5	5	4	4	3	17	100
(ox-N)%	100	50	48	100	33	31	73	100	50	60	52	65
(re-N)%	0	50	52	0	67	69	27	0	50	40	48	35
EEZ185	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	DE	DK	SE	GB	NOS	BAS	PL	FR	NL	NO	Others	Sum
kt(N)/yr	1.7	1.3	0.8	0.8	0.8	0.6	0.6	0.5	0.5	0.2	1.3	9.0
%	19	15	9	9	9	7	6	5	5	2	14	100
(ox-N)%	43	25	26	61	100	100	50	44	51	60	57	53
(re-N)%	57	75	74	39	0	0	50	56	49	40	43	47

Table 23. Continued.

EEZ187	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	DE	NOS	DK	GB	SE	PL	BAS	FR	NL	NO	Others	Sum
kt(N)/yr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
%	18	11	10	8	7	7	6	6	5	5	16	100
(ox-N)%	46	100	38	67	40	50	100	40	50	50	58	57
(re-N)%	54	0	63	33	60	50	0	60	50	50	42	43
EEZ188	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		

Source	GB	FR	BE	NOS	NL	DE	BIC	IE	ATL	ES	Others	Sum
kt(N)/yr	0.7	0.7	0.6	0.5	0.3	0.2	0.1	0.1	0.1	0.0	0.1	3.3
%	21	20	19	14	8	7	2	2	2	1	4	100
(ox-N)%	51	30	10	100	27	44	100	39	100	41	67	45
(re-N)%	49	70	90	0	73	56	0	61	0	59	33	55
EEZ189	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	GB	NL	NOS	DE	FR	BE	IE	BIC	ATL	PL	Others	Sum
kt(N)/yr	11.8	7.3	6.5	6.3	5.5	2.9	0.9	0.9	0.7	0.7	3.3	46.7
%	25	16	14	13	12	6	2	2	2	1	7	100
(ox-N)%	55	22	100	35	37	31	39	100	100	58	59	51
(re-N)%	45	78	0	65	63	69	61	0	0	42	41	49
EEZ190	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	DE	GB	NL	NOS	FR	BE	DK	PL	BIC	IE	Others	Sum
kt(N)/yr	10.7	5.6	4.5	4.1	2.6	1.3	1.0	0.8	0.5	0.5	2.8	34.5
%	31	16	13	12	8	4	3	2	2	2	8	100
(ox-N)%	23	60	29	100	42	51	32	55	100	40	69	47
(re-N)%	77	40	71	0	58	49	68	45	0	60	31	53
EEZ191	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	DE	DK	GB	NOS	NL	FR	PL	BAS	BE	SE	Others	Sum
kt(N)/yr	9.4	7.6	7.1	5.2	3.1	3.0	2.3	1.7	1.3	1.0	6.1	48.0
%	20	16	15	11	6	6	5	4	3	2	13	100
(ox-N)%	41	16	60	100	47	43	51	100	56	41	61	52
(re-N)%	59	84	40	0	53	57	49	0	44	59	39	48
EEZ209	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	FR	ES	GB	ATL	NOS	DE	BIC	IE	BE	NL	Others	Sum
kt(N)/yr	32.5	11.7	9.6	9.5	6.4	4.2	3.7	2.7	1.9	1.9	4.7	88.7
%	37	13	11	11	7	5	4	3	2	2	5	100
(ox-N)%	19	36	56	100	100	52	100	32	43	48	60	49
(re-N)%	81	64	44	0	0	48	0	68	57	52	40	51
EEZ212	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	BIC	GB	DE	RU	FR	NO	NOS	IS	NL	PL	Others	Sum
kt(N)/yr	7.2	2.6	1.9	1.1	1.0	0.8	0.8	0.8	0.6	0.6	3.8	21.2
%	34	12	9	5	5	4	4	4	3	3	18	100
(ox-N)%	100	37	31	32	22	54	100	37	34	29	44	61
(re-N)%	0	63	69	68	78	46	0	63	66	71	56	39

Table 23. Continued.

EEZ213	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	GB	NOS	FR	IE	DE	BIC	ATL	NL	BE	ES	Others	Sum
kt(N)/yr	80.2	20.6	20.5	19.5	16.3	10.4	9.5	8.0	4.8	4.2	17.8	211.6
%	38	10	10	9	8	5	4	4	2	2	8	100
(ox-N)%	43	100	31	27	45	100	100	46	46	37	61	53
(re-N)%	57	0	69	73	55	0	0	54	54	63	39	47
EEZ215	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	BIC	RU	GB	DE	NO	ATL	PL	FR	NOS	FI	Others	Sum
kt(N)/yr	8.4	4.5	2.0	1.5	1.3	1.1	0.8	0.7	0.7	0.5	4.0	25.6
%	33	18	8	6	5	4	3	3	3	2	15	100

(ox-N)%	100	40	37	35	70	100	32	24	100	50	39	64
(re-N)%	0	60	63	65	30	0	68	76	0	50	61	36
EEZ216	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	GB	NO	DE	NOS	BIC	FR	ATL	NL	DK	PL	Others	Sum
kt(N)/yr	25.2	16.0	15.3	15.0	9.0	7.6	6.4	5.4	5.3	4.3	24.8	134.3
%	19	12	11	11	7	6	5	4	4	3	19	100
(ox-N)%	59	61	48	100	100	40	100	52	38	50	59	65
(re-N)%	41	39	52	0	0	60	0	48	62	50	41	35
EEZ224	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	BIC	GB	DE	FR	NOS	NO	IE	ATL	NL	RU	Others	Sum
kt(N)/yr	2.9	2.3	1.1	0.8	0.8	0.7	0.6	0.6	0.4	0.4	2.3	12.9
%	22	18	8	7	7	6	5	4	3	3	18	100
(ox-N)%	100	48	46	29	100	71	28	100	48	56	51	65
(re-N)%	0	52	54	71	0	29	72	0	52	44	49	35
EEZ273	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		
Source	ES	FR	ATL	BIC	GB	PT	DE	NOS	MED	NOA	Others	Sum
kt(N)/yr	21.5	12.0	10.8	4.4	3.2	2.8	2.5	1.7	1.5	1.2	4.4	66.0
%	33	18	16	7	5	4	4	3	2	2	7	100
(ox-N)%	32	27	100	100	57	50	50	100	100	61	45	54
(re-N)%	68	73	0	0	43	50	50	0	0	39	55	46

7 Conclusions

The main outcome from this work can be summarised as follows:

- Emission data have been updated by the EMEP Centre for Emission Inventories and Projections (EMEP CEIP) for the entire 32-year period from 1990 to 2021 period (based on data submissions received from Contracting Parties by June 2023);
- based on emission data from CEIP and meteorological data from ECWMF (European Centre for Medium-Range weather forecasts), EMEP MSC-W has calculated nitrogen depositions to the five OSPAR Regions, the twenty-four Exclusive Economic Zones (EEZs) in the OSPAR Maritime Area, the twenty-five 'partial EEZs' and the sixty-four COMP4 Assessment Units for the 1990-2021 period;
- in all OSPAR Regions, actual (non-normalized) deposition of *oxidized* nitrogen was clearly lower in 2021 than in 1990, with the maximum decline in Region I (61%), followed by Region V (59%);
- actual deposition of *reduced* nitrogen was lower in 2021 than in 1990 in OSPAR Regions I, II, IV and V (in the range of 3-28%), but larger by 5% in OSPAR region III;
- actual deposition of *total* nitrogen was lower in 2021 than in 1990 in all OSPAR Regions (in the range of 34-54%), with the largest reduction in Region I and the smallest reduction in Region III;
- the decrease in actual nitrogen deposition over the whole 1990-2021 period is statistically significant in all OSPAR Regions, except for reduced nitrogen deposition in OSPAR Regions III and IV;
- normalized nitrogen deposition shows statistically significant downward trends over the 32-year period in all OSPAR regions for both reduced, oxidized and total nitrogen; however, when limiting the trend analysis to the last decade (2011-2021) no statistically significant downward trend in *reduced* nitrogen deposition was detected in any of the OSPAR regions;
- qualitatively, the findings for the EEZs, partial EEZs and COMP4 Assessment Units are similar to the results for the OSPAR Regions, with clear decreases for oxidized nitrogen deposition over the 32-year period, but much smaller (or absent) decreases for reduced nitrogen deposition;
- over the 1990-2021 period, (actual) oxidized and total nitrogen deposition has decreased significantly in all EEZs, but for reduced nitrogen deposition the decrease is statistically significant in less than half of the EEZs; for *normalized* depositions, all downward trends are significant even for reduced nitrogen (albeit smaller than those for oxidized and total nitrogen);
- in all COMP4 Assessment Units, normalized deposition of *oxidized* nitrogen was clearly lower in 2021 than in 1990 (with decreases in the range of 18 to 67%); for *reduced* nitrogen it was lower in all but one assessment unit; for *total* nitrogen there where decreases in all assessment units (in the range of 15 to 55%);
- source-receptor relationships (source apportionment) have been calculated, and the Top-10 contributors have been identified for all OSPAR Regions and EEZs;
- in general, receptor areas are most influenced by the countries adjacent to them, but large emitters can make important contributions even if they are far away, mainly as oxidized nitrogen deposition;
- contributions tend to be larger for sources located upwind of the receptor area, 'upwind' usually meaning 'west of' in the annual average;
- the largest contribution to nitrogen deposition in OSPAR Regions II and III is made by the United Kingdom, while OSPAR Region IV receives the single-largest contribution from Spain; the more remote

Regions I and V are strongly influenced by the boundary condition (i.e. sources outside the EMEP model domain).

8 Accompanying data sheets

As the number of receptor areas relevant to OSPAR is quite large, not all results can be shown in this report. Three data files have therefore been submitted along with this report:

a) 'N_depositions_OSPAR_2023' (Excel format): Actual and normalized depositions of oxidized, reduced and total nitrogen to all OSPAR receptors of interest in the period 1990-2021. The Excel file also contains a 'README' sheet for information about versions, units, contact details, etc., as well as a sheet with definitions of all receptor areas considered in this work (i.e. OSPAR Regions, EEZs, partial EEZs and COMP4 Assessment Units).

b) 'N_emissions_OSPAR_2023' (Excel format): Emissions for oxidized nitrogen (NOx) and reduced nitrogen (ammonia) from OSPAR Contracting parties, as provided by CEIP for modelling purposes.

c) SR_OSPAR_normalized_2023 (ASCII format): All contributions to OSPAR Regions, EEZs and partial EEZs. Tables for each source-receptor pair are preceded by a header specifying:

- the species, i.e. oxidized nitrogen ("ox-N") or reduced nitrogen ("re-N")
- the unit (Mg(N)/year = tonnes(N)/year)
- the receptor ("Basin"), and the source country ("Source") abbreviated by its Alpha-2 code.

OSPAR regions I to V are abbreviated as 'OR1', 'OR2', … 'OR5' in the file. An example screenshot is shown in Figure 14. Minimum and maximum values are given in addition to the Normalized value. The column 'Annual' is for internal checks only and should not be used.

Ox-N deposition in Mg(N)/year: Basin=OR4; Source=SI

Year	Minimum	Normalised	Actual	Maximum
1990	24.35	30.36	0.00	33.44
1991	22.52	28.08	0.00	30.93
1992	22.20	27.68	0.00	30.49
1993	23.74	29.60	0.00	32.60
1994	24.62	30.70	0.00	33.81
1995	24.37	30.39	0.00	33.47
1996	25.02	31.19	0.00	34.36
1997	25.18	31.40	0.00	34.58
1998	22.15	27.62	0.00	30.42
1999	19.74	24.61	0.00	27.10
2000	18.98	23.66	0.00	26.06
2001	19.22	23.96	0.00	26.39
2002	18.96	23.64	0.00	26.04
2003	17.90	22.32	0.00	24.59
2004	17.48	21.79	0.00	24.00
2005	17.84	22.25	0.00	24.50
2006	17.90	22.31	0.00	24.58
2007	17.47	21.78	0.00	23.99
2008	18.85	23.49	0.00	25.88
2009	15.72	19.59	0.00	21.58
2010	15.47	19.29	0.00	21.25
2011	15.21	18.97	0.00	20.89
2012	14.75	18.39	0.00	20.25
2013	13.87	17.29	0.00	19.04
2014	12.56	15.66	0.00	17.25
2015	11.39	14.20	0.00	15.64
2016	11.21	13.97	15.35	15.39
2017	11.05	13.77	14.66	15.17
2018	10.60	13.22	14.26	14.56
2019	9.58	11.95	10.21	13.16
2020	8.27	10.31	11.36	11.36
2021	8.35	10.42	8.35	11.47

Ox-N deposition in Mg(N)/year: Basin=OR4; Source=SK

Year	Minimum	Normalised	Actual	Maximum
1990	13.51	29.58	0.00	52.71
1991	11.93	26.11	0.00	46.53

Figure 14: Screenshot of the source-receptor data table provided along with this report, containing contributions from all OSPAR Contracting Parties and other sources in the EMEP model domain to the OSPAR Regions, EEZs and partial EEZs. The example shows SI (Slovenia) and SK (Slovakia) contributions to OSPAR Region IV (OR4). The column 'Annual' is for internal checks only and should not be used.

The data files are sent to the OSPAR secretariat with file names as given above and a version identifier ('v1', 'v2', etc.). Numerous figures are included in the Excel files.

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