OSPAR COMMISSION

Atmospheric Deposition of Nitrogen to the OSPAR Maritime Area in the period 1995-2018

Hazardous Substances and Eutrophication Series

2021

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 of Great Britain and Northern Ireland.

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.

EMEP MSC-W Report for OSPAR

Atmospheric Deposition of Nitrogen to the OSPAR Maritime Area in the period 1995-2018

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Acknowledgements

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Contents

Executive Summary

Nitrogen deposition to the OSPAR Maritime Area for the 24-year period 1995-2018 has been calculated with the EMEP MSC-W Chemistry Transport Model on a horizontal resolution of 0.1 x 0.1 degrees.

Data on annual deposition of nitrogen are provided in this report for each of the 5 OSPAR Regions and the 24 Extended Economic Zones (EEZs), for each year within the trend period 1995-2018. As usual, depositions of nitrogen are calculated separately for oxidised nitrogen (NO, NO_2, etc.) and reduced nitrogen (ammonia, ammonium nitrate, etc.) as these two groups of nitrogen-containing molecules have different emission sources and thus require different policy measures for mitigation.

According to our model results, annual deposition of oxidised nitrogen was clearly lower in 2018 than in 1995 in all OSPAR Regions, with the largest decline in Region V (52.2%). Annual deposition of reduced nitrogen decreased in three out of five OSPAR Regions, but the reductions are much smaller than in the case of oxidised nitrogen. Increases are calculated for OSPAR Regions II and IV. Concerning annual deposition of total (oxidised+reduced) nitrogen, there is a decline between 1995 and 2018 in all Regions (in the range 20.4-41.4%), the largest decline being in Region V.

In all considered EEZs, there is a clear decline in the annual deposition of oxidised nitrogen between 1995 and 2018 (in the range 18.1-57.8%), while the annual deposition of reduced nitrogen was higher in 2018 than in 1995 in 18 EEZs. In 6 EEZs, deposition of reduced nitrogen has decreased as well, by up to 25%. In all considered EEZs, the annual deposition of total nitrogen has decreased from 1995 to 2018 (in the range 3.4-48.4%).

It has to be noted, however, that percentage changes reported here with respect to the reference year 1995 can vary significantly from year to year due to meteorological conditions. This is especially true for the smallest EEZs. Therefore, we have calculated changes in 5-year means as well, allowing for more robust results.

This year, changes with respect to earlier reports have also occurred due to a change in area definitions of OSPAR Regions II and III.

Récapitulatif

Le dépôt d'azote dans la zone maritime OSPAR pour la période de 24 ans 1995-2018 a été calculé à l'aide du modèle de transport de la chimie MSC-W de l'EMEP, avec une résolution horizontale de 0,1 x 0,1 degré.

Les données sur les dépôts annuels d'azote sont fournies dans ce rapport pour chacune des 5 Régions OSPAR et des 24 zones économiques étendues (ZEE), pour chaque année de la période de tendance 1995-2018. Comme d'habitude, les dépôts d'azote sont calculés séparément pour l'azote oxydé (NO, NO2, etc.) et l'azote réduit (ammoniac, nitrate d'ammonium, etc.) car ces deux groupes de molécules contenant de l'azote ont des sources d'émission différentes et nécessitent donc des mesures politiques d'atténuation différentes.

En relation aux résultats de notre modèle, le dépôt annuel d'azote oxydé était nettement plus faible en 2018 qu'en 1995 dans toutes les Régions OSPAR, la baisse la plus importante étant enregistrée dans la Région V (52,2%). Les retombées annuelles d'azote réduit ont diminué dans trois des cinq Régions OSPAR, mais les réductions sont beaucoup plus faibles que dans le cas de l'azote oxydé. Des augmentations sont calculées pour les Régions OSPAR II et IV. En ce qui concerne les dépôts annuels d'azote total (oxydé + réduit), on observe une baisse entre 1995 et 2018 dans toutes les Régions (dans la fourchette 20,4-41,4%), la baisse la plus importante étant dans la Région V.

1 Introduction

Nitrogen deposition to OSPAR Convention Waters has been a subject of a cooperation between MSC-W (Meteorological Synthesizing Centre – West) of EMEP 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.

2 Tasks in 2020

In 2020, OSPAR requested data on atmospheric nitrogen deposition (oxidised, reduced and total) to the five OSPAR Regions, as well as to the twenty-four Exclusive Economic Zones (EEZ), for the period 1995 to 2018. If feasible, this period should be extended backward to 1990.

The work this year also included an update of the boundary between OSPAR Regions II and III.

Additional products, such as normalised depositions and source-receptor matrices, have not been requested this year. These were last provided by Bartnicki et al. (2018) for the period 1995 to 2015.

3 Modelling

3.1 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 (see Simpson et al., 2020, and references therein).

The model is regularly evaluated against measurements from the EMEP network under the LRTAP convention (e.g. Gauss et al., 2019; 2020), but also in a large number of international research projects and operational services, for example in the Copernicus Atmosphere Monitoring Service (CAMS, see http://www.regional.atmosphere.copernicus.eu/), where evaluation graphs are updated every day and quarterly evaluation reports are issued online on a quarterly basis.

As in every model, deviations between model and observations do occur and are highly variable both in space and time, and these are subject of 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 model results and activities is further ensured by the availability of the EMEP 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.

3.2 Experimental setup

The meteorological data for the entire trend period 1995-2018 have been generated by running the ECMWF IFS model cycle 40r1 (see ECMWF model documentation). Emission data for the 1995-2017 period were obtained in June 2019 from the EMEP Centre CEIP and listed in the EMEP Status Report 1/2019 (EMEP, 2019). For the first time in 2019, emission data were delivered on 0.1°×0.1° resolution for the entire period of 1995-2017. However, for some countries, PM emissions were not submitted for the 1990s. Therefore, for the EMEP MSC-W simulations of 1995-1999, PM emissions of 2000 were used for these countries, while all other

emissions were used as reported for 1995-1999. As the importance of PM emissions for nitrogen depositions in the OSPAR Regions are negligible, this methodology was considered as justifiable in this case, as the calculation for OSPAR are exclusively concerned with nitrogen depositions. The period 1990 to 1994 was not simulated due to the high computational cost and (given the absence of PM emissions for some countries) the absence of synergies with other projects.

Emission data for 2018 were obtained in June 2020 from the EMEP Centre CEIP and listed in the EMEP Status Report 1/2020 (EMEP, 2020). As emission data for historical years (1995-2017) were not updated this year, the EMEP MSC-W model was not rerun for 1995-2017, i.e. new simulations were made only for 2018. Results for the 1995-2017 period are thus based on EMEP MSC-W model version rv4.33 (documented and evaluated in EMEP Status report 1/2019), while results for 2018 are based on EMEP MSC-W model version rv4.34 (documented and evaluated in EMEP Status report 1/2020). Differences between these two model versions in regard to nitrogen deposition are assumed to be negligible.

The model was run within the longitude-latitude domain outlined in green in Figure 1.

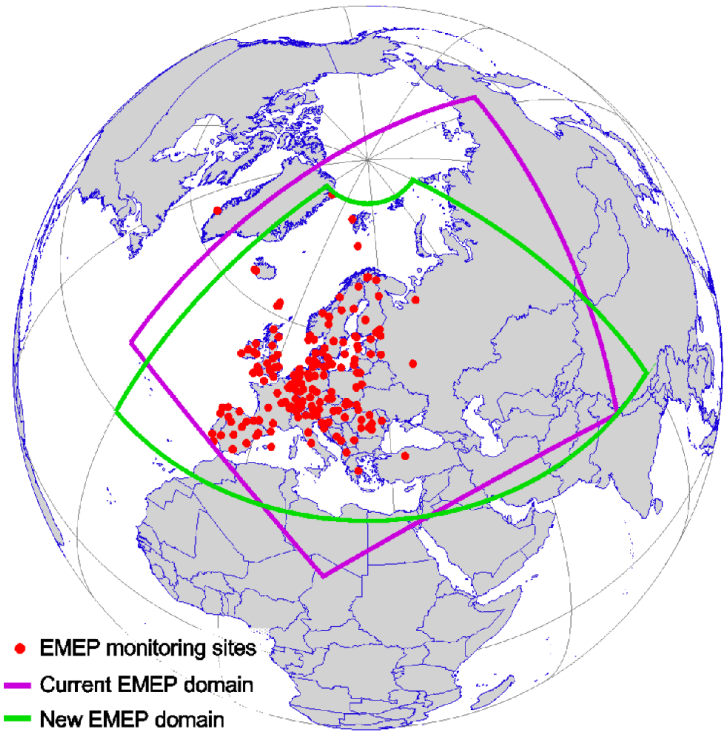


Figure 1: *The old (purple) and new (green) official EMEP domains. The new domain was used for the first time for the EMEP status runs in 2017 (EMEP, 2017), and has 0.1°×0.1° resolution in a regular longitude-latitude grid. All calculations for this report were done on the new official EMEP domain on 0.1°×0.1° resolution.*

4 OSPAR Regions and EEZs in the EMEP model grid

Depositions are calculated for 5 OSPAR Regions and for 24 Exclusive Economic Zones (EEZ). However, some areas are not fully covered by the EMEP model domain (Figure 1), as for example OSPAR Regions I and V, and EEZ 48. In this chapter, all OSPAR Regions and EEZs considered in this report are plotted in the way they are included in the EMEP model domain.

4.1 OSPAR Regions

All OSPAR Regions cover a certain number of grid cells in the EMEP grid system, either in full or only partly. We have calculated this percentage for each EMEP grid square covered by each OSPAR Region. The results are illustrated in Figure 2 for the 0.1°×0.1° longitude-latitude grid.

The border between OSPAR Regions II and III was redefined this year on request from OSPAR (Figures 2b and 2c show both the old and new definitions). In particular, parts of the waters off the northern coast of France now belong to OSPAR Region III rather than OSPAR Region II. This change was implemented in EMEP MSC-W's analysis routines and necessitated a recalculation of depositions backward in time. This explains the differences in depositions for OSPAR Regions II and III between this year's and last year's reports. More specifically, the depositions in OSPAR Region III are somewhat larger (and those in OSPAR Region II correspondingly smaller) than in the 2019 report.

Table 1 lists the OSPAR Regions and their areas within the EMEP model domain, calculated on the 0.1°×0.1° longitude-latitude grid.

Table 1: *The five OSPAR Regions as implemented in the EMEP MSC-W analysis in the 0.1°×0.1° longitude-latitude grid*.

Region	EMEP ID	Area covered by the EMEP model domain
OSPAR Region I	CC_451	4.34e6 km^2 (out of 5.53e6 km^2)
OSPAR Region II	CC_452	Fully covered
OSPAR Region III	CC_453	Fully covered
OSPAR Region IV	CC_454	Fully covered
OSPAR Region V	CC_455	4.08e6km^2 (of 6.35e6 km^2)

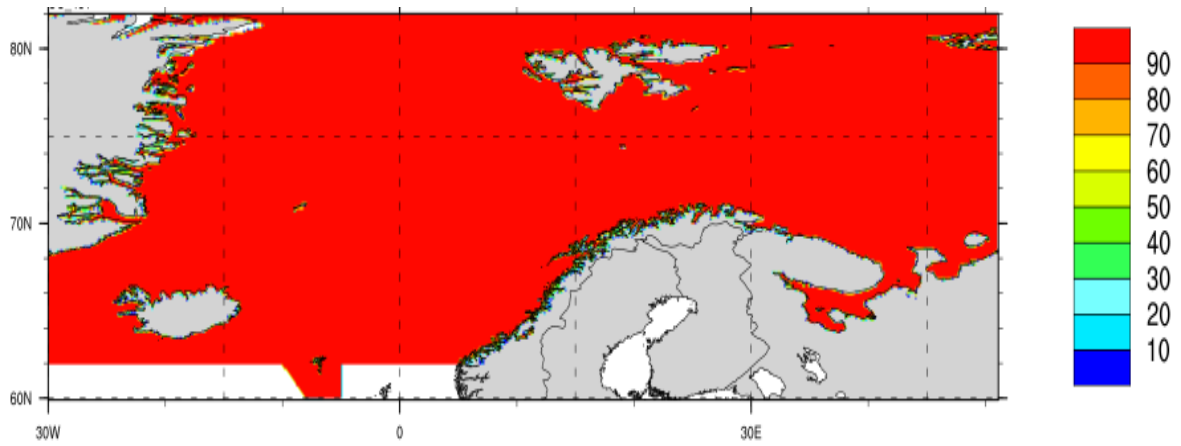


Figure 2a: *Visualisation of OSPAR Region I in the EMEP grid. The plot shows how large a percentage of each EMEP model grid cell lies within OSPAR Region I. EMEP model grid cells are only 0.1°×0.1° large (longitude-latitude), and thus appear very small in this plot. Red colour means that the model grid cell is fully within OSPAR Region I. Other colours mean that the grid cell is only partly within OSPAR Region I. OSPAR Region I is not fully covered by the EMEP model domain; it is cut at 30°W, which is the western boundary of the EMEP model domain (and this plot) and at 82°N, which is the northern boundary of the EMEP model domain (and this plot*).

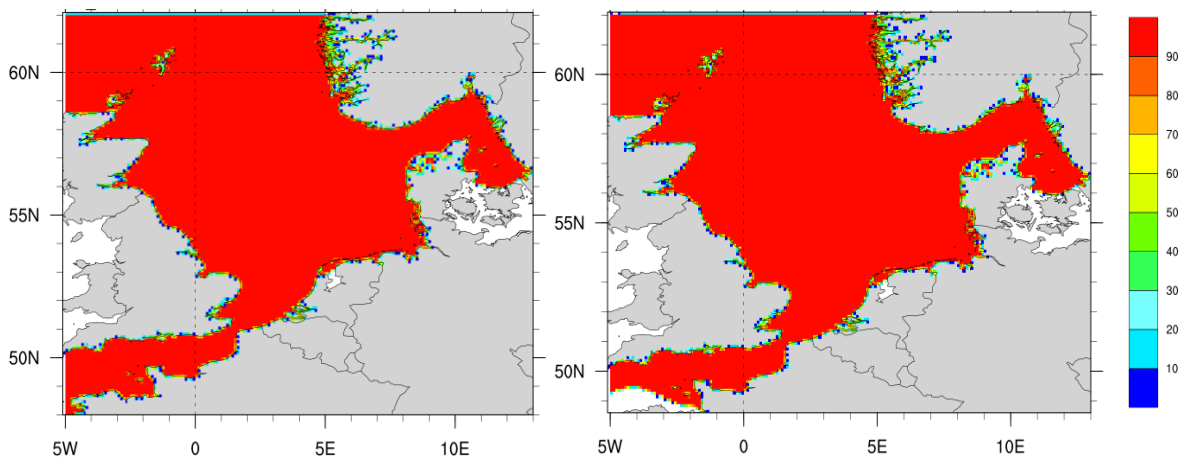


Figure 2b: *As Figure 2a, but for OSPAR Region II. Left panel: old definition (used in 2019 report), right panel: new definition (used in this report*).

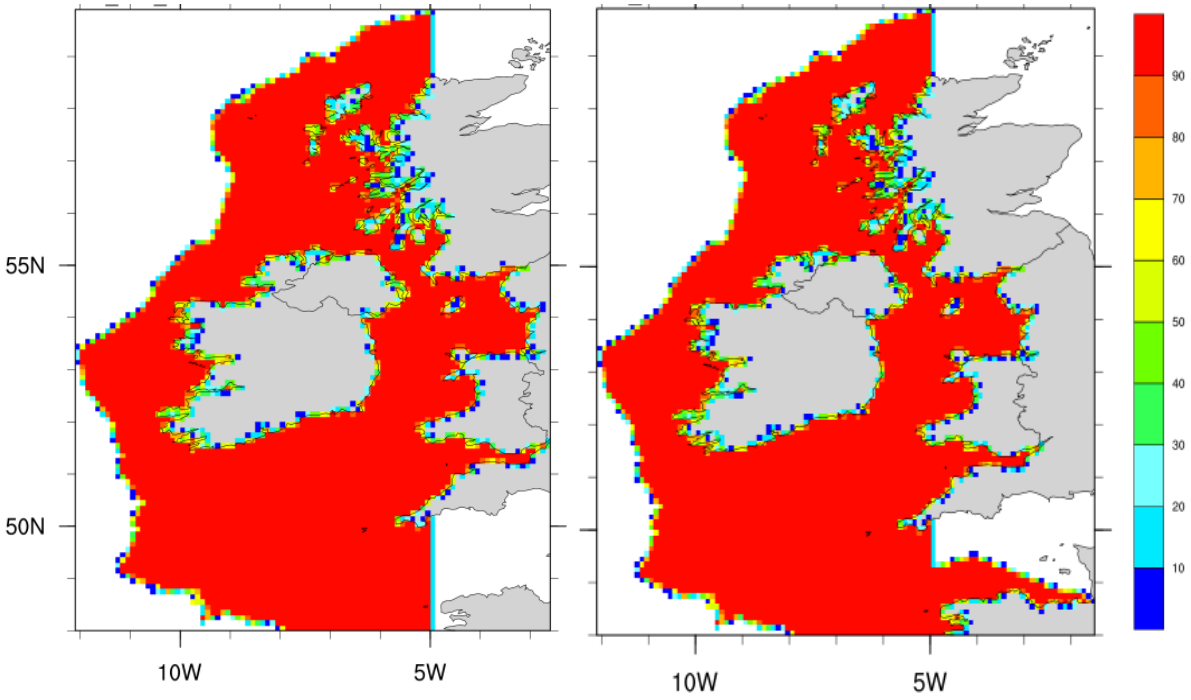


Figure 2c: *As Figure 2b, but for OSPAR Region III*.

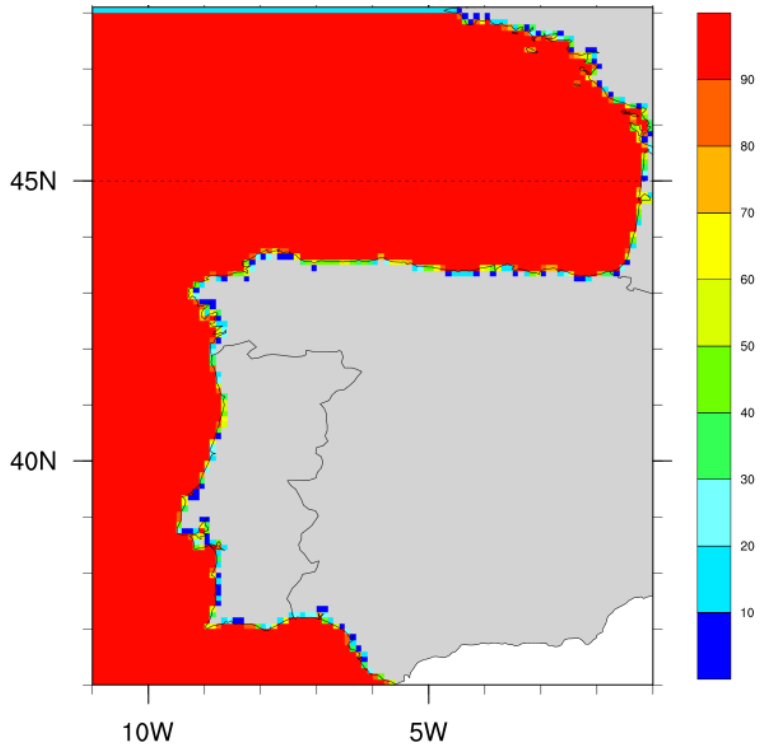


Figure 2d: *As Figure 2a, but for OSPAR Region IV*.

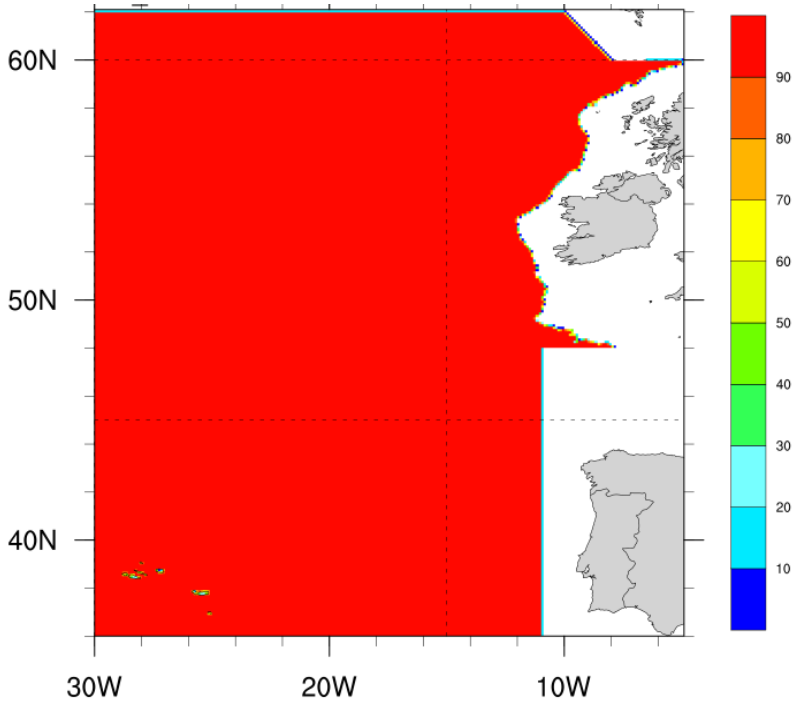


Figure 2e: *As Figure 2a, but for OSPAR Region V.*

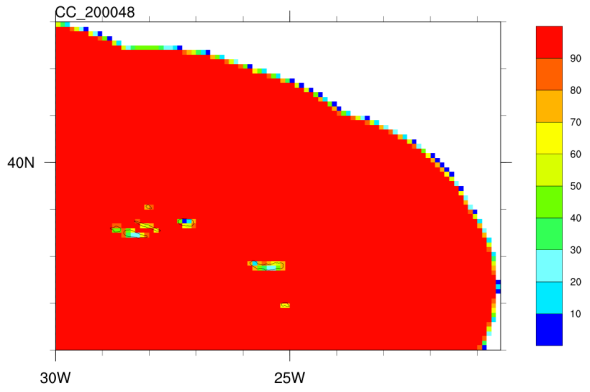
4.2 Exclusive Economic Zones

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 area were implemented in the EMEP grid. Table 2 lists the regions and their areas within the EMEP model domain, calculated on the 0.1°×0.1° longitude-latitude grid. The percentages of EMEP grids covered by each of the selected EEZ are shown in Figure 3. In the case of EEZs that cross OSPAR region borders, the analyses in this report consider the whole EEZ, and not separately the parts belonging to different OSPAR regions.

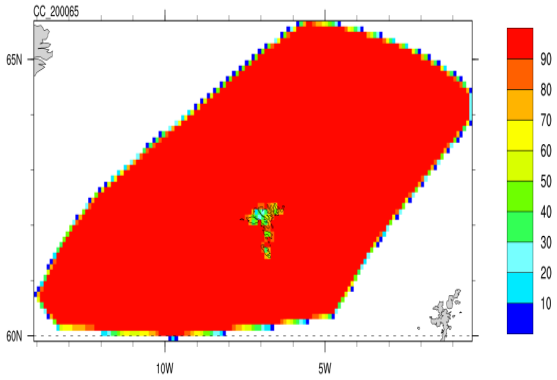
Table 2: *The twenty-four Extended Economic Zones implemented in the EMEP MSC-W analysis in the 0.1°×0.1° longitude-latitude grid. Areas listed here include only the parts that are located within the OSPAR Convention area (i.e. within OSPAR regions). For example, those parts of the French and Spanish 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 access 13 Feb 2021), showing the entire EEZs' definitions*.

Number EEZ	Name	EMEP ID	Area in the EMEP MSC-W model domain (km^2)
EEZ 48	Portuguese Exclusive Economic Zone (Azores)	CC_200048	4.89E+05
EEZ 65	Faeroe Exclusive Economic Zone	CC_200065	2.64E+05
EEZ 71	Icelandic Exclusive Economic Zone	CC_200071	7.55E+05
EEZ 91	Portuguese Exclusive Economic Zone	CC_200091	2.71E+05
EEZ 99	Joint regime area Spain / France	CC_200099	3.02E+03
EEZ 100	Joint regime area UK / Denmark (Faeroe Islands)	CC_200100	8.33E+03
EEZ 108	Irish Exclusive Economic Zone	CC_200108	4.29E+05
EEZ 109	Guernsey Exclusive Economic Zone	CC_200109	6.76E+03
EEZ 110	Jersey Exclusive Economic Zone	CC_200110	2.40E+03
EEZ 119	Joint regime area Iceland / Denmark (Faeroe)	CC_200119	1.42E+03
EEZ 123	Joint regime area Iceland / Norway (Jan Mayen)	CC_200123	4.53E+04
EEZ 185	Swedish Exclusive Economic Zone	CC_200185	1.46E+04
EEZ 187	Joint regime area Sweden / Norway	CC_200187	1.72E+02
EEZ 188	Belgian Exclusive Economic Zone	CC_200188	3.63E+03
EEZ 189	Dutch Exclusive Economic Zone	CC_200189	6.33E+04
EEZ 190	German Exclusive Economic Zone	CC_200190	4.18E+04
EEZ 191	Danish Exclusive Economic Zone	CC_200191	7.64E+04
EEZ 209	French Exclusive Economic Zone	CC_200209	2.59E+05
EEZ 212	Greenlandic Exclusive Economic Zone	CC_200212	6.42E+05
EEZ 213	United Kingdom Exclusive Economic Zone	CC_200213	7.40E+05
EEZ 215	Svalbard Exclusive Economic Zone	CC_200215	7.04E+05
EEZ 216	Norwegian Exclusive Economic Zone	CC_200216	9.45E+05
EEZ 224	Jan Mayen Exclusive Economic Zone	CC_200224	2.91E+05
EEZ 273	Spanish Exclusive Economic Zone	CC_200273	3.01E+05

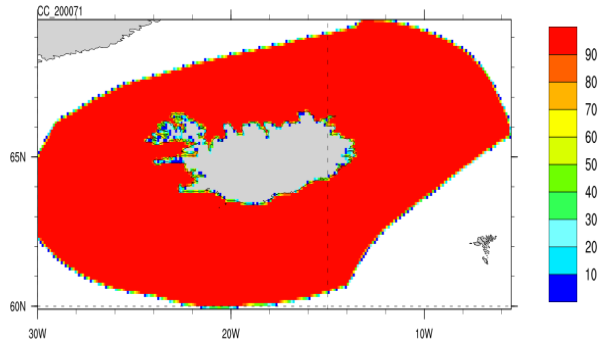
EEZ 48: Portuguese EEZ (Azores)



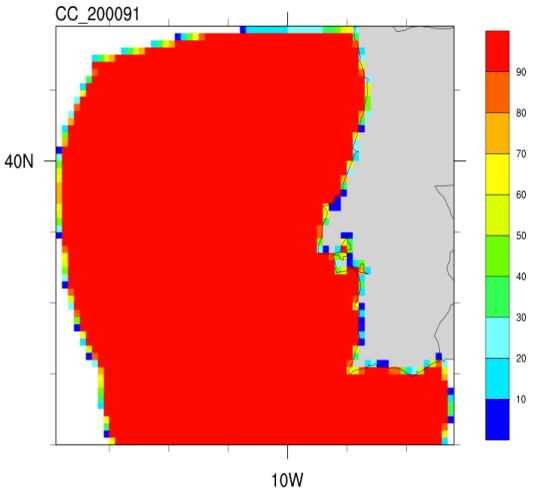
EEZ 65: Faeroe EEZ



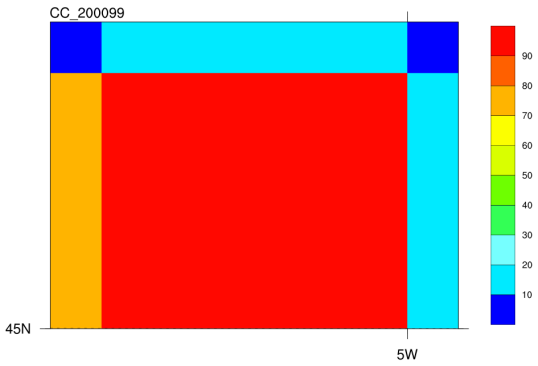
EEZ 71: Icelandic EEZ



EEZ 91: Portuguese EEZ



EEZ 99: Joint regime area Spain / France



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

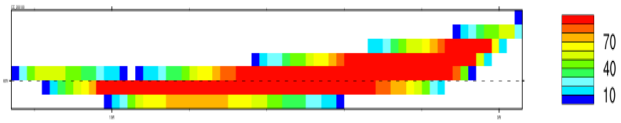
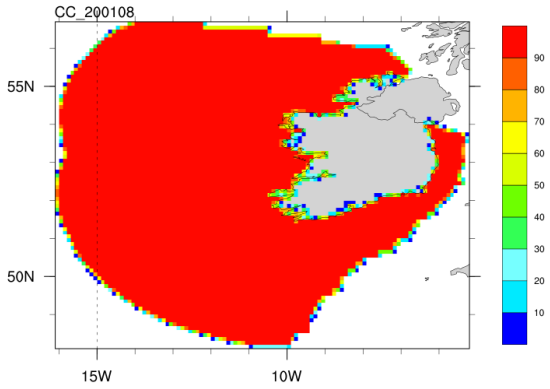
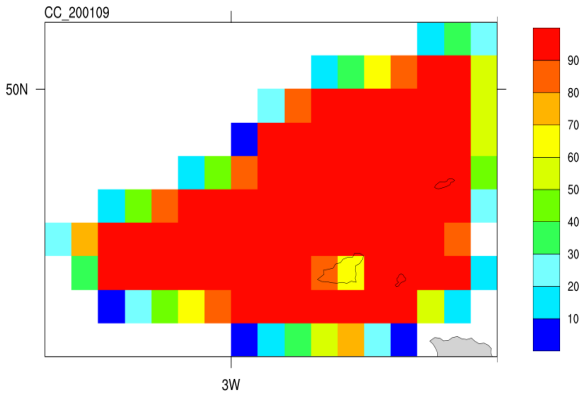


Figure 3: *Visualisation of EEZs in the EMEP grid. The plots show how large a percentage of each EMEP model grid cell lies within the respective EEZ. EMEP model grid cells are 0.1°×0.1° large (longitude-latitude), and appear very small in some of the plots. Red colour means that the model grid cell is fully within the EEZ. Other colours mean 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).*

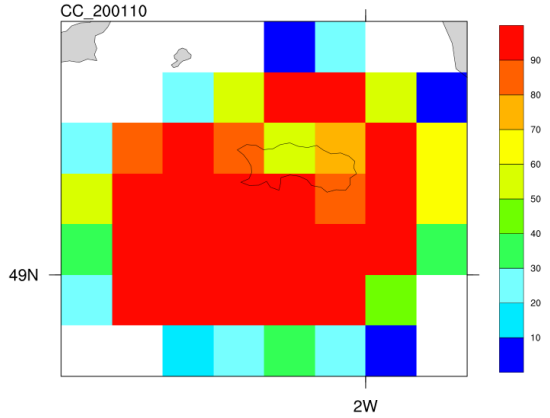
EEZ 108: Irish EEZ



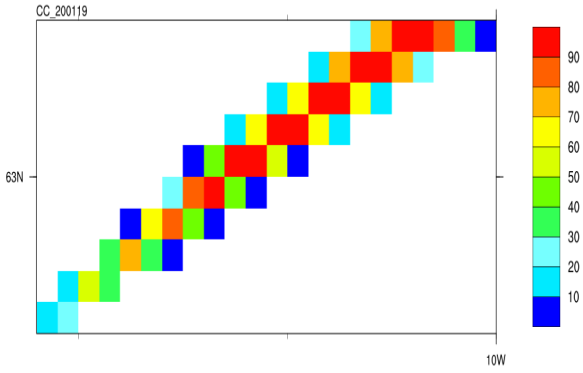
EEZ 109: Guernsey EEZ



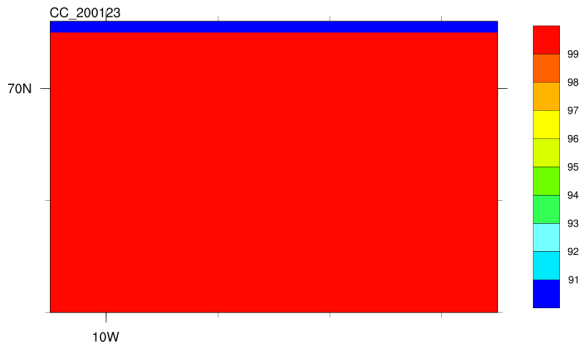
EEZ 110: Jersey EEZ



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



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



EEZ 185: Swedish EEZ

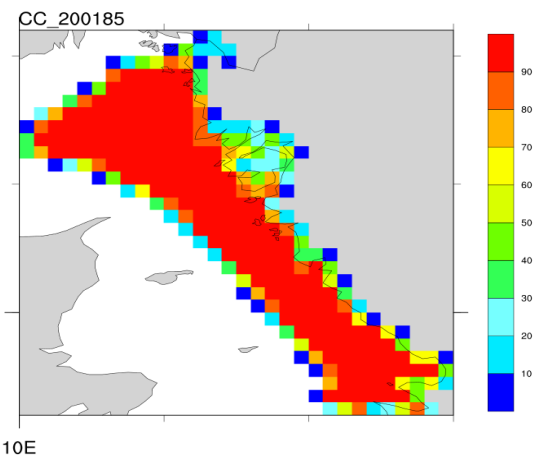
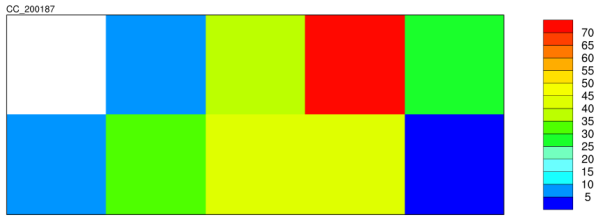
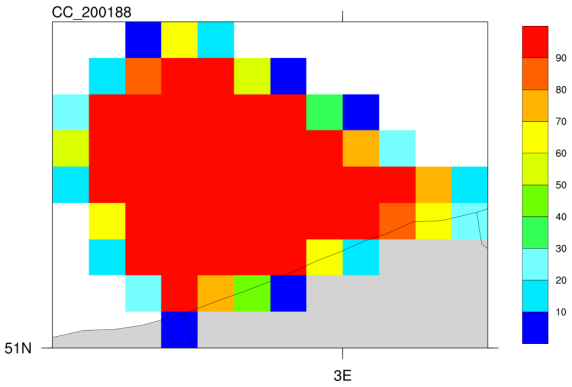


Figure 3: *(continued)*

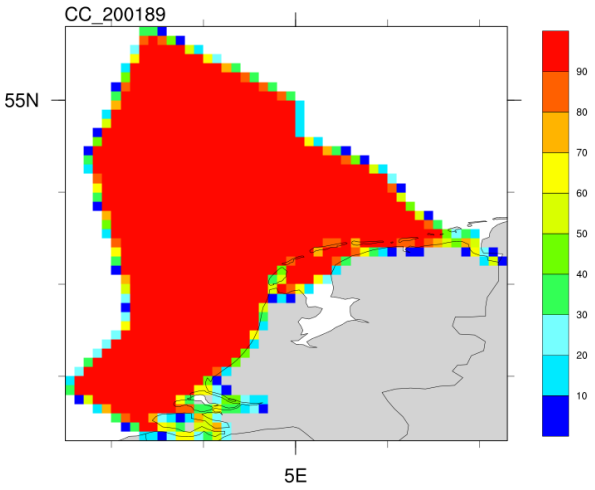
EEZ 187: Joint regime area Sweden / Norway



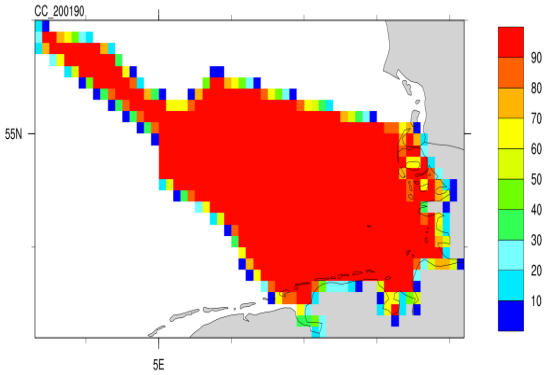
EEZ 188: Belgian EEZ



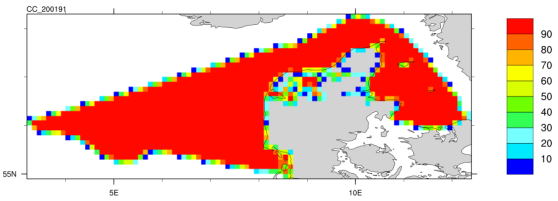
EEZ 189: Dutch EEZ



EEZ 190: German EEZ



EEZ 191: Danish EEZ



EEZ 209: French EEZ

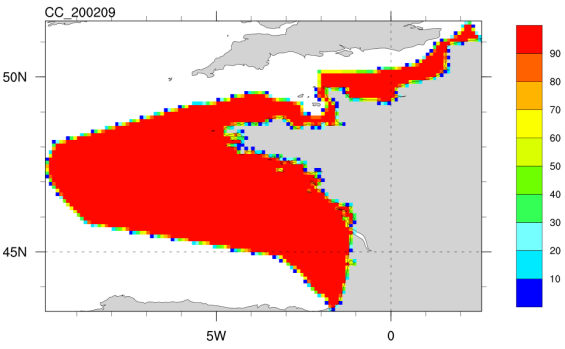
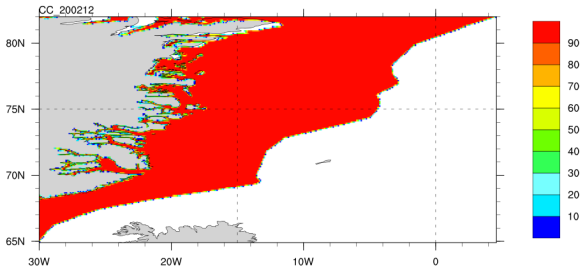
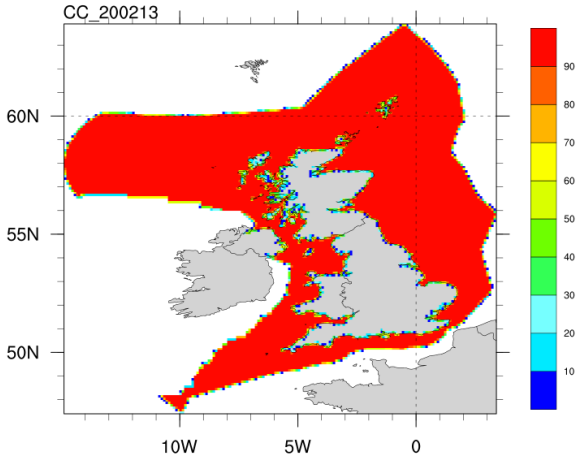


Figure 3: *(continued)*

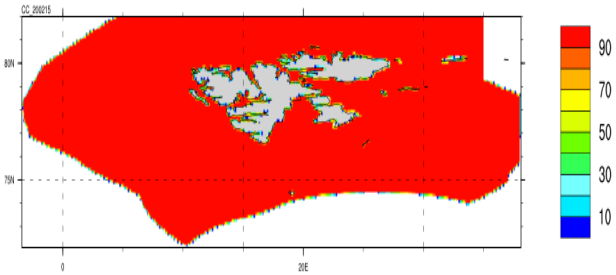
EEZ 212: Greenlandic EEZ



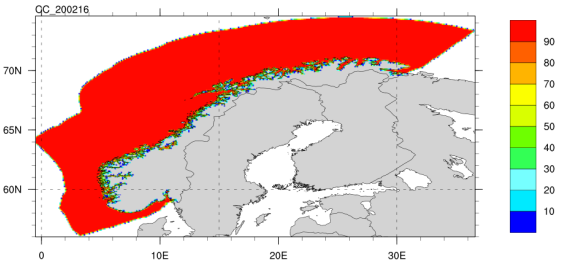
EEZ 213: United Kingdom EEZ



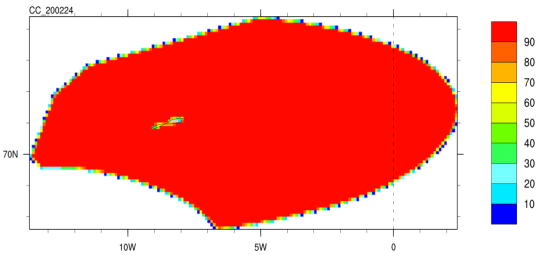
EEZ 215: Svalbard EEZ



EEZ 216: Norwegian EEZ



EEZ 224: Jan Mayen EEZ



EEZ 273: Spanish EEZ

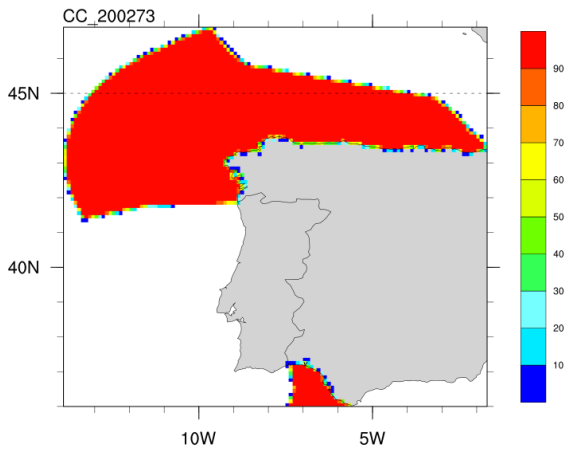


Figure 3: *(continued)*

5 Annual atmospheric depositions to OSPAR Regions

All results have been provided to OSPAR in a separate file in Excel format. Table 3 only lists the percentage differences between 1995 and 2018, and between the two 5-year periods of 1995-1999 and 2014-2018. Due to the large inter-annual variability in meteorological conditions, differences between depositions in one year with respect those in one reference year (1995 in this case) can change considerably from year to year. Therefore, 5-year averages are calculated to provide a more robust result for the changes since the 1990s.

Annual depositions of oxidised nitrogen and reduced nitrogen have clearly decreased since the 1990s. The only exception is reduced nitrogen deposition in OSPAR Regions II and IV. However, the 2014-2018 average is lower than the 1995-1999 average also in this case.

Figure 4 shows the entire 24-year time series of nitrogen deposition for all OSPAR Regions.

Table 3: *Percentage differences in 2018 compared to 1995 for oxidised, reduced and total nitrogen, in the five OSPAR Regions. Also shown are the percentage differences between the 5-year periods of 2014-2018 and 1995-1999.*

OSPAR Region	Oxidised N		Reduced N		Total N	
	1995→2018	(1995-1999) →(2014-2018)	1995→2018	(1995-1999) →(2014-2018)	1995→2018	(1995-1999) →(2014-2018)
I	-36 %	-41 %	-11 %	-17 %	-30 %	-35 %
II	-39 %	-39 %	20 %	-2 %	-20 %	-27 %
III	-51 %	-52 %	-9 %	-15 %	-36 %	-39 %
IV	-40 %	-44 %	8 %	-4 %	-26 %	-32 %
V	-52 %	-52 %	-8 %	-15 %	-41 %	-43 %

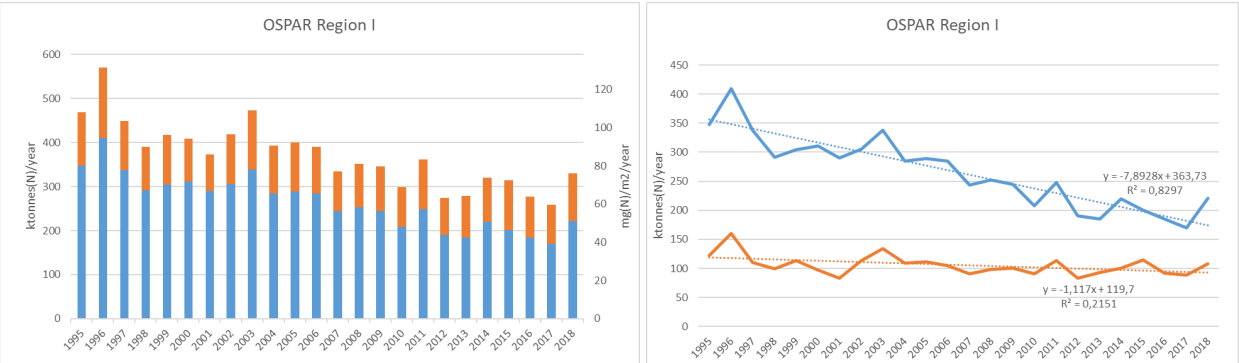


Figure 4a: *Left panel: Time series of annual depositions of oxidised (blue), reduced (red) and total nitrogen (sum of blue and red) to OSPAR Region I, as calculated by the EMEP MSC-W model for the period 1995-2018. Unit: ktonnes(N)/year (left axis) or mg(N)/m^2/year (right axis). Right panel: Linear regression for oxidised (blue) and reduced (red) nitrogen deposition, with coefficients of determination (R^2) indicated in the figure.*

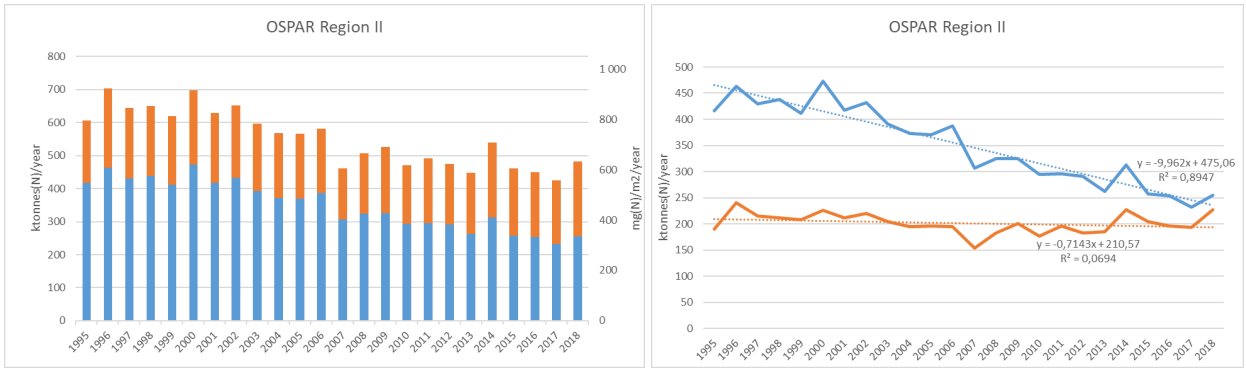


Figure 4b: *As Figure 4a, but for OSPAR region II.*

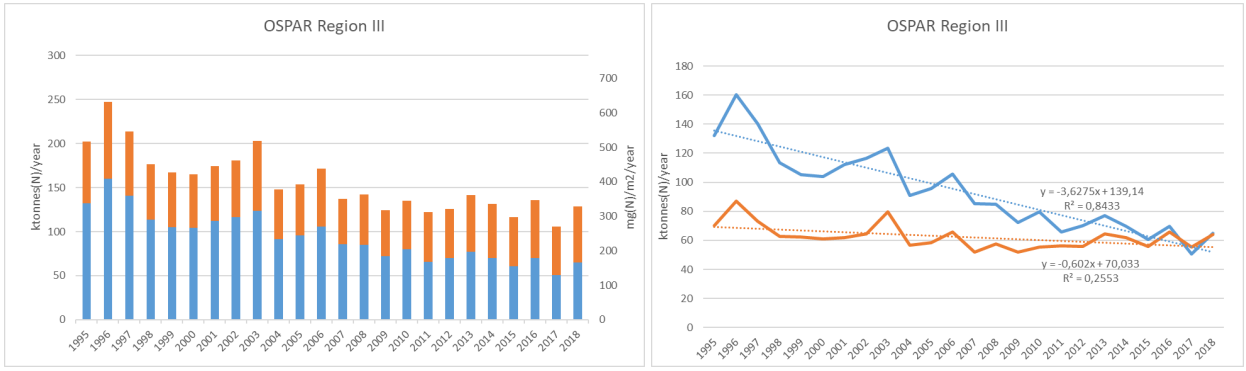


Figure 4c: *As Figure 4a, but for OSPAR region III.*

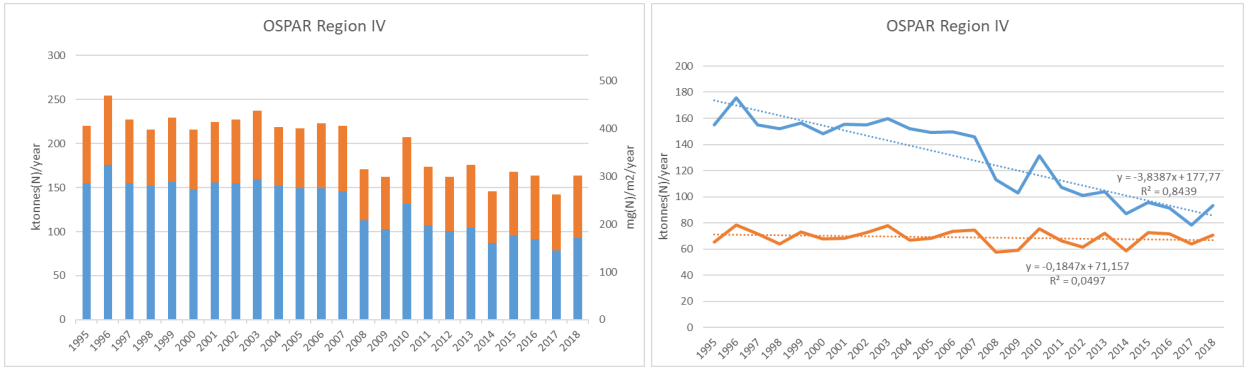


Figure 4d: *As Figure 4a, but for OSPAR region IV.*

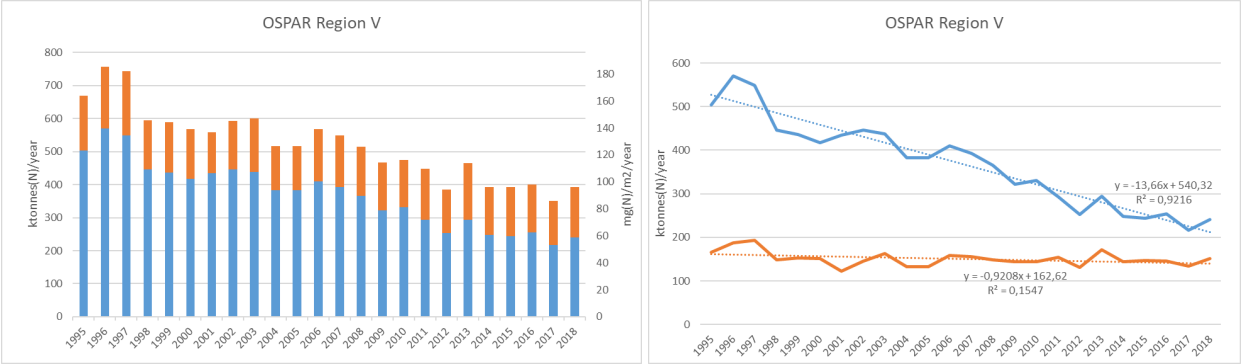


Figure 4e: *As Figure 4a, but for OSPAR region V.*

6 Annual atmospheric depositions to EEZs

Annual atmospheric nitrogen depositions have been computed for each of the twenty-four Extended Economic Zones, for each year of the period 1995-2018. All results are provided in a separate file in Excel format. Table 4 lists the percentage differences between 1995 and 2018, and between the two 5-year periods of 1995-1999 and 2014-2018.

There is clear decline in the deposition of oxidised nitrogen between 1995 and 2018 in all considered EEZs. The deposition of reduced nitrogen was larger in 2018 than in 1995 in many of the EEZs. Again, one has to 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 in reduced nitrogen deposition is much smaller than that of oxidised nitrogen deposition.

Table 4: *Percentage differences in 2018 compared to 1995 for oxidised, reduced and total nitrogen, in the twenty-four Extended Economic Zones. Also shown are the percentage differences in the 5-year period 2014-2018 with respect to the 5-year period of 1995-1999.*

EEZ	**Oxidised N**		**Reduced N**		**Total N**	
	1995→2018	**(1995-1999) →(2014-2018)**	**1995→2018**	**(1995-1999) →(2014-2018)**	**1995→2018**	**(1995-1999) →(2014-2018)**
EEZ 48	-58 %	-53 %	-20 %	-17 %	-48 %	-44 %
EEZ 65	-37 %	-45 %	4 %	-24 %	-27 %	-39 %
EEZ 71	-34 %	-45 %	17 %	-10 %	-21 %	-36 %
EEZ 91	-31 %	-35 %	19 %	6 %	-20 %	-26 %
EEZ 99	-41 %	-48 %	18 %	-4 %	-23 %	-34 %
EEZ 100	-42 %	-46 %	-6 %	-26 %	-33 %	-41 %
EEZ 108	-54 %	-55 %	-12 %	-19 %	-42 %	-44 %
EEZ 109	-41 %	-45 %	18 %	-4 %	-22 %	-31 %
EEZ 110	-48 %	-47 %	10 %	0 %	-26 %	-28 %
EEZ 119	-20 %	-37 %	34 %	-12 %	-7 %	-31 %
EEZ 123	-18 %	-39 %	46 %	-10 %	-3 %	-32 %
EEZ 185	-34 %	-34 %	1 %	-4 %	-22 %	-23 %
EEZ 187	-33 %	-35 %	-7 %	-9 %	-25 %	-26 %
EEZ 188	-44 %	-40 %	19 %	-6 %	-19 %	-26 %
EEZ 189	-43 %	-40 %	23 %	1 %	-21 %	-26 %
EEZ 190	-40 %	-34 %	21 %	9 %	-18 %	-17 %
EEZ 191	-32 %	-33 %	20 %	1 %	-14 %	-20 %
EEZ 209	-45 %	-48 %	5 %	-5 %	-28 %	-33 %
EEZ 212	-36 %	-45 %	7 %	-12 %	-25 %	-36 %
EEZ 213	-44 %	-45 %	11 %	-8 %	-27 %	-34 %
EEZ 215	-44 %	-44 %	-25 %	-14 %	-39 %	-36 %
EEZ 216	-37 %	-39 %	-2 %	-19 %	-27 %	-34 %
EEZ 224	-29 %	-40 %	10 %	-18 %	-20 %	-35 %
EEZ 273	-39 %	-44 %	13 %	-5 %	-24 %	-32 %

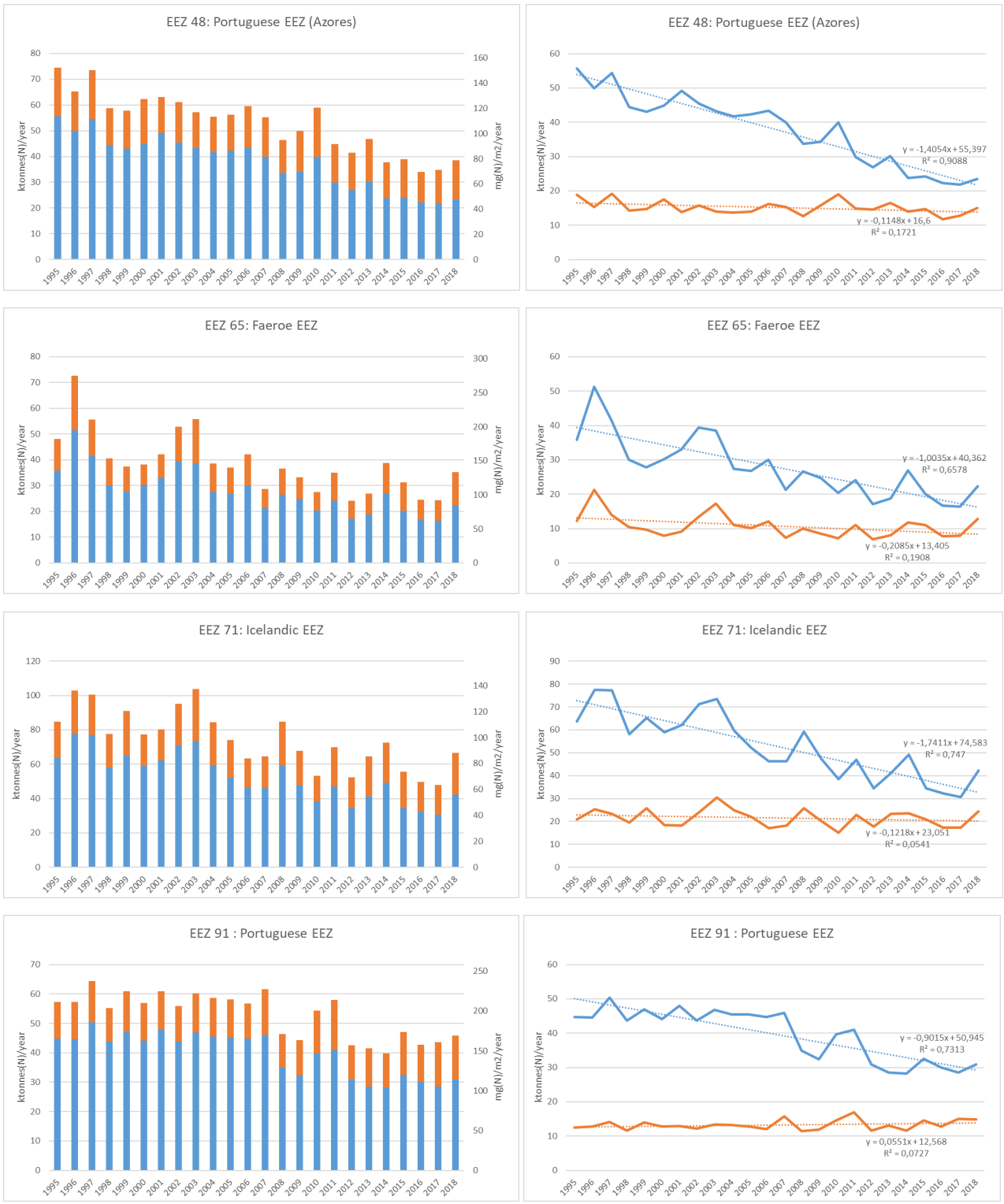
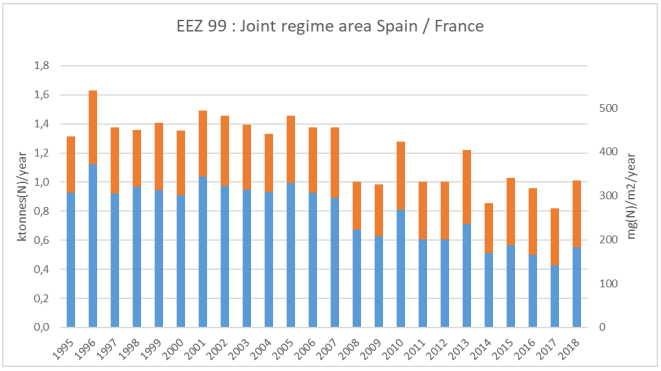
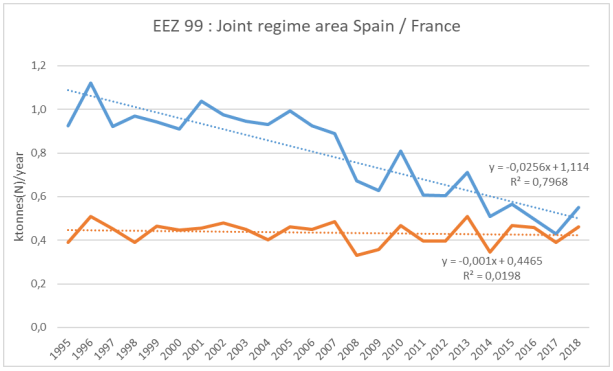
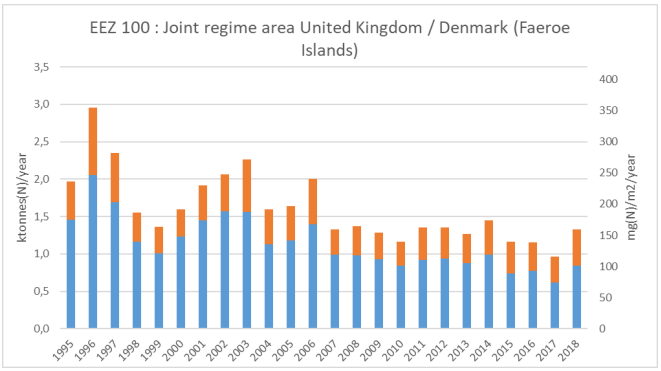
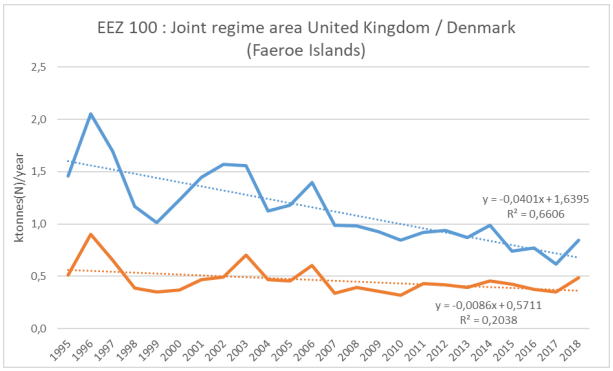


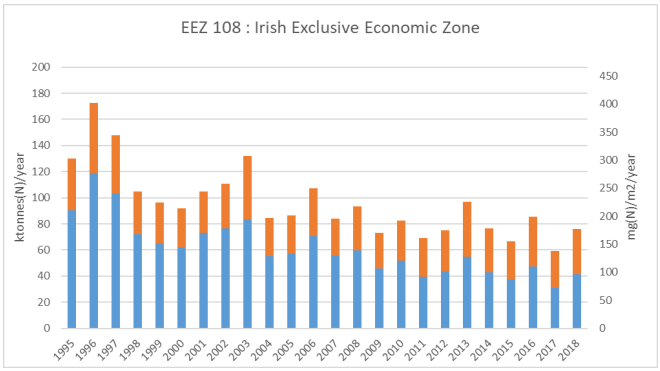
Figure 5: *Left panels: Time series of annual depositions of oxidised (blue), reduced (red) and total nitrogen (sum of blue and red) to selected EEZs, as calculated by the EMEP MSC-W model for the period 1995-2018. Unit: ktonnes(N)/year (left axis) or mg(N)/m^2/year (right axis). Right panel: Linear regression for oxidised (blue) and reduced (red) nitrogen deposition, with coefficients of determination (R^2) indicated in the figure.*

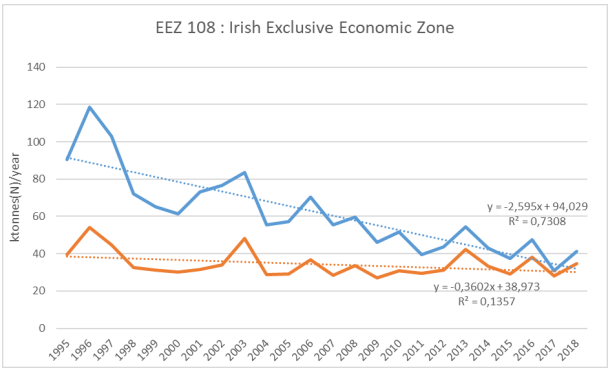


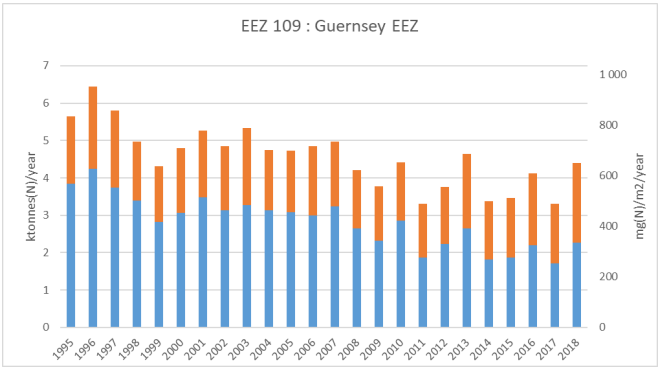


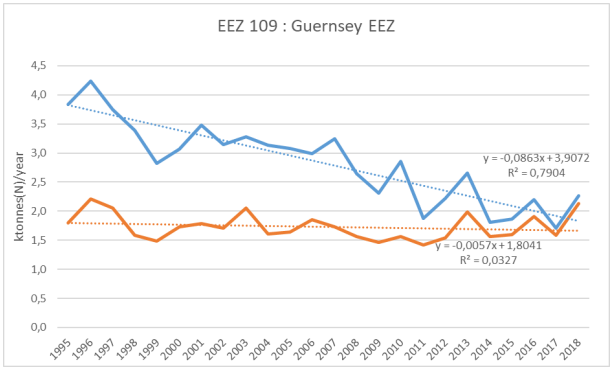












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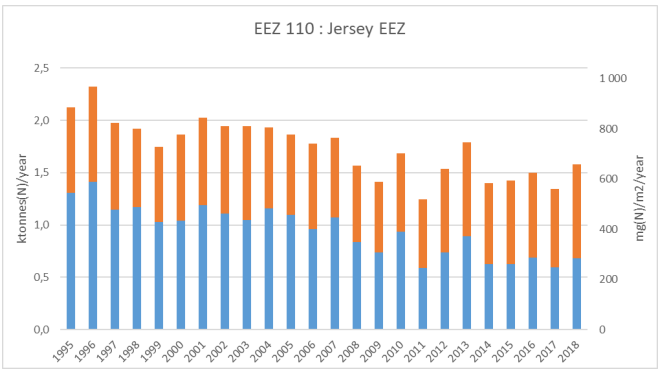

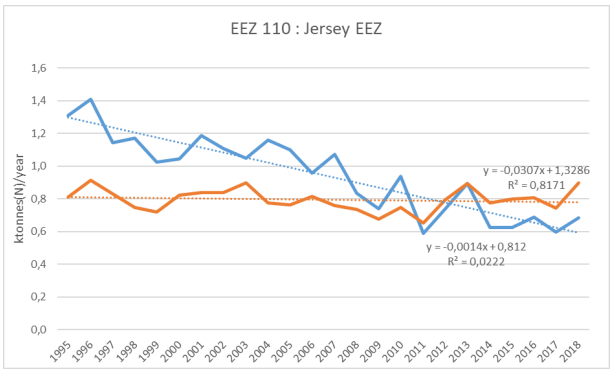

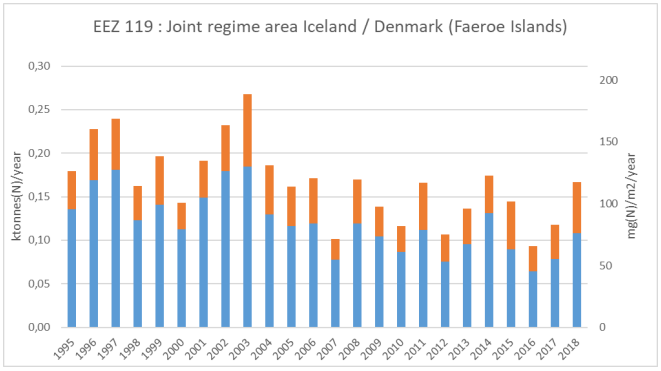

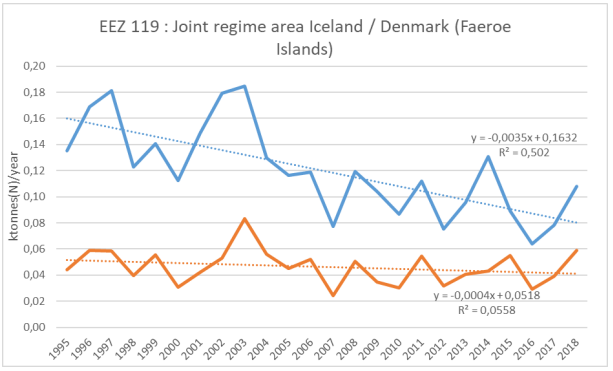

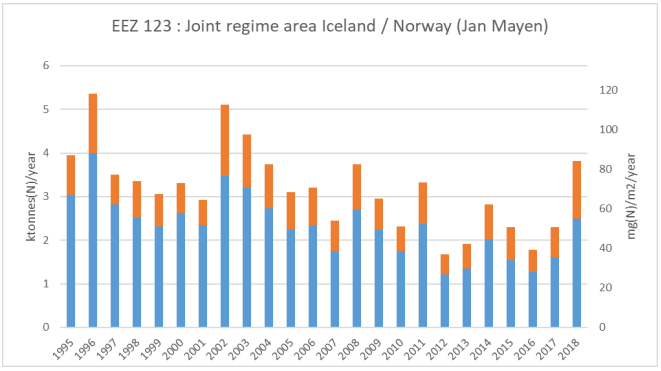

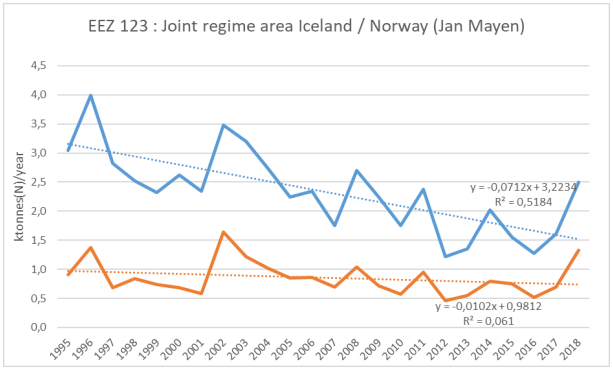

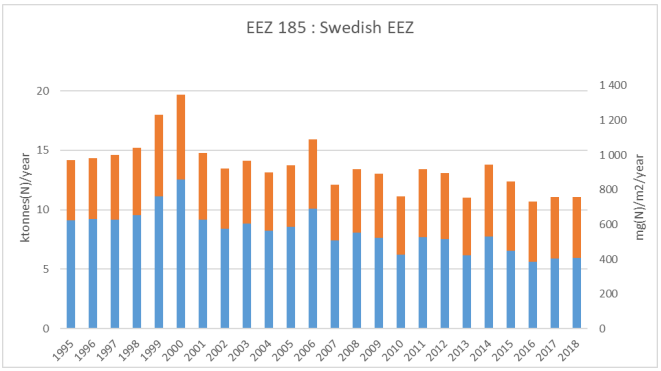

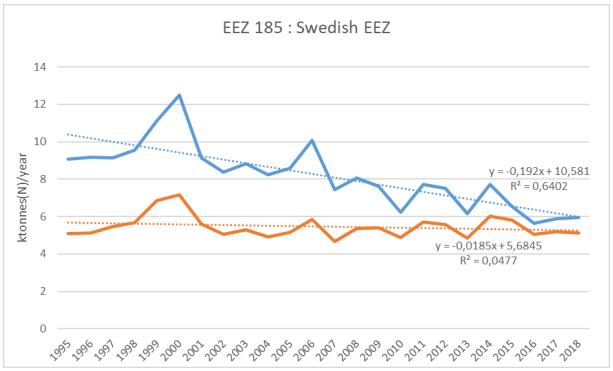

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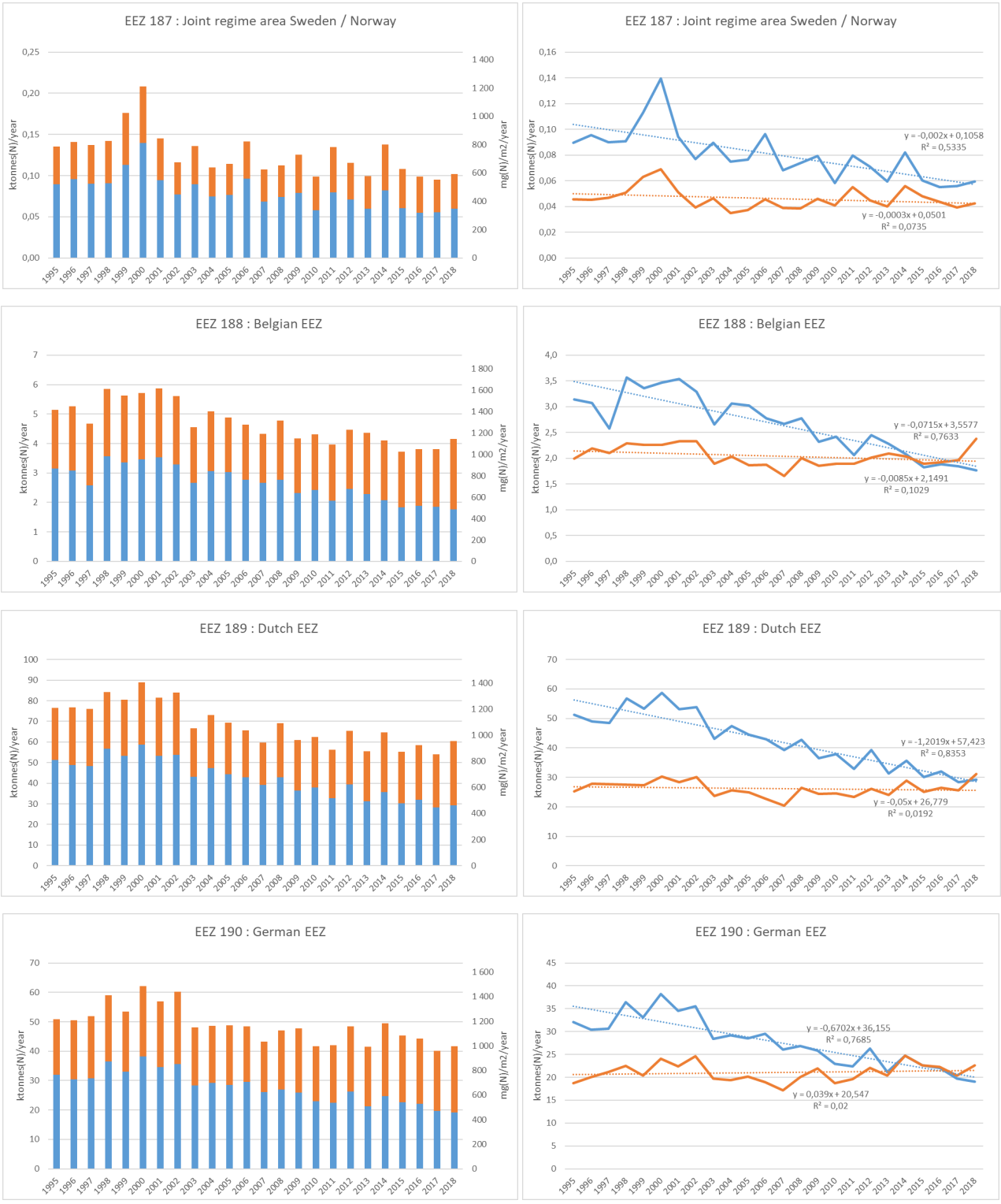

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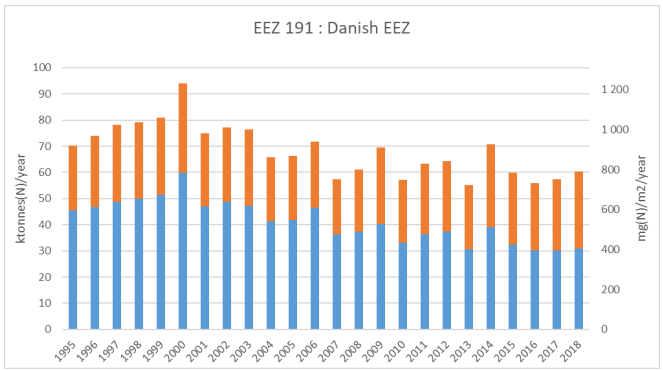

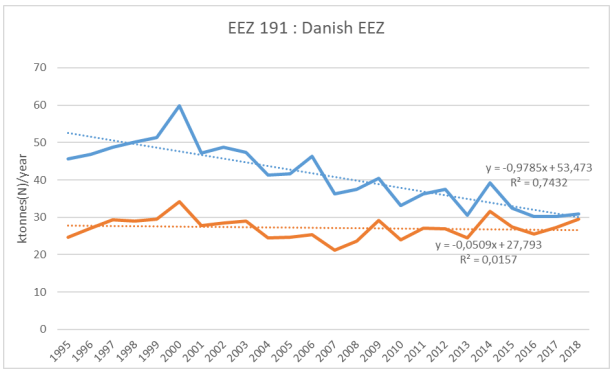

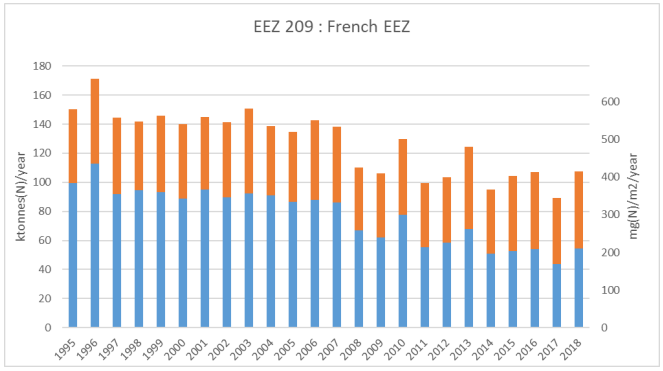

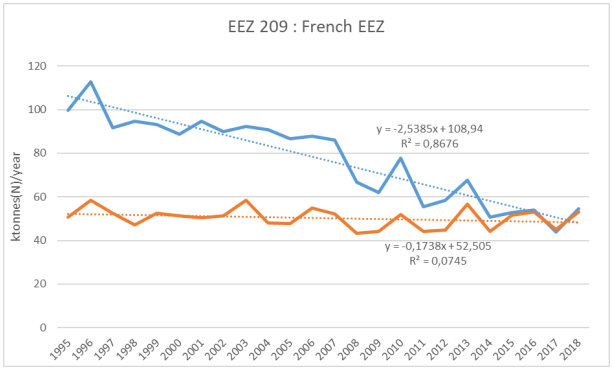

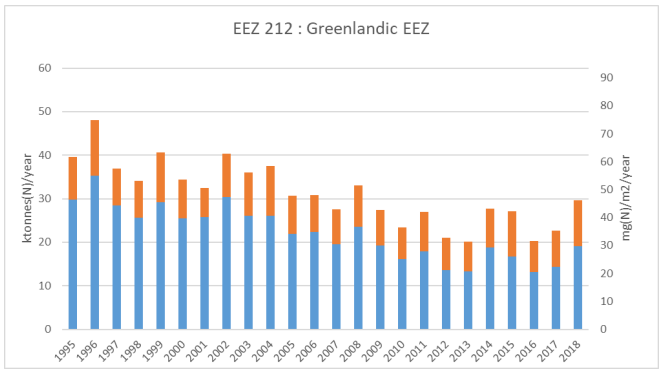

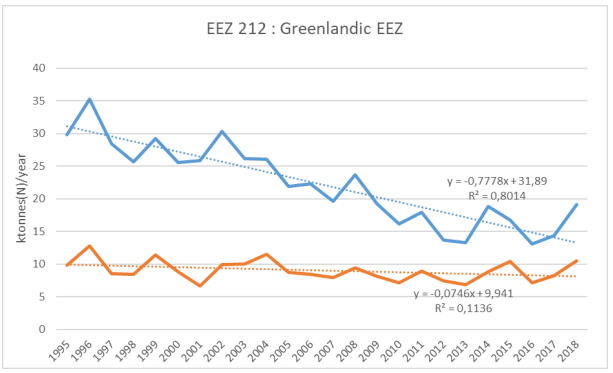

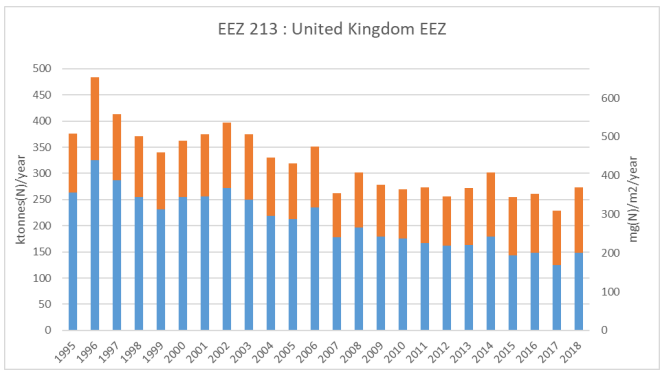

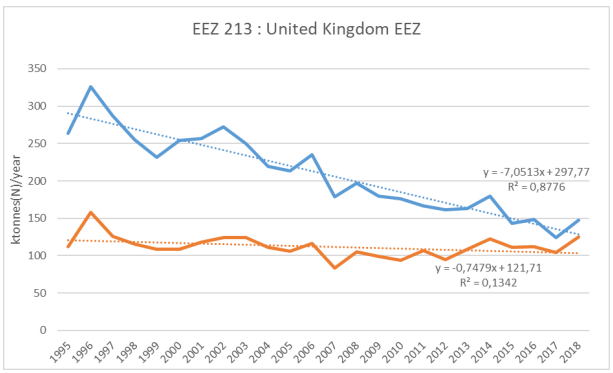

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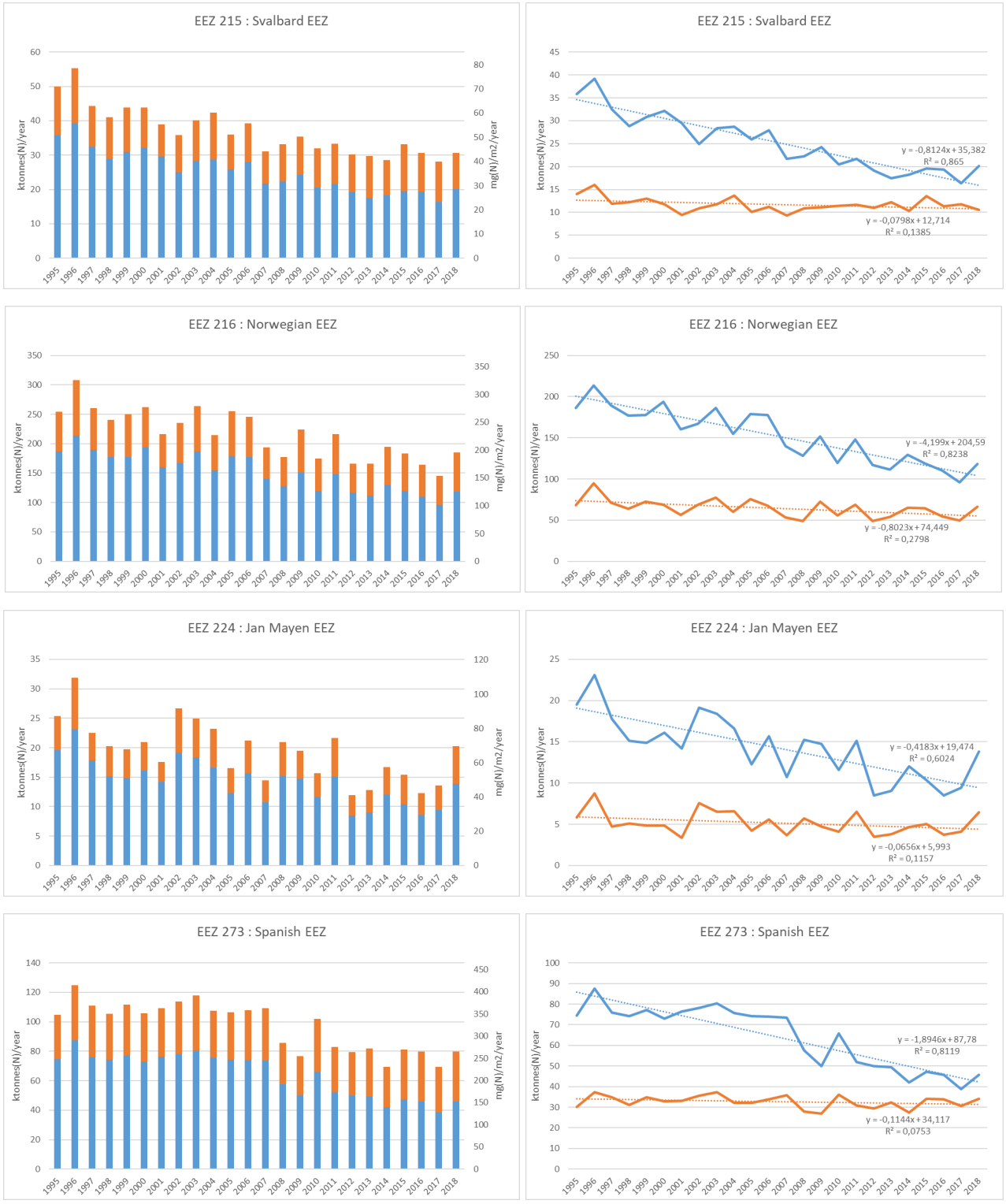

Figure 5: *(continued)*

7 Conclusions

The main outcome from this work can be summarised:

- The areas of OSPAR Regions II and III have been redefined for this analysis following a request from OSPAR;
- annual depositions of oxidised, reduced and nitrogen have been calculated with the EMEP MSC-W model on 0.1°×0.1° resolution for the 5 OSPAR Regions and the 24 Exclusive Economic Zones;
- in all OSPAR Regions, annual deposition of *oxidised* nitrogen was clearly lower in 2018 than in 1995, with the maximum decline in Region V (52.2%);
- there is a decrease in the annual deposition of *reduced* nitrogen, too, in three out of five OSPAR Regions, in the range 8.4-11.2% (much lower decrease than in case of *oxidised* nitrogen). Increases are calculated for Regions II (19.9%) and IV (7.9%);
- concerning annual deposition of *total* nitrogen, there is decline between 1995 and 2018 in all OSPAR Regions, in the range 20.4-41.4%, with the largest decline in Region V;
- in all considered EEZs, there is a clear decrease in the annual deposition of *oxidised* nitrogen between 1995 and 2018, in the range 18.1-57.8%;
- in six EEZs, annual deposition of *reduced* nitrogen was smaller in 2018 than in 1995, while in all other considered EEZs it has increased, by up to 46.1%;
- in all considered EEZs, the annual deposition of *total* nitrogen has decreased from 1995 to 2018, in the range 3.4-48.4%;
- it must be noted that inter-annual variability in nitrogen depositions is large, mainly due to meteorological conditions. Therefore, changes have been calculated also for the 2014-2018 period with respect to the 1995-1999 period. In this calculation, decreases are seen in most EEZs also for *reduced* nitrogen deposition.

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