Supplement of:

Impact of a nitrogen emission control area (NECA) on the future air quality and nitrogen deposition to seawater in the Baltic Sea region

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Table S1: Percentage fraction of dry days, as observed and as predicted by COSMO-CLM model with configuration "0025_convper" for summer (JJA) and for winter (JFD) of 2012 in the four regions of Sweden. Values are given as average of all stations in a region. For the fraction of predicted dry days it is assumed that the "delta01" days (days with model-observation difference below the threshold of 0.1 mm d^{-1}) correspond to dry days.

Region	Summer		Winter	
	Predicted dry days [%]	Observed dry days [%]	Predicted dry days [%]	Observed dry days [%]
Götaland	38	47	34	43
Svealand	29	41	32	42
S. Norrland	31	47	23	34
N. Norrland	31	49	18	28

Table S2: Seasonal averages of wet deposition of nitrate for stations of the EMEP monitoring network in the Baltic Sea region. CMAQ model results were taken from the CD04 grid domains. For spring (MAM), summer (JJA) and autumn (SON), the mean value of model (μ_{Mod}) and mean value of observations (μ_{Obs}) is given based on daily sums. Unit of mean values is mg(N) m^{-2} d^{-1}. Observational and model data was evaluated independently. N_{Obs} is the number of observations in the respective season, used to calculate μ_{Obs}. N_{Mod} is the number of days with simulated precipitation in the respective season, used to calculate μ_{Mod}.

Station, Code	Spring				Summer				Winter			
	N_{Mod}	N_{Obs}	μ_{Mod}	μ_{Obs}	N_{Mod}	N_{Obs}	μ_{Mod}	μ_{Obs}	N_{Mod}	N_{Obs}	μ_{Mod}	μ_{Obs}
Zingst, DE0009R	9	11	1.71	3.54	18	10	2.25	5.71	22	13	1.85	4.98
Råö SE0014R	13	24	3.38	3.48	15	29	1.51	3.80	42	48	2.23	2.83
Leba, PL0004R	14	24	1.76	1.47	10	31	2.88	5.27	33	58	1.43	2.21
Diabla Gora, PL0005R	20	29	1.75	3.64	19	25	2.22	4.06	30	46	1.60	3.06
Ähtäri, FI0004R	7	9	1.09	3.25	14	9	0.92	2.73	17	12	1.36	3.46
Virolahti II FI0017R	13	11	1.98	3.30	14	9	1.33	3.48	36	16	1.26	6.50
Hailuoto II, FI0053R	9	11	0.70	3.16	11	8	0.86	1.61	23	15	1.03	3.24
Lahemaa, EE0009R	17	29	1.37	1.64	17	21	1.24	1.27	24	39	1.32	2.11
Preila LT0015R	14	10	1.52	3.09	17	24	2.63	2.16	29	41	1.61	3.04

Table S3: Seasonal averages of wet deposition of ammonium for stations of the EMEP monitoring network in the Baltic Sea region. CMAQ model results were taken from the CD04 grid domains. For spring (MAM), summer (JJA) and autumn (SON), the mean value of model (μ_{Mod}) and mean value of observations (μ_{Obs}) is given based on daily sums. Unit of mean values is mg(N) m^{-2} d^{-1}. Observational and model data was evaluated independently. N_{Obs} is the number of observations in the respective season, used to calculate μ_{Obs}. N_{Mod} is the number of days with simulated precipitation in the respective season, used to calculate μ_{Mod}.

Station, Code	Spring				Summer				Winter			
	N_{Mod}	N_{Obs}	μ_{Mod}	μ_{Obs}	N_{Mod}	N_{Obs}	μ_{Mod}	μ_{Obs}	N_{Mod}	N_{Obs}	μ_{Mod}	μ_{Obs}
Zingst, DE0009R	9	11	2.36	7.73	19	11	2.01	9.68	19	14	2.30	6.33
Råö SE0014R	13	24	3.87	5.03	17	11	1.02	1.64	34	40	2.17	2.42
Leba, PL0004R	13	22	2.12	2.20	14	7	1.08	1.94	28	55	1.33	2.21
Diabla Gora, PL0005R	23	27	2.32	6.18	14	9	1.44	3.51	28	39	1.47	2.44
Ähtäri, FI0004R	7	9	1.11	3.03	14	7	1.08	1.94	17	11	0.98	2.28
Virolahti II FI0017R	14	11	2.61	2.98	14	9	1.44	3.51	28	15	1.12	5.62
Hailuoto II, FI0053R	9	11	0.75	3.86	10	8	1.00	1.51	18	14	0.74	3.64
Lahemaa, EE0009R	17	22	1.64	2.01	17	11	1.02	1.64	23	17	0.90	1.78
Preila LT0015R	15	10	1.60	4.19	16	22	3.24	2.57	23	39	1.25	2.42

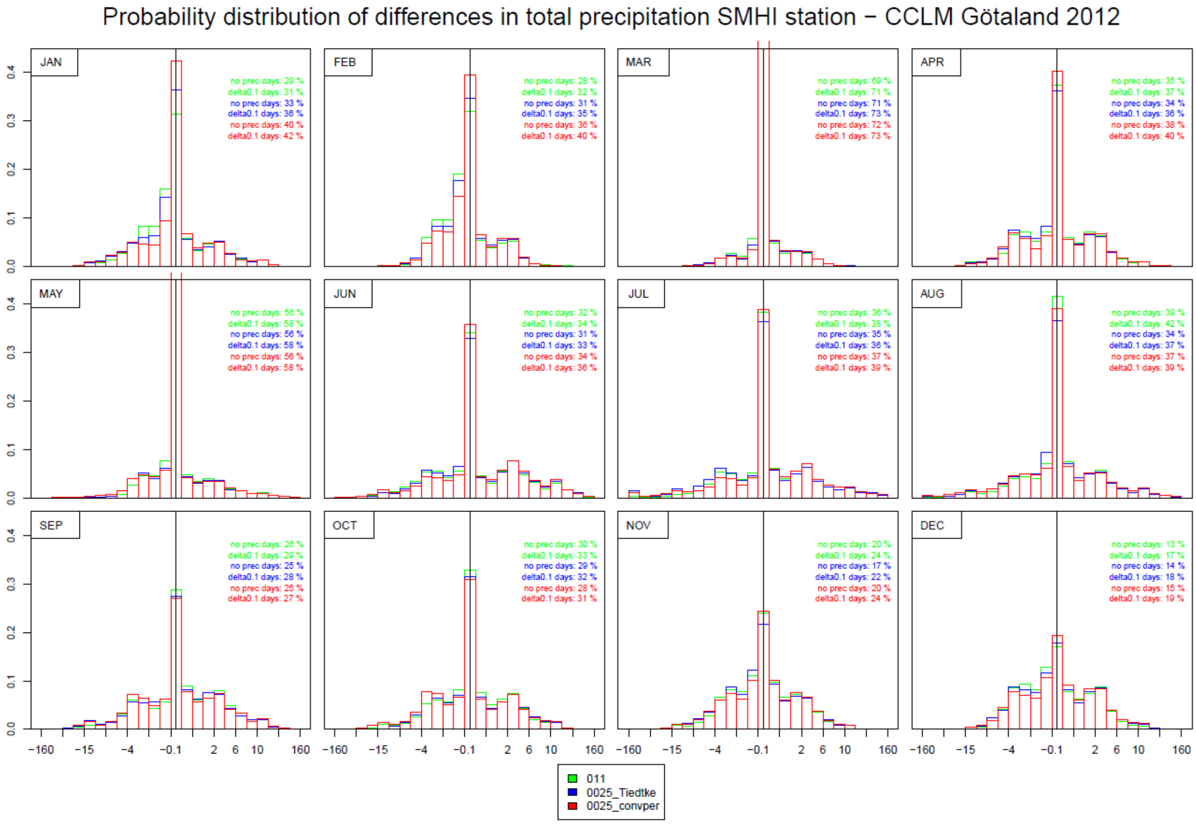

Figure S1. Probability distribution of the differences in daily precipitation sums (mm d^{-1}) between the SMHI station observations and COSMO-CLM with different configurations ("011", "0025_Tiedtke", and "0025_convper") in Götaland for the months of 2012. The percentage fraction of days with zero difference between model and observation ("no prec. days") and the percentage fraction of days with difference of ±0.1 mm d^{-1} ("delta0.1 days") is indicated in the plots for each model configuration

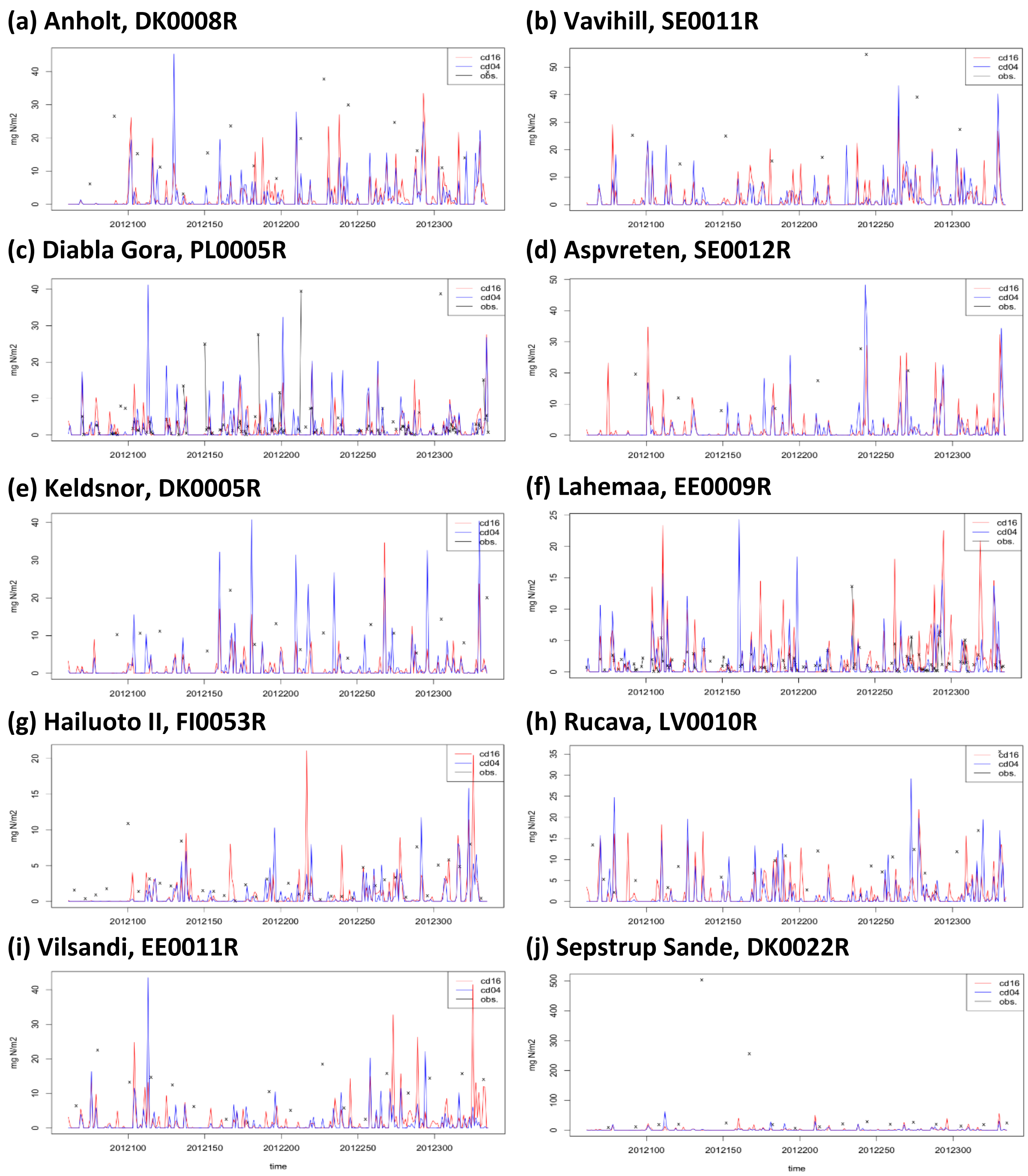

Figure S2. Comparison of modelled wet deposition of nitrate as daily sums (mg(N) m^{-2} d^{-1}) from the 16-km resolution grid (red) and 4km-resolution grid (blue) against observed daily sums of nitrate wet deposition (black crosses) at regional background stations around the Baltic Sea from the EMEP monitoring network: (a) Anholt, DK0008R, (b) Vavihill, SE0011R, (c) Diabla Gora, PL0005R, (d) Aspvreten, SE0012R, (e) Keldsnor, DK0005R, (f) Lahemaa, EE0009R, (g) Hailuoto II, FI0053R, (h) Rucava, LV0010R, (i) Vilsandi, EE0011R, and (j) Sepstrup Sande, DK0022R. Comparison time period: 1 March to 30 November 2012.

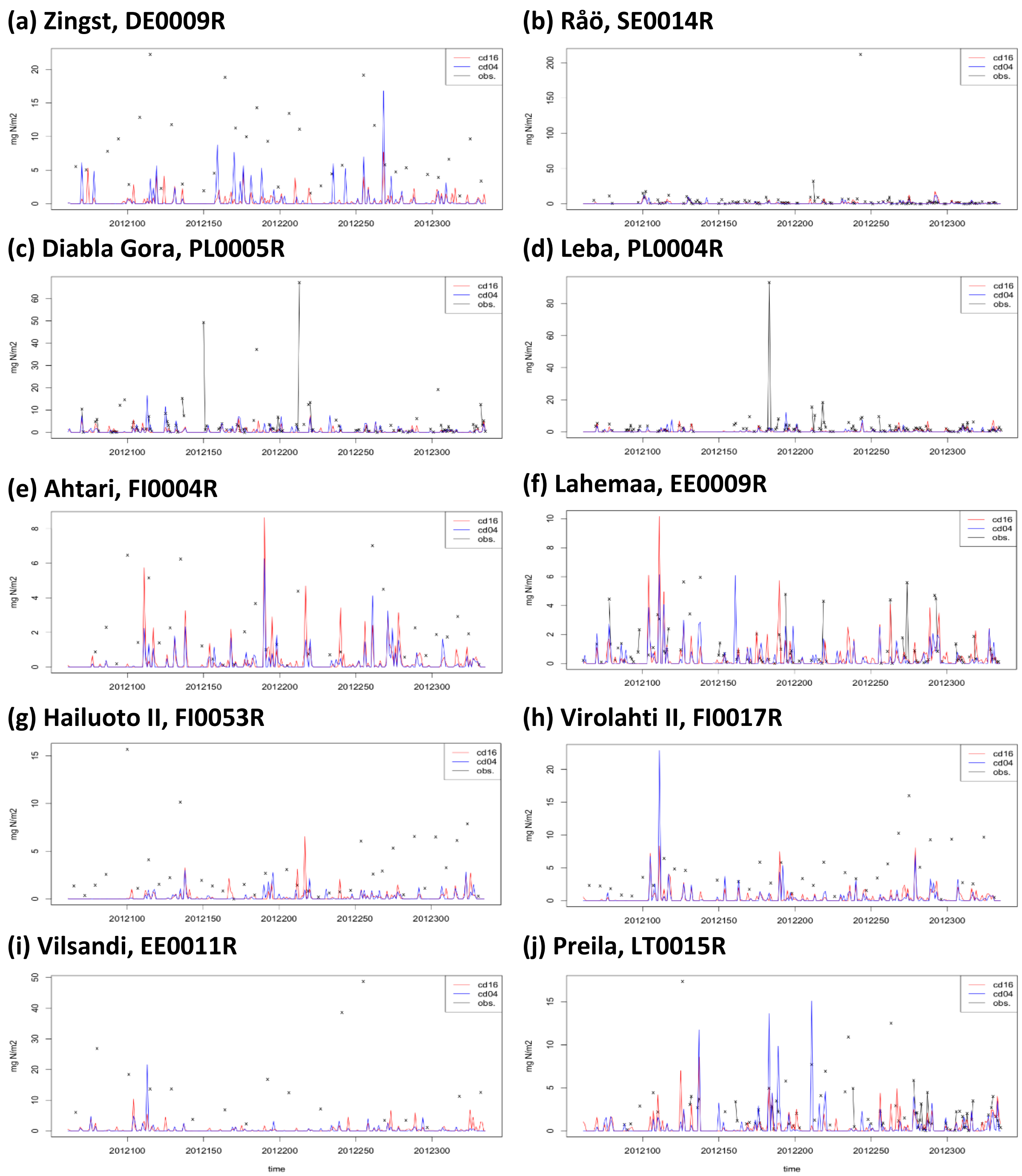

Figure S3. Comparison of modelled wet deposition of ammonium as daily sums (mg(N) m^{-2} d^{-1}) from the 16-km resolution grid (red) and 4km-resolution grid (blue) against observed daily sums of nitrate wet deposition (black crosses) at regional background stations around the Baltic Sea from the EMEP monitoring network: (a) Zingst, DE0009R, (b) Råö, SE0014R, (c) Diabla Gora, PL0005R, (d) Leba, PL0004R, (e) Ähtäri, FI0004R, (f) Lahemaa, EE0009R, (g) Hailuoto II, FI0053R, (h) Virolahti II, FI0017R, (i) Vilsandi, EE0011R, and (j) Preila, LT0015R. Stations correspond to those in Table 5. Comparison time period: 1 March to 30 November 2012.

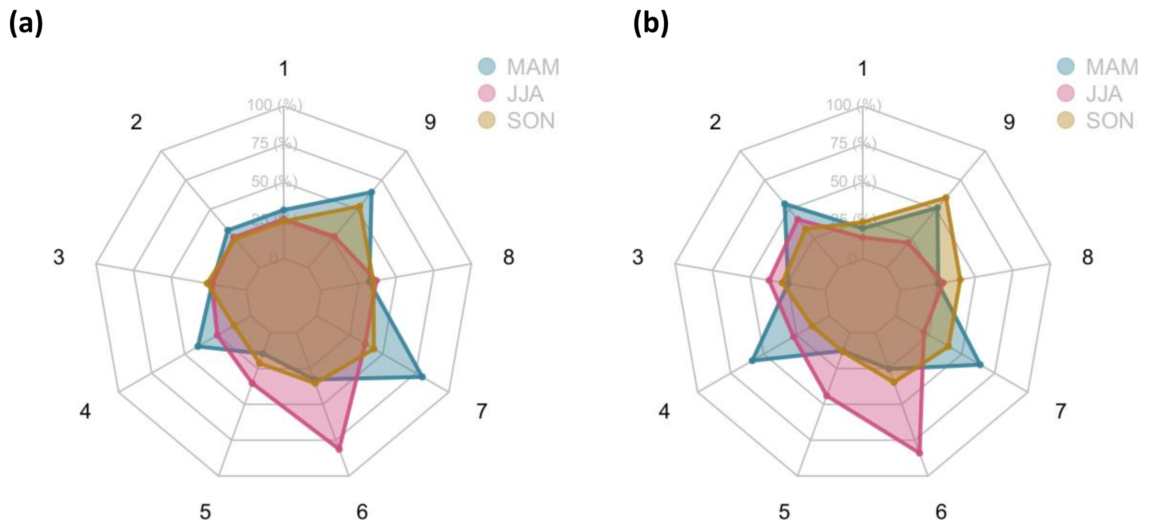

Figure S4. Spider charts of the ratio between modelled and observed seasonal averages: (a) wet deposition of nitrate and (b) wet deposition of ammonium, for spring (MAM), summer (JJA) and autumn (SON). Stations indicated by numbers 1: Zingst, DE0009R; 2: Lahemaa, EE0009R; 3: Ähtäri, FI0004R; 4: Virolahti II, FI0017R; 5: Hailuoto II, 6: Preila, LT0015R; 7: Leba, PL0004R; 8: Diabla Gora, PL0005R; 9: Råö, SE0014R. The maximum (100 %) corresponds to a ratio of 1.5.

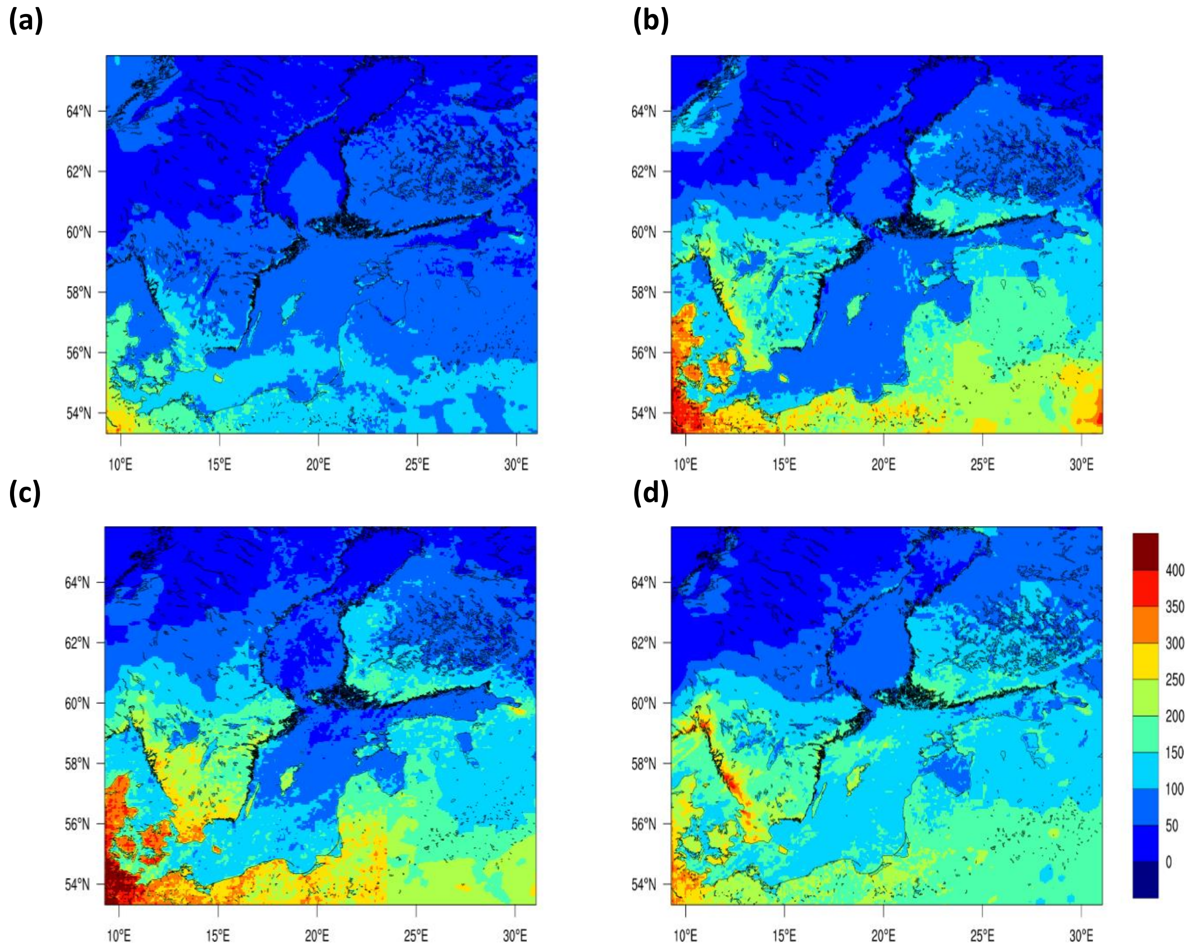

Figure S5. Present-day (2012) seasonal sums of total nitrogen deposition (in mg(N) m^{-2}) from the CMAQ run with all emissions: (a) in winter (JFD), (b) in spring (MAM), (c) in summer (JJA), and (d) in autumn (SON).

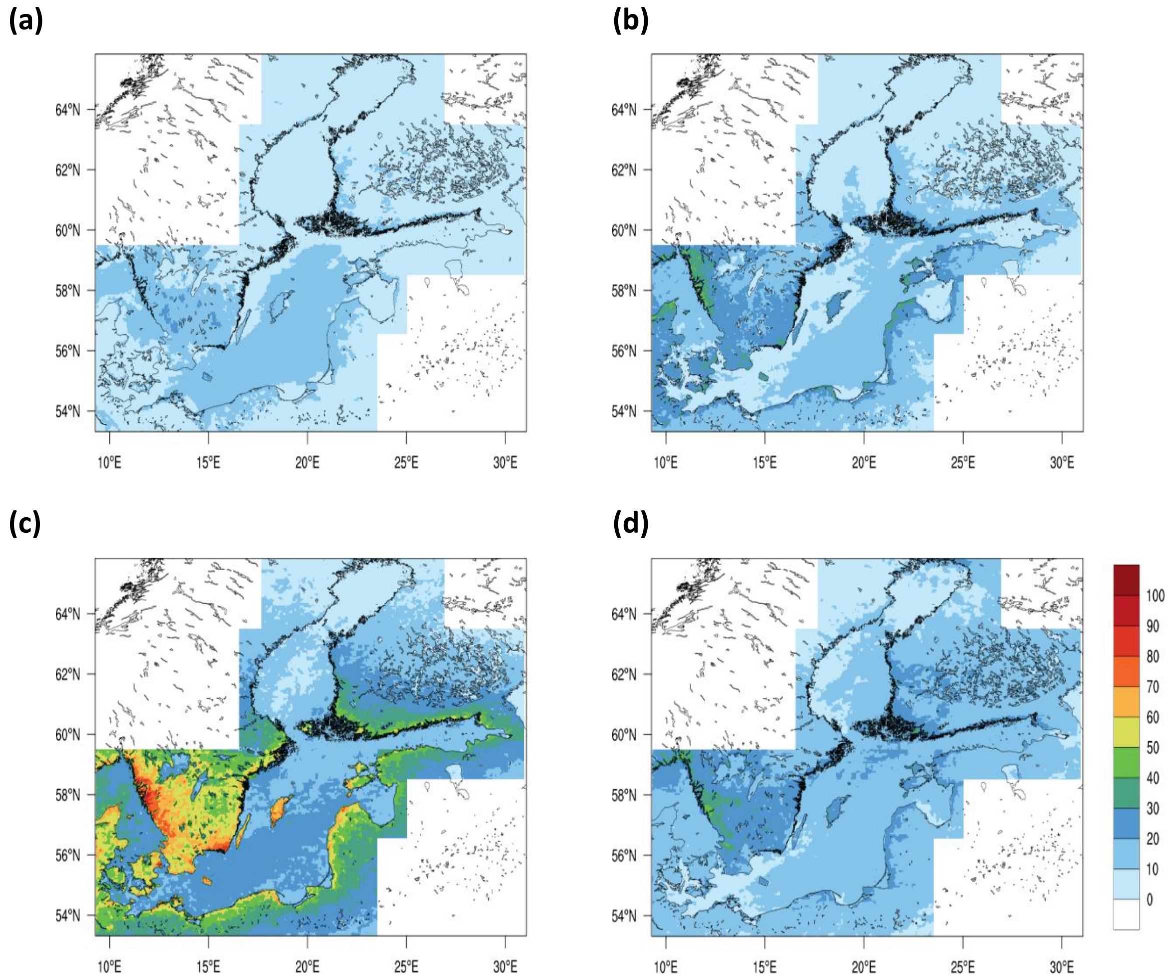

Figure S6. Present-day (2012) absolute ship contribution to the seasonal sums of nitrogen deposition (in mg(N) m^{-2}): (a) in winter (JFD), (b) in spring (MAM), (c) in summer (JJA), and (d) in autumn (SON). Maps only show results for the high-resolution area.

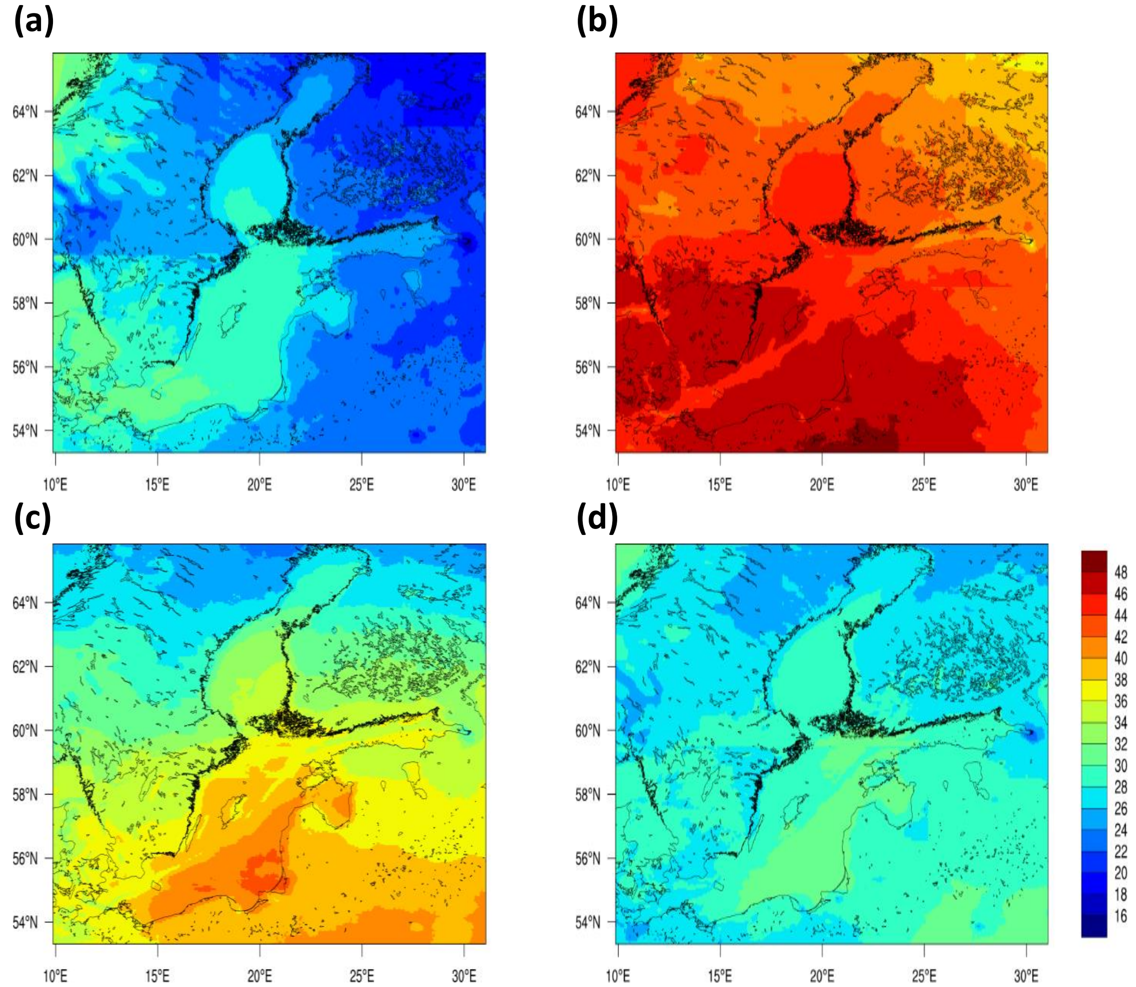

Figure S7. Present-day (2012) seasonal average of the daily maximum O_3 concentration (in ppbv) in the Baltic Sea region from the CMAQ run with all emissions: (a) mean of winter months (JFD), (b) mean of spring months (MAM), (c) mean of summer months (JJA), and (d) mean of autumn months (SON).

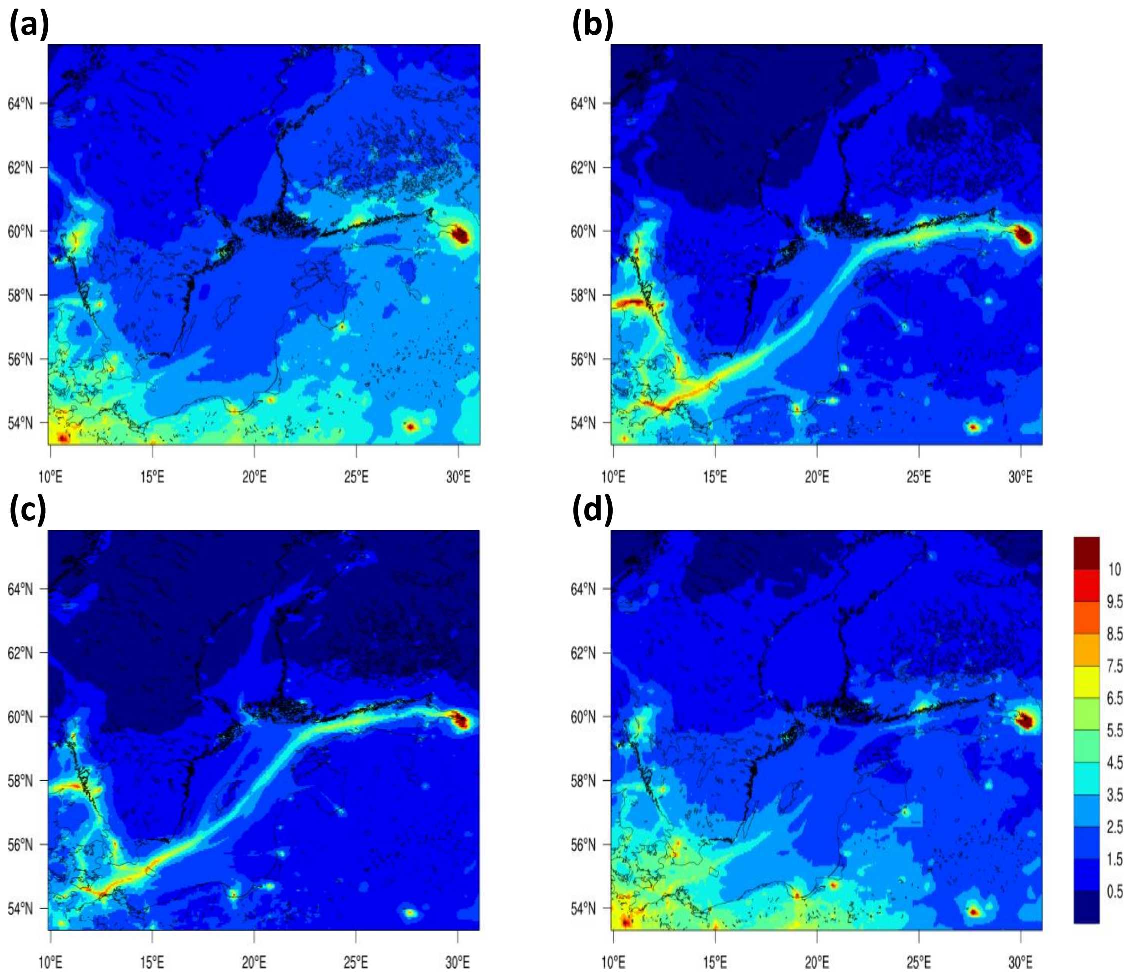

Figure S8. Present-day (2012) seasonal average concentration of NO_2 (in ppbv) in the Baltic Sea region from the CMAQ run with all emissions: (a) mean of winter months (JFD), (b) mean of spring months (MAM), (c) mean of summer months (JJA), and (d) mean of autumn months (SON).

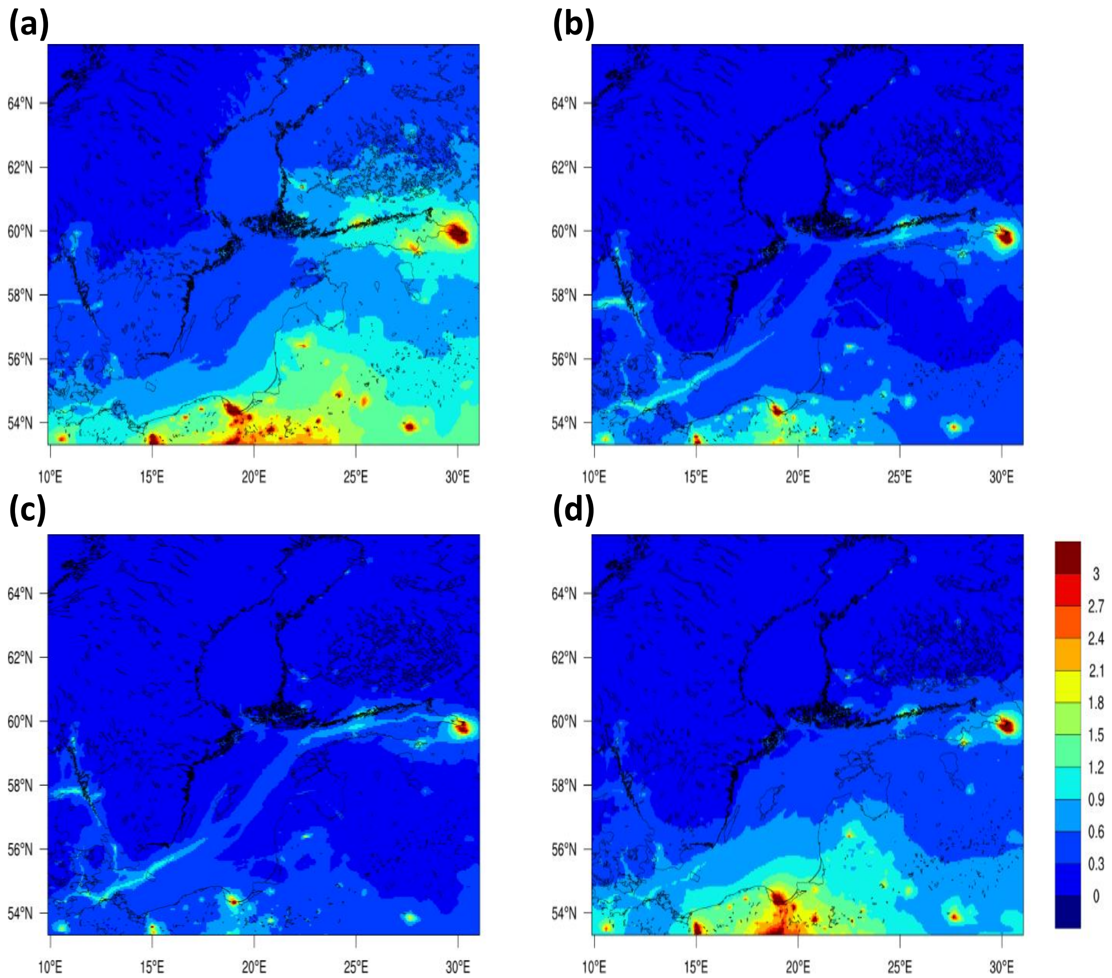

Figure S9. Present-day (2012) seasonal average concentration of SO_2 (in ppbv) in the Baltic Sea region from the CMAQ run with all emissions: (a) mean of winter months (JFD), (b) mean of spring months (MAM), (c) mean of summer months (JJA), and (d) mean of autumn months (SON).

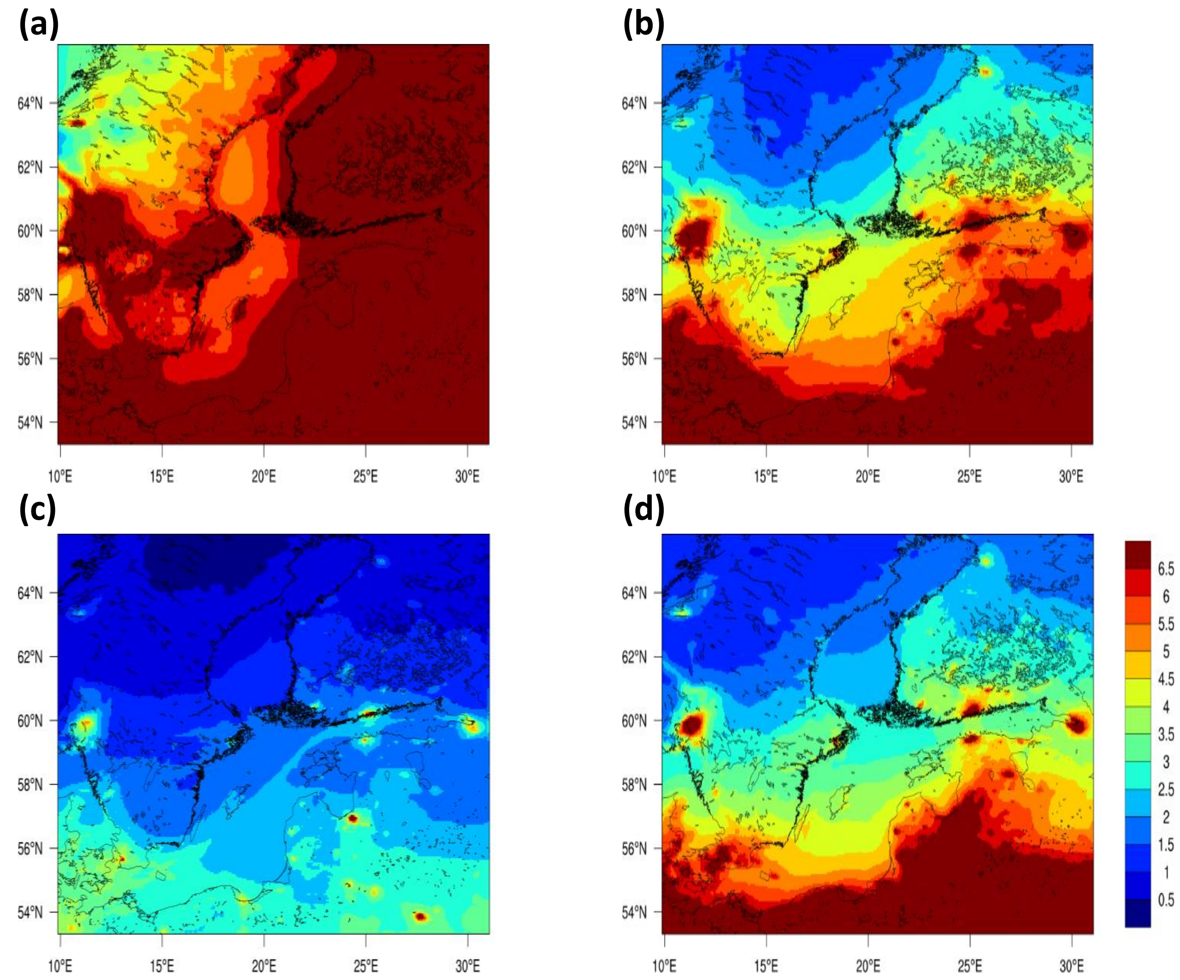

Figure S10. Present-day (2012) seasonal average concentration of PM2.5 (in μg m^{-3}) in the Baltic Sea region from the CMAQ run with all emissions: (a) mean of winter months (JFD), (b) mean of spring months (MAM), (c) mean of summer months (JJA), and (d) mean of autumn months (SON).

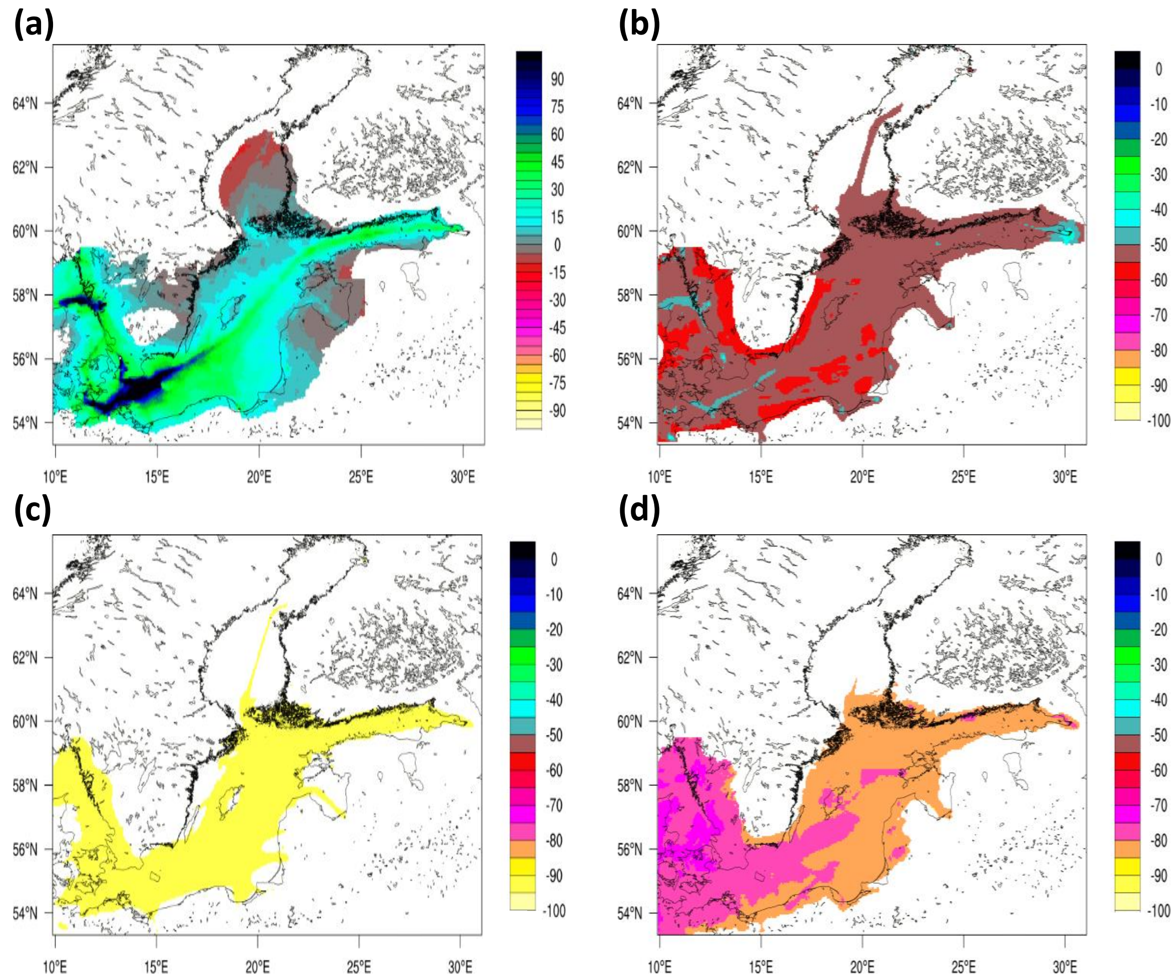

Figure S11. Future (2040) change of the ship-related contribution in summer (JJA) in percent compared to 2012, given as rel. difference between the ship contribution from the "NoNECA 2040" simulation and the ship contribution from the present-day simulation: (a) daily maximum O_3, (b) NO_2, (c) SO_2, (d) $PM_{2.5}$. Not coloured (empty) areas indicate grid cells with ship contribution in "BAU 2040" of less than 1.0 ppbv, 0.1 ppbv, 0.01 ppbv, 0.005 μg m^{-3}, for daily max. O_3, NO_2, SO_2, $PM_{2.5}$, respectively. Ship-related contribution only shown for the high-resolution area. Note the different scale for daily max. O_3 (from -100 % to 100 %).

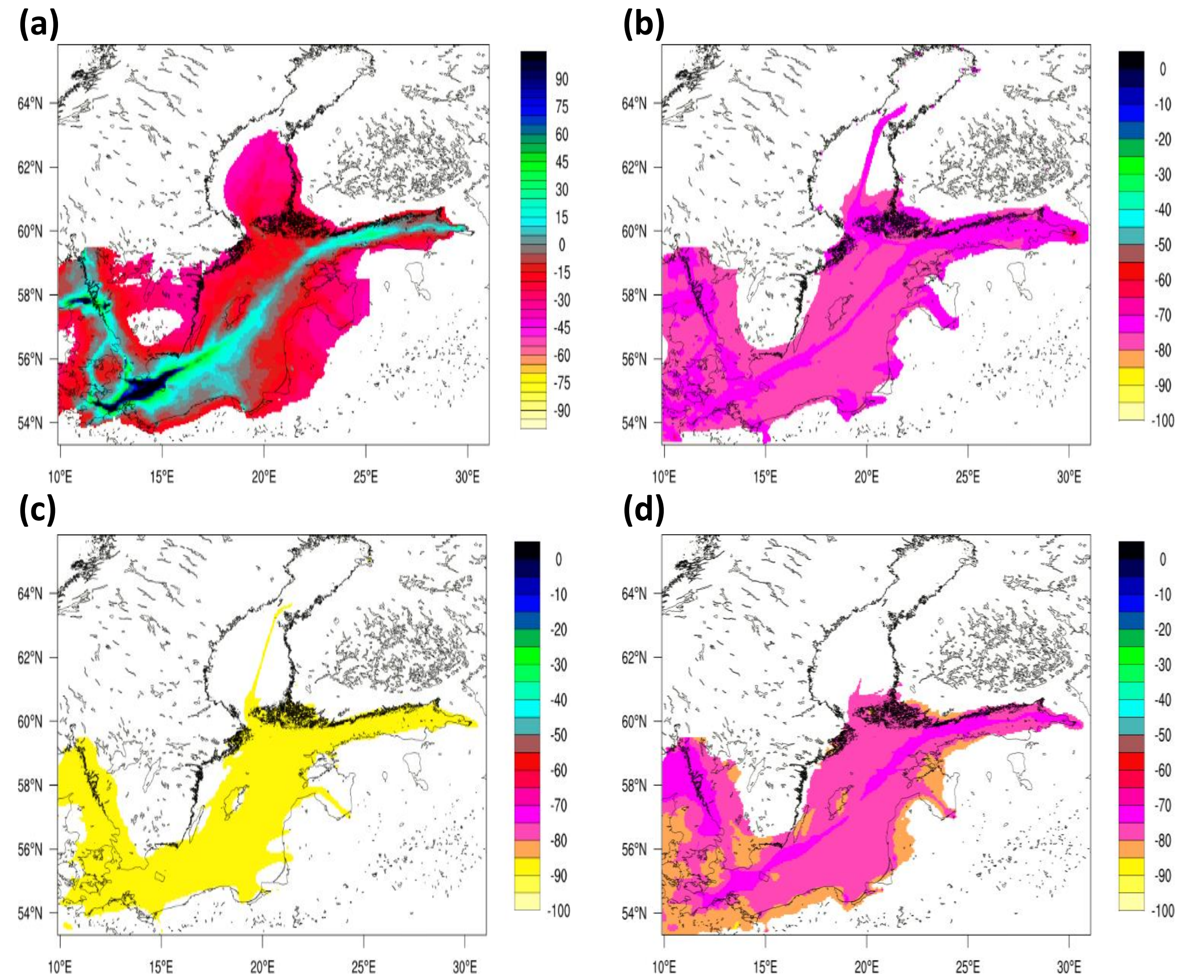

Figure S12. Future (2040) change of the ship-related contribution in summer (JJA) in percent compared to 2012, given as rel. difference between the ship contribution from the "EEDI 2040" simulation and the ship contribution from the present-day simulation: (a) daily maximum O_3, (b) NO_2, (c) SO_2, (d) $PM_{2.5}$. Not coloured (empty) areas indicate grid cells with ship contribution in "BAU 2040" of less than 1.0 ppbv, 0.1 ppbv, 0.01 ppbv, 0.005 μg m^{-3}, for daily max. O_3, NO_2, SO_2, $PM_{2.5}$, respectively. Ship-related contribution only shown for the high-resolution area. Note the different scale for daily max. O_3 (from -100 % to 100 %).

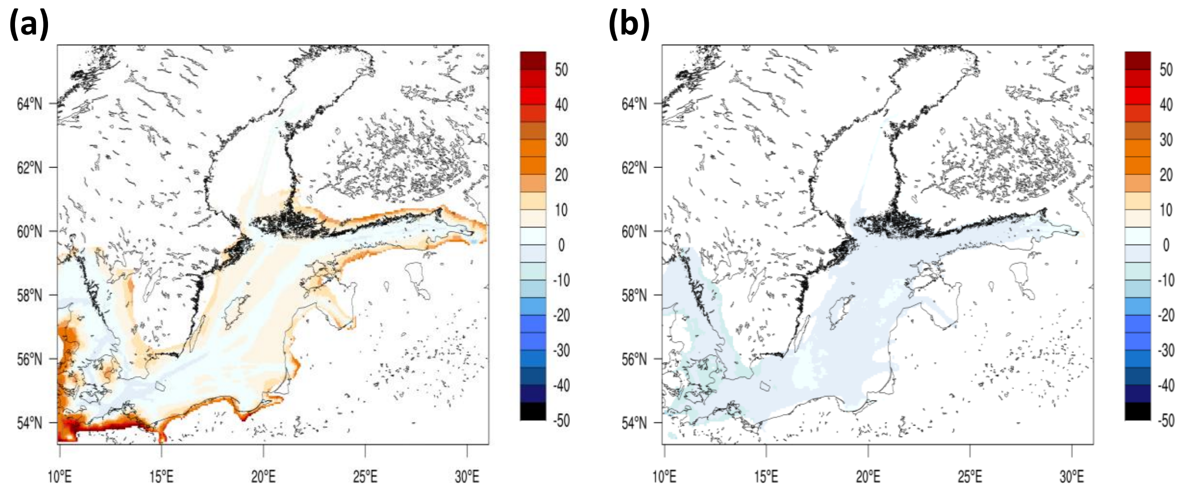

Figure S13. Effect of reduced land-based emissions (in percent) on the future ship contribution of (a) NO_2 and (b) SO_2 in summer (JJA) 2040 in the Baltic Sea region. Not coloured (white) areas indicate grid cells with ship contribution in the scenario “BAU 2040” of less than 0.1 ppbv for NO_2 and less than 0.01 ppbv for SO_2.