atmosphere

MDPI

Supplementary Materials:

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1. Mapping for MEIC to SNAP Sectors and EDGAR Activity Codes

The mapping of sectors present in the MEIC emission inventory for China to SNAP sectors and EDGAR activity codes is shown in Table S1. The mapping to SNAP sectors was used to apply the vertical emission profile developed by TNO to the MEIC inventory. The mapping to EDGAR activity codes was used to apply the country and sector specific high resolution temporal profiles developed by Crippa et al. [2020] to the MEIC inventory and generate hourly resolved emission data.

Table S1. Mapping of MEIC emission inventory sectors to SNAP sectors and EDGAR Activity Codes.

MEIC sector	SNAP sector	EDGAR activity codes
Agriculture	L_AgriOther	AGS (agricultural soils), AWB (agricultural waste burning), ENF (enteric fermentation), MNM (manure management)data
Industry	B_Industry	CHE (production of chemicals), FOO (production of foods), IND (manufacturing industry), IRO (production of iron and steel), NFE (production of non-ferrous metals), NMM (production of non-metallic minerals), PAP (production of pulp and paper), PRO (fuel production/transmission), PRU (production, use of products), REF (oil refineries), SOL (application of solvents), SWD (solid waste disposal), TRF (transformation industry)
Power	A_PublicPower	ENE (power industry)
Residential	C_OtherStationaryComb	RCO (residential)
Transportation	F_RoadTransport	TNR (non-road transportation), TRO (road transportation)

2. Model Performance Data

Following, the comparison data of the modeled "base" case, that includes all emission sources, and the "no ships" case, that omits ships, with measurements is shown in Tables S2 to S9. For each pollutant and station the geometric mean, the normalized mean bias (NMB) and the Spearman correlation coefficient was calculated. Furthermore, the number of available hourly measurements is shown.

Table S2. Comparison of modeled NO_2 concentrations in _g ·m-3 with measurements in Europe.

Station	Meanbase	NMBbase	Corr.base	Meannoships	NMBnoships	Corr.noships	Meanmeas	No. samples
Dublin	3.05	−0.38	0.62	2.70	−0.47	0.63	4.94	8618
Blackpool	2.47	−0.63	0.69	1.83	−0.67	0.70	11.46	8343
Narberth	1.60	−0.14	0.53	1.10	−0.35	0.54	1.63	8572
Plymouth	2.27	−0.81	0.58	1.00	−0.90	0.60	13.53	8650
Brighton	4.77	−0.53	0.67	2.71	−0.67	0.63	10.72	8619
Lullington Heath	4.44	−0.09	0.66	1.91	−0.44	0.60	4.79	5834
Newcastle	6.06	−0.69	0.59	4.39	−0.76	0.61	25.56	8341
Houtem	7.19	−0.01	0.64	4.36	−0.35	0.63	7.12	8186
Gent	13.51	−0.29	0.63	7.05	−0.61	0.66	23.40	8022
Schoten	17.79	−0.05	0.63	10.18	−0.43	0.65	21.26	8388
Den Haag	17.91	−0.03	0.70	8.47	−0.51	0.66	22.20	8653
De Zilk	12.99	0.40	0.70	7.02	−0.19	0.66	9.83	8565
Wieringerwerf	5.30	−0.27	0.78	2.35	−0.62	0.75	8.55	8714
Ostfr. Inseln	3.43	−0.39	0.75	1.01	−0.68	0.75	6.39	8347
Elbmündung	5.33	−0.37	0.64	1.70	−0.72	0.62	9.56	8415
Hamburg	12.12	−0.45	0.51	5.49	−0.73	0.50	26.39	8727
Westerland	1.34	−0.55	0.79	0.51	−0.77	0.77	2.17	8287
Ulborg	1.54	−0.43	0.69	0.86	−0.62	0.66	2.77	7691
Århus	3.23	−0.67	0.61	1.61	−0.83	0.50	9.61	7962
Copenhagen	7.13	−0.36	0.51	4.71	−0.53	0.46	12.32	7965
Zingst	2.95	−0.19	0.71	1.04	−0.60	0.60	3.73	8216
Gdansk Nowy Port	5.80	−0.41	0.58	3.21	−0.63	0.63	10.44	8353
Vilsandi	0.98	−0.42	0.62	0.35	−0.73	0.38	1.37	8444
Utö	1.16	−0.47	0.59	0.26	−0.85	0.33	2.25	8633
Õismäe	3.65	−0.42	0.52	1.23	−0.78	0.57	5.13	8603
Helsinki Kallio	5.90	−0.48	0.45	4.35	−0.60	0.41	14.01	8725
Lahemaa	1.33	−0.18	0.49	0.80	−0.46	0.45	1.61	8644
Virolahti	1.56	−0.36	0.53	0.88	−0.62	0.38	2.74	8601
Pyykösjärvi	3.00	−0.55	0.48	2.91	−0.55	0.47	6.61	8728

Table S3. Comparison of modeled SO_2 concentrations in _g ·m-3 with measurements in Europe.

Station	Meanbase	NMBbase	Corr.base	Meannoships	NMBnoships	Corr.noships	Meanmeas	No. samples
Narberth	0.37	0.04	−0.05	0.19	−0.12	−0.01	0.68	8367
Lullington Heath	0.28	−0.40	0.08	0.18	−0.46	0.08	0.95	8266
Houtem	1.19	1.20	0.19	1.08	1.13	0.19	1.07	8408
Gent	0.94	0.64	0.37	0.73	0.51	0.37	1.23	8335
De Zilk	0.73	0.22	0.32	0.54	0.10	0.32	0.95	7298
Ostfr. Inseln	0.14	0.12	0.35	0.08	0.03	0.35	0.40	6422
Hamburg	1.07	−0.50	0.29	0.83	−0.55	0.30	3.28	8727
Westerland	0.09	0.71	0.09	0.05	0.58	0.08	0.26	8315
Zingst	0.21	0.36	0.55	0.14	0.29	0.54	0.39	7830
Gdansk Nowy Port	1.67	−0.04	0.44	1.59	−0.06	0.44	2.17	8690

Vilsandi	0.11	−0.03	0.37	0.07	−0.08	0.38	0.27	6862
Utö	0.10	−0.32	0.49	0.05	−0.38	0.51	0.30	8707
Õismäe	0.39	0.03	0.27	0.32	−0.05	0.26	0.47	7818
Helsinki Kallio	1.00	0.11	0.16	0.95	0.08	0.16	0.61	7491
Lahemaa	0.23	−0.31	0.15	0.19	−0.33	0.15	0.53	8079
Virolahti	0.26	0.24	0.41	0.23	0.19	0.41	0.21	8590

Table S4. Comparison of modeled O_3 8-hour mean concentrations in _g ·m-3 with measurements.in Europe.

Station	Meanbase	NMBbase	Corr.base	Meannoships	NMBnoships	Corr.noships	Meanmeas	No. samples
Blackpool	68.55	0.29	0.71	67.43	0.27	0.71	49.39	8662
Narberth	75.12	0.21	0.54	73.81	0.19	0.56	61.09	8647
Plymouth	76.77	0.54	0.57	75.8	0.52	0.55	45.59	8621
Brighton	72.4	0.31	0.66	72.39	0.31	0.6	51.52	8653
Lullington Heath	73.98	0.34	0.61	74.31	0.34	0.55	53.61	8603
Newcastle	66.52	0.63	0.68	67.14	0.64	0.64	36.56	8411
Phare d'Ailly	76.09	0.23	0.61	74.7	0.21	0.62	59.62	8700
Houtem	64.51	0.28	0.75	67.08	0.31	0.72	47.15	7829
Gent	50.48	0.42	0.72	61.01	0.55	0.71	32.78	7683
Schoten	45.04	0.36	0.78	56.81	0.52	0.78	29.5	8328
Den Haag	39.51	0.22	0.82	57.67	0.45	0.75	33.29	8657
De Zilk	48.49	0.12	0.8	59.38	0.23	0.73	42.27	8615
Wieringerwerf	68.96	0.42	0.68	72.78	0.46	0.57	44.15	8504
Ostfr. Inseln	72.08	0.2	0.7	72.72	0.2	0.6	55.72	8570
Elbmündung	67.33	0.28	0.72	69.55	0.3	0.65	47.54	8725
Westerland	77.55	0.18	0.64	76.3	0.15	0.52	61.91	8561
Ulborg	73.55	0.15	0.58	71.75	0.12	0.46	61.99	7664
Århus	72.37	0.33	0.65	72.26	0.32	0.55	50.36	8323
Råö	74.34	0.16	0.68	73.69	0.15	0.59	62.74	8647
Copenhagen	66.14	0.17	0.67	67.03	0.17	0.57	53.76	7973
Zingst	72.69	0.21	0.73	72.47	0.2	0.64	57.1	8596
Vilsandi	75.61	0.14	0.59	72.72	0.09	0.45	65.64	8504
Utö	74.56	0.12	0.59	72.21	0.08	0.46	66.32	8672
Õismäe	67.6	0.27	0.62	68.15	0.27	0.52	51.05	8482
Helsinki Kallio	58.39	0.26	0.61	58.41	0.25	0.54	44.94	8744
Lahemaa	65.52	0.24	0.63	64.04	0.21	0.61	50.24	8735
Virolahti	67.24	0.33	0.53	66.2	0.31	0.5	47.51	8622
Pyykösjärvi	51.92	0.16	0.61	51.19	0.14	0.61	43.39	8744

Table S5. Comparison of modeled $PM_{2.5}$ concentrations in _g ·m-3 with measurements in Europe.

Station	Mean-base	NMB-base	Corr.base	Mean-noships	NMB-noships	Corr.noships	Mean-meas	No. samples
Blackpool	8.17	0.32	0.36	7.74	0.26	0.34	5.78	7508

Plymouth	8.52	0.01	0.29	7.79	−0.07	0.25	9.33	6502
Newcastle	7.96	0.03	0.32	7.58	−0.02	0.29	7.8	5540
Houtem	9.65	0.19	0.46	8.66	0.09	0.43	8.12	8632
Gent	10.57	−0.04	0.5	10.57	−0.04	0.5	11.15	8575
Schoten	10.87	−0.02	0.53	9.93	−0.09	0.53	10.79	8701
De Zilk	9.73	0.24	0.45	8.7	0.13	0.44	6.61	7868
Wier-ingerwerf	8.93	0.25	0.44	7.94	0.13	0.4	6.04	8140
Utö	4	0.11	0.28	3.71	0.04	0.28	3.45	8197
Helsinki Kal-lio	4.84	0.2	0.29	4.55	0.13	0.29	4.22	8366
Virolahti	3.87	0.13	0.21	3.66	0.08	0.2	4.19	8595

Table S6. Comparison of modeled NO_2 concentrations in _g ·m-3 with measurements in China.

Station	Mean-base	NMB-base	Corr.base	Mean-noships	NMB-noships	Corr.noships	Mean-meas	No. samples
Dalian	53.68	1.03	0.33	45.6	0.68	0.42	29.53	8576
Huludao	16.78	−0.38	0.64	16.37	−0.40	0.64	29.73	8576
Qinhuangdao	29.04	−0.14	0.6	26.27	−0.22	0.62	38.01	8577
Tianjin	56.95	0.59	0.64	56.19	0.58	0.64	33.53	8575
Lianyungang	15.05	−0.14	0.66	13.95	−0.18	0.65	24.31	8576
Yancheng	18.57	0.17	0.61	17.3	0.1	0.6	19.6	8576
Nantong	36.79	0.35	0.6	31.98	0.13	0.6	30.45	8575
Shanghai	59.11	0.54	0.53	49.11	0.3	0.6	39.27	8576
Ningbo	44.97	0.34	0.57	36.53	0.11	0.58	37.27	8576
Wenzhou	30.72	−0.05	0.37	28.74	−0.11	0.37	38.75	8576
Fuzhou	23.77	0.04	0.34	22.86	0.01	0.34	28.91	8575
Quanzhou	24.96	0.29	0.4	23.66	0.22	0.39	21.22	8577
Shantou	15.01	0.05	0.48	12.55	−0.09	0.5	16.98	8576
Shenzhen	47.27	0.8	0.41	42.3	0.6	0.42	30.07	8576
Guangzhou	58.01	0.6	0.49	58.01	0.6	0.49	41.38	8576
Zhongshan	20.33	0.05	0.35	15.91	−0.17	0.35	23.39	8576
Zhuhai	14.25	−0.25	0.48	7.71	−0.57	0.45	23.3	8576
Haikou	6.92	−0.37	0.35	6.18	−0.45	0.38	11.34	8576
Beihai	5.38	−0.51	0.27	4.83	−0.57	0.32	12.1	8576
Fangcheng-gang	5.04	−0.42	0.42	4.07	−0.52	0.43	10.45	8578

Table S7. Comparison of modeled SO_2 concentrations in _g ·m-3 with measurements in China.

Station	Mean-base	NMB-base	Corr.base	Mean-noships	NMB-noships	Corr.noships	Mean-meas	No. samples
Dalian	24.74	0.16	0.19	21.76	−0.07	0.27	19.59	8576
Huludao	7.85	−0.78	0.51	7.69	−0.78	0.51	33.1	8576
Qinhuangdao	14.51	−0.45	0.61	13.28	−0.50	0.64	28.64	8577
Tianjin	29.83	0.38	0.66	29.44	0.37	0.66	19	8575
Lianyungang	4.75	−0.60	0.63	4.23	−0.62	0.63	22.07	8576
Yancheng	3.75	−0.48	0.55	3.21	−0.52	0.55	15.53	8576
Nantong	11.84	−0.40	0.54	9.97	−0.52	0.52	23.5	8575
Shanghai	27.09	1.08	0.5	23.16	0.77	0.52	14.7	8576
Ningbo	16.06	0.34	0.47	12.32	0.01	0.47	14.36	8576
Wenzhou	9.05	−0.24	0.22	8.15	−0.31	0.21	11.96	8576
Fuzhou	6.19	0.22	0.17	5.79	0.14	0.17	5.78	8575
Quanzhou	9.87	0.12	0.23	9.26	0.07	0.23	8.6	8577
Shantou	6.05	−0.43	0.5	5.22	−0.51	0.5	11.64	8576
Shenzhen	15.55	1.18	0.24	14.43	1.03	0.24	7.93	8576

Guangzhou	20.86	1.02	0.3	20.86	1.02	0.3	10.96	8576
Zhongshan	7.03	−0.10	0.24	5.73	−0.26	0.26	9.99	8576
Zhuhai	5.03	−0.12	0.64	3.33	−0.38	0.64	7.03	8576
Haikou	3	−0.31	0.41	2.75	−0.38	0.41	4.84	8576
Beihai	4.93	−0.28	0.32	4.67	−0.33	0.31	7.9	8576
Fangcheng-gang	4.48	0.12	0.06	4.05	0.03	0.07	4.89	8578

Table S8. Comparison of modeled O_3 8-hour average concentrations in _g ·m−3 with measurements in China.

Station	Mean-base	NMB-base	Corr.base	Mean-noships	NMB-noships	Corr.noships	Mean-meas	No. samples
Dalian	26.28	−0.15	0.74	32.07	−0.09	0.77	64.12	8648
Huludao	52.85	0.5	0.79	53.57	0.46	0.8	48.38	8648
Qinhuangdao	31.46	0.91	0.73	34.27	0.94	0.73	30.5	8648
Tianjin	4.32	0.36	0.81	4.43	0.35	0.81	29.99	8648
Lianyungang	57.19	0.38	0.74	58.22	0.33	0.74	60.35	8648
Yancheng	59.14	0.14	0.7	60.01	0.1	0.7	72.76	8648
Nantong	37.06	0.12	0.7	45.14	0.14	0.69	62.88	8648
Shanghai	21.57	−0.05	0.67	29.85	−0.02	0.68	60.07	8648
Ningbo	36.73	0.21	0.67	44.06	0.22	0.65	50.95	8648
Wenzhou	51.9	0.65	0.55	47.63	0.51	0.54	33.98	8647
Fuzhou	70.8	0.85	0.49	62.36	0.69	0.51	40.27	8647
Quanzhou	63.49	0.56	0.57	54.04	0.41	0.58	46.82	8647
Shantou	78.48	0.35	0.61	71.36	0.23	0.6	61.95	8648
Shenzhen	27.79	0.15	0.64	27.5	0.07	0.62	48.69	8648
Guangzhou	22.08	0.53	0.67	22.73	0.48	0.67	26.21	8648
Zhongshan	64.65	0.97	0.47	66.04	0.9	0.43	33.83	8648
Zhuhai	79.18	0.64	0.62	81.63	0.62	0.61	51.72	8648
Haikou	85.7	0.85	0.62	80.24	0.73	0.6	44.2	8648
Beihai	92.03	0.41	0.3	85.43	0.3	0.3	65.84	8648
Fangcheng-gang	87.99	1.21	0.46	83.27	1.08	0.45	36.73	8648

Table S9. Comparison of modeled $PM_{2.5}$ concentrations in _g ·m−3 with measurements in China.

Station	Mean-base	NMB-base	Corr.base	Mean-noships	NMB-noships	Corr.noships	Mean-meas	No. samples
Dalian	43.42	0.17	0.56	42.24	0.14	0.57	33.98	8576
Huludao	31.79	−0.16	0.67	31.44	−0.17	0.67	40.38	8576
Qinhuangdao	38.45	0.15	0.69	37.75	0.13	0.69	30.11	8577
Tianjin	59.93	0.19	0.64	59.46	0.19	0.64	50.52	8575
Lianyungang	42.26	0.1	0.61	41.19	0.08	0.61	39.82	8576
Yancheng	41.12	0.18	0.59	39.77	0.15	0.59	35.52	8576
Nantong	42.19	−0.04	0.53	40.75	−0.06	0.52	45.28	8575
Shanghai	41.51	0.02	0.5	39.76	−0.02	0.49	41.1	8576
Ningbo	37.51	0.07	0.43	35.83	0.03	0.42	35.3	8576
Wenzhou	36.03	−0.01	0.31	34.48	−0.04	0.3	37.3	8576
Fuzhou	34.67	0.37	0.28	33.44	0.33	0.27	24.41	8575
Quanzhou	44.64	0.86	0.32	43.34	0.81	0.32	23.66	8577
Shantou	42.11	0.46	0.25	40.73	0.42	0.23	28.22	8576
Shenzhen	48.7	0.79	0.17	47.48	0.75	0.16	25.08	8576
Guangzhou	52.25	0.51	0.3	52.25	0.51	0.3	32.91	8576
Zhongshan	48.02	0.59	0.12	46.64	0.55	0.1	26.3	8576
Zhuhai	45.85	0.66	0.2	44.41	0.61	0.17	23.98	8576
Haikou	37.56	1.1	0.47	37.05	1.08	0.46	17.73	8576

Beihai	42.38	0.66	0.38	41.59	0.63	0.36	19.2	8435
Fangcheng-gang	41.99	0.58	0.3	41.27	0.55	0.28	24.14	8578

3. Pollutant concentration patterns 14

The following sections contain figures of seasonally averaged, modeled pollutant concen-trations in the ground layer for the SC12NSBS domain in Europe and the CNC12 domain in China in 2015. These include the "base" case, modeled with all emission sources and for ships-only, determined by the zero-out method. Furthermore, the share of shipping on total concentrations is shown. Averages were calculated for the winter months: December, January, February; the spring months: March, April, May; the summer months: June, July,August; the autumn months: September, October, November. These are shown in that order from left to right.

3.1. NO_2

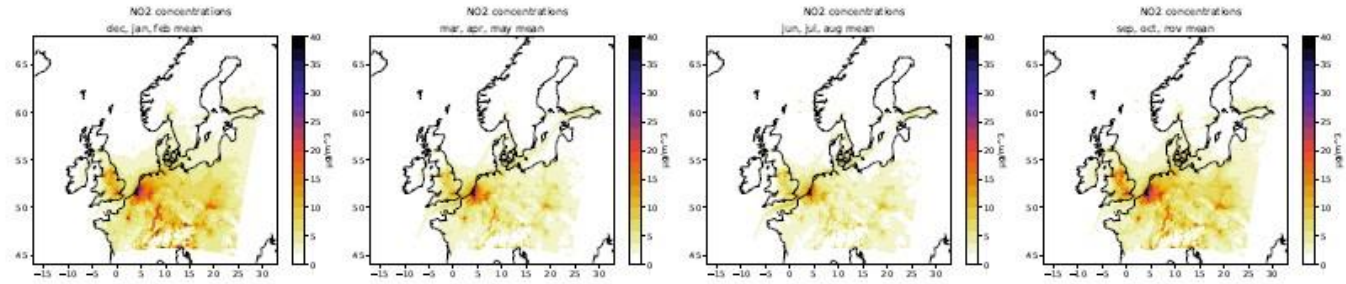

Figure S1. Seasonally averaged, modeled NO_2 concentrations in the ground layer from all emission sources in Europe.

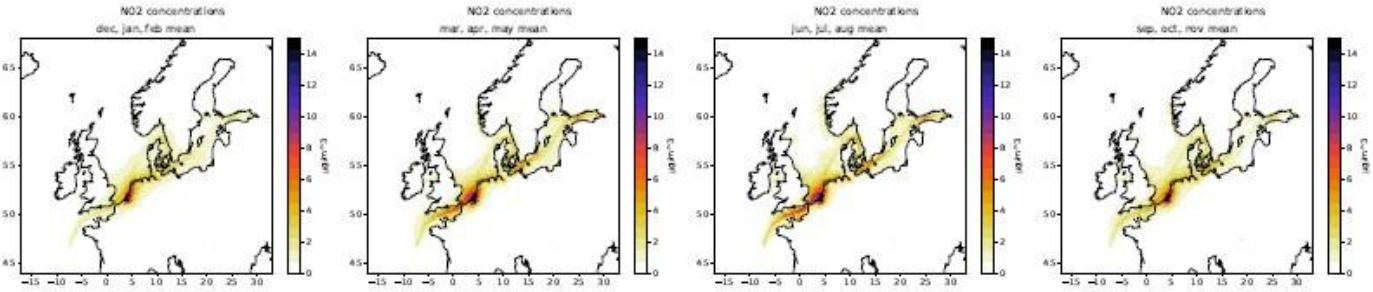

Figure S2. Seasonally averaged, modeled NO_2 concentrations in the ground layer from ships in Europe.

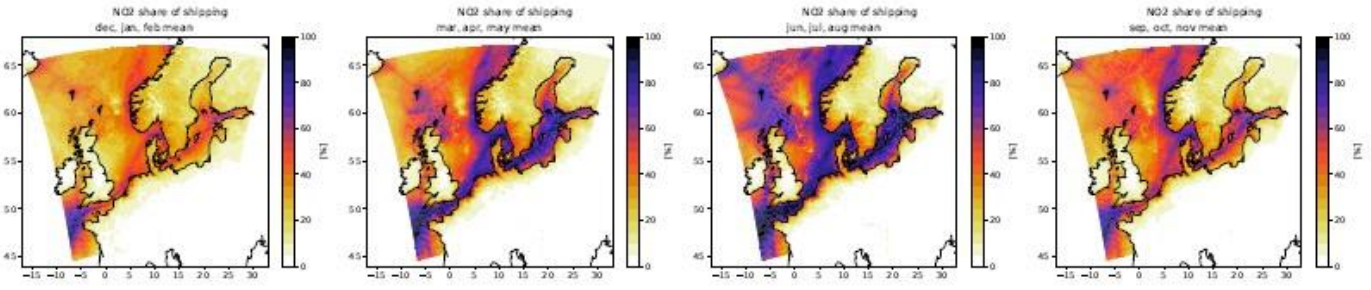

Figure S3. Seasonally averaged, modeled percentage share of ships on NO_2 concentrations in the ground layer in Europe.

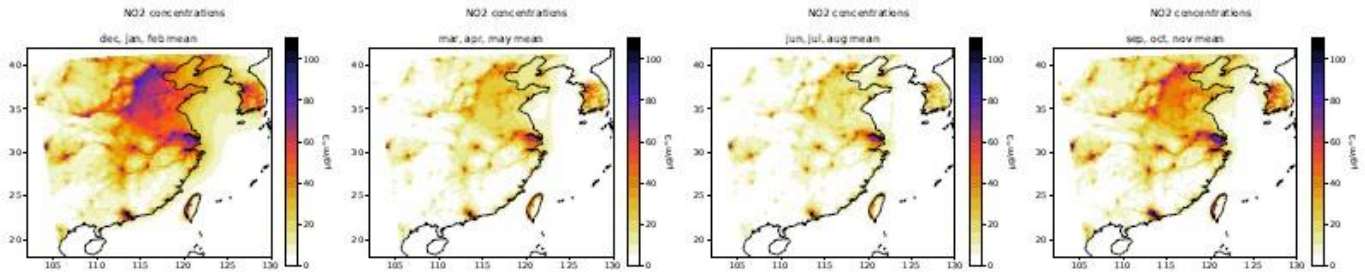

Figure S4. Seasonally averaged, modeled NO_2 concentrations in the ground layer from all sources in China.

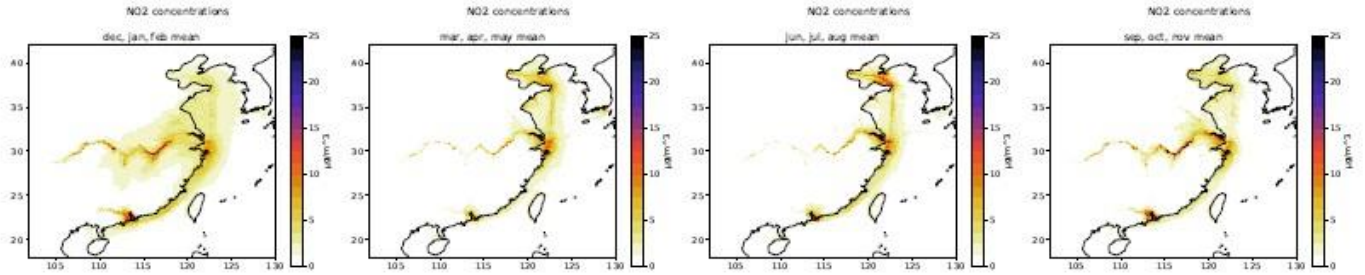

Figure S5. Seasonally averaged, modeled NO_2 concentrations in the ground layer from ships in China.

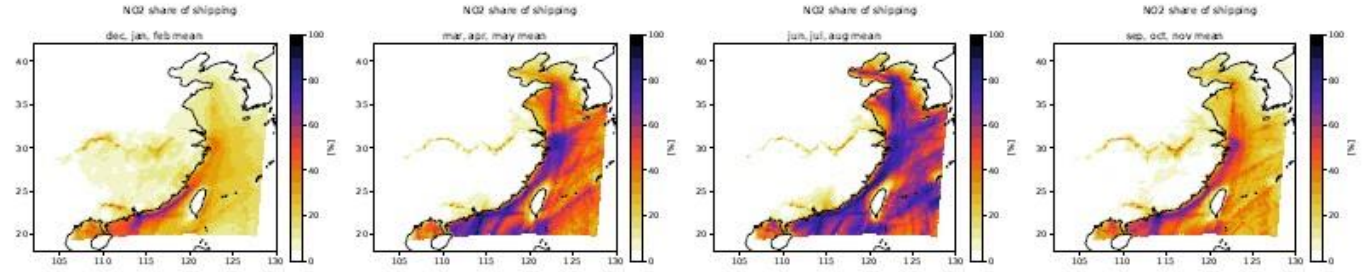

Figure S6. Seasonally averaged, modeled percentage share of ships on NO_2 concentrations in the ground layer in China.

3.2. SO_2

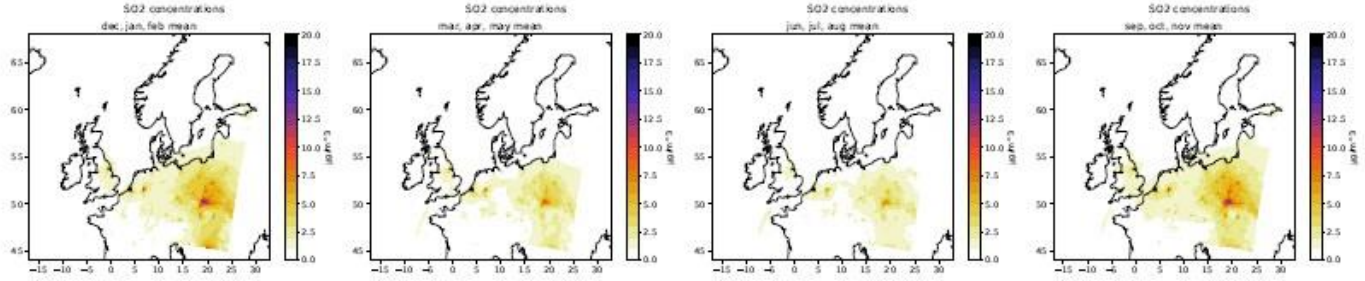

Figure S7. Seasonally averaged, modeled SO_2 concentrations in the ground layer from all sources in Europe.

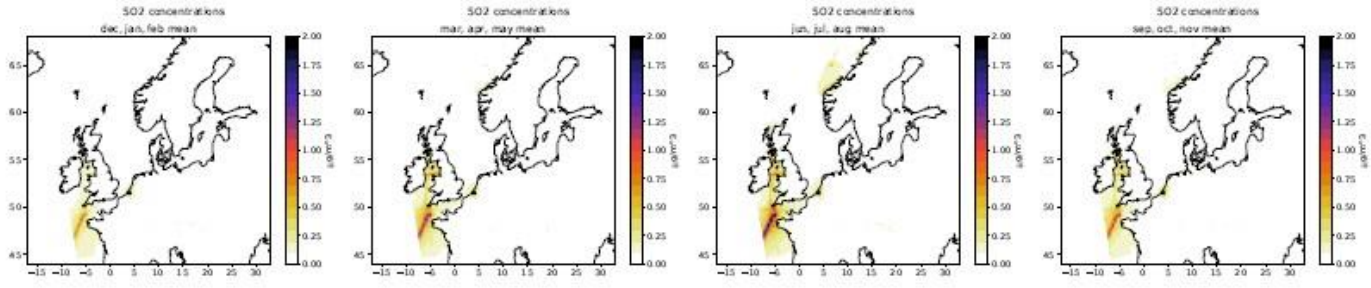

Figure S8. Seasonally averaged, modeled SO_2 concentrations in the ground layer from ships in Europe.

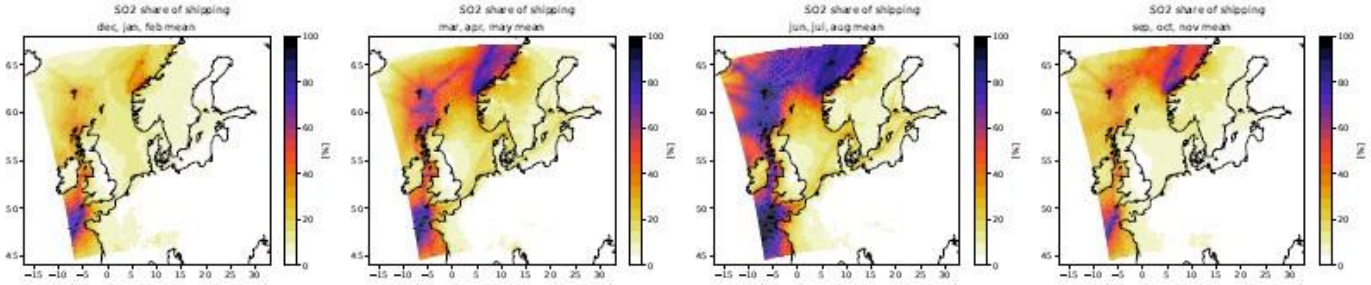

Figure S9. Seasonally averaged, modeled percentage share of ships on SO_2 concentrations in the ground layer in Europe.

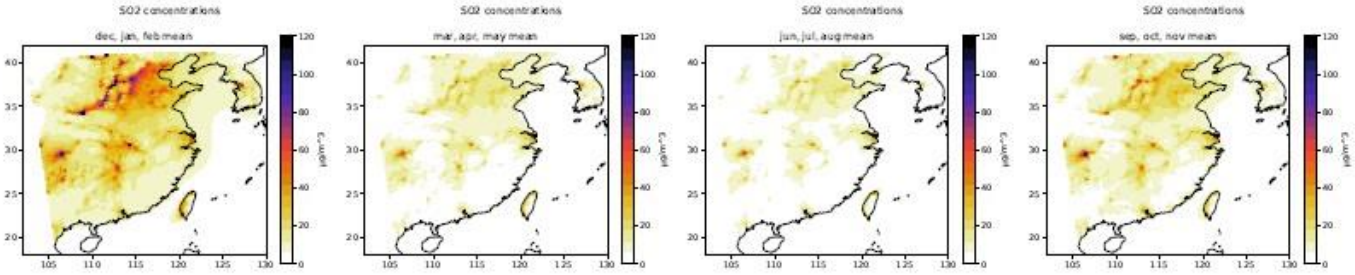

Figure S10. Seasonally averaged, modeled SO_2 concentrations in the ground layer from all sources in China.

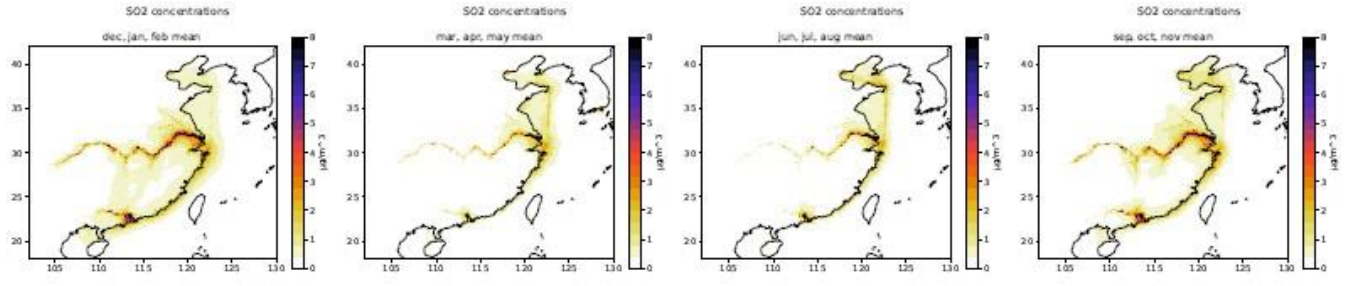

Figure S11. Seasonally averaged, modeled SO_2 concentrations in the ground layer from ships in China.

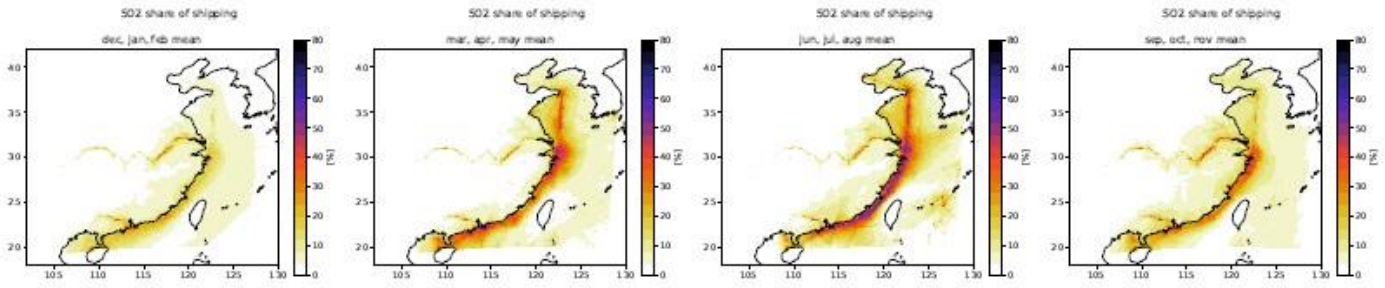

Figure S12. Seasonally averaged, modeled percentage share of ships on SO_2 concentrations in the ground layer in China.

3.3. Ozone

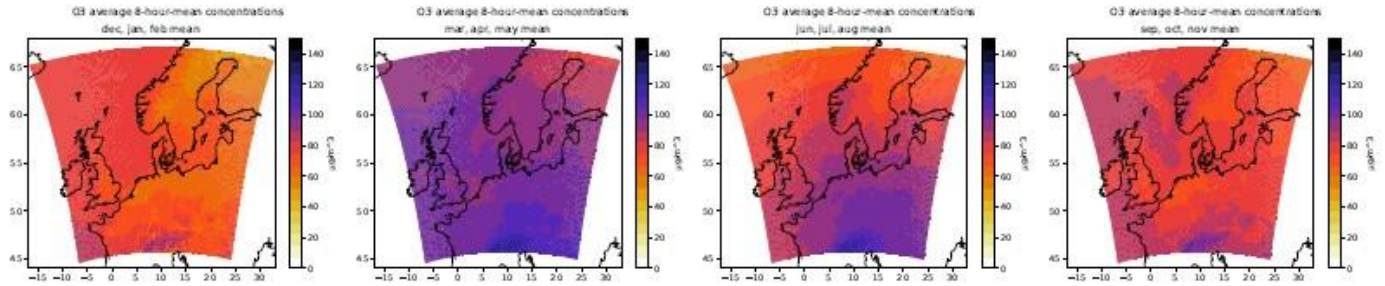

Figure S13. Seasonally averaged, modeled O3 concentrations in the ground layer from all sources in Europe.

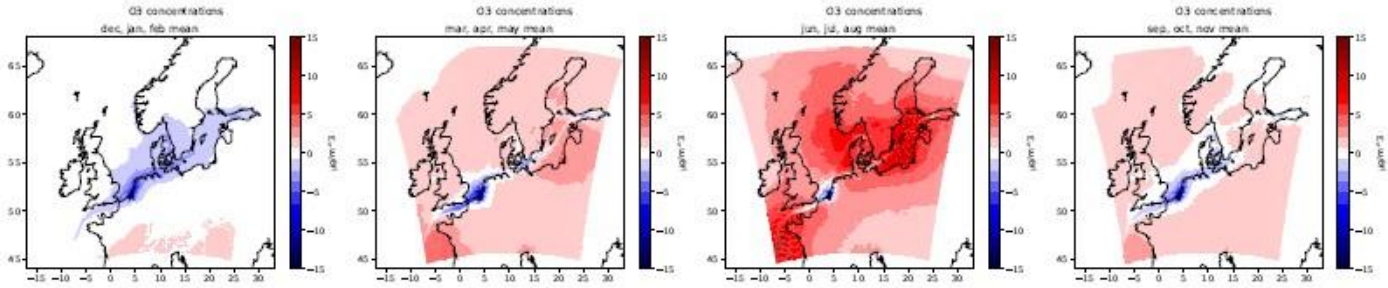

Figure S14. Seasonally averaged, modeled O_3 concentrations in the ground layer from ships in Europe.

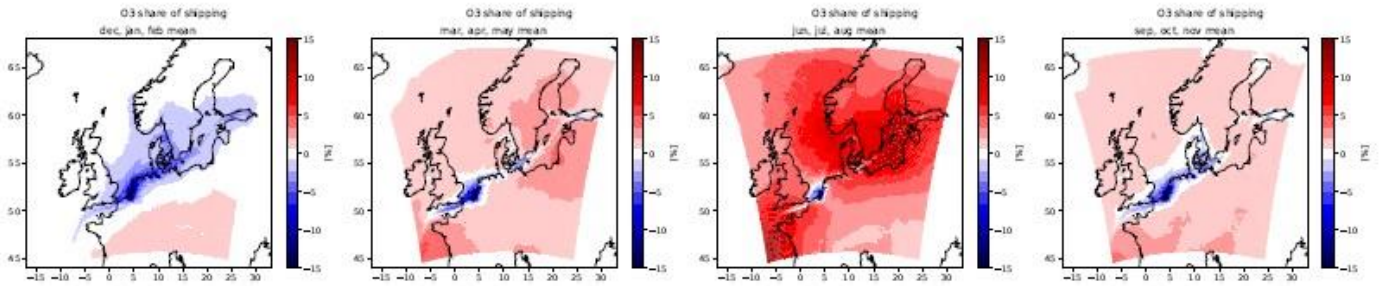

Figure S15. Seasonally averaged, modeled percentage share of ships on O_3 concentrations in the ground layer in Europe.

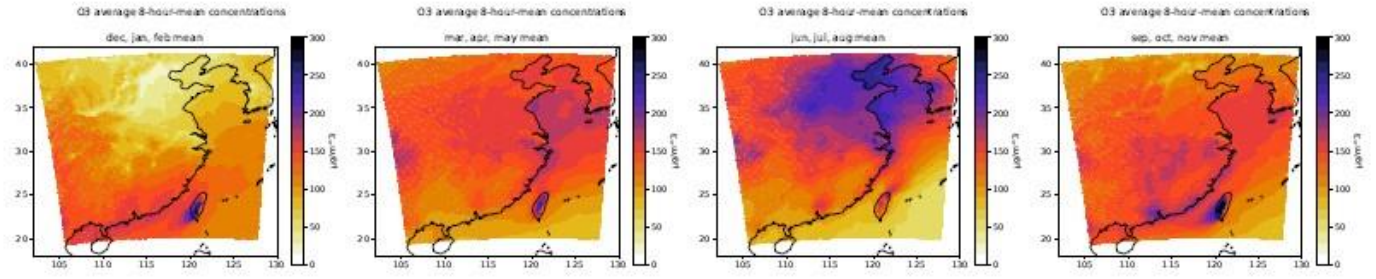

Figure S16. Seasonally averaged, modeled O_3 concentrations in the ground layer from all sources in China.

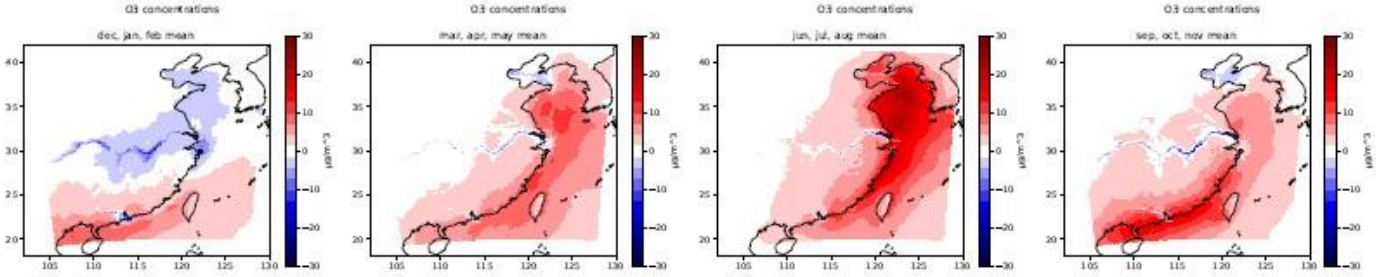

Figure S17. Seasonally averaged, modeled O_3 concentrations in the ground layer from ships in China.

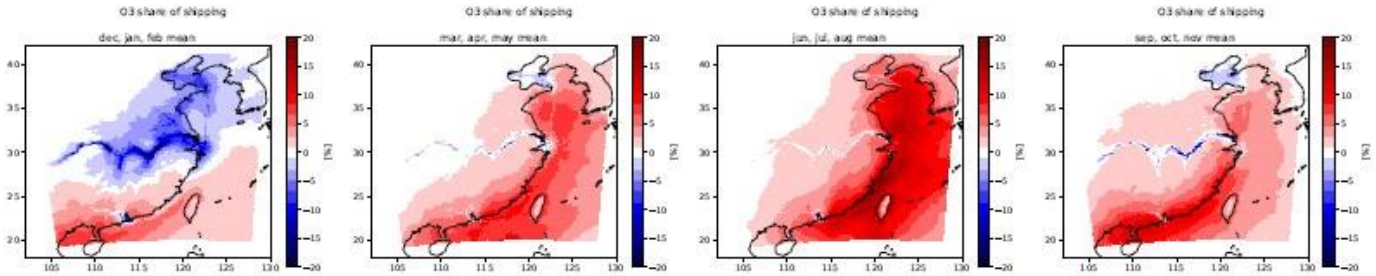

Figure S18. Seasonally averaged, modeled percentage share of ships on O_3 concentrations in the ground layer in China.

3.4. $PM_{2.5}$

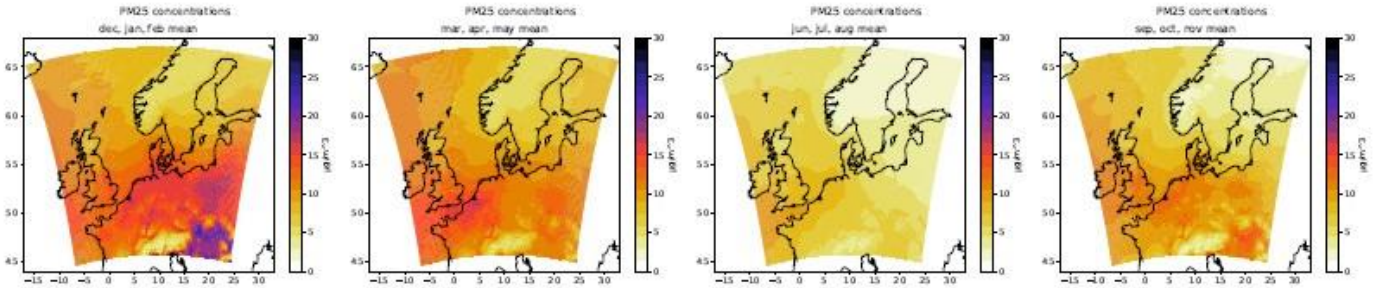

Figure S19. Seasonally averaged $PM_{2.5}$ concentrations in the ground layer from all sources in Europe.

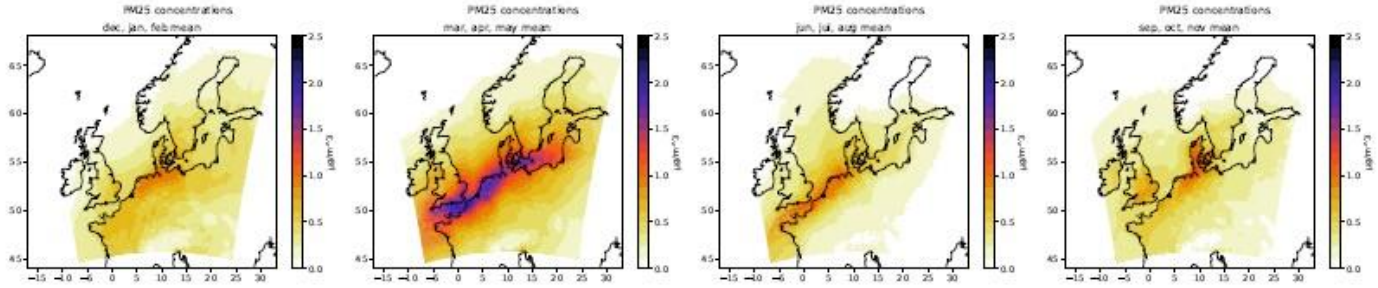

Figure S20. Seasonally averaged, modeled $PM_{2.5}$ concentrations in the ground layer from ships in Europe.

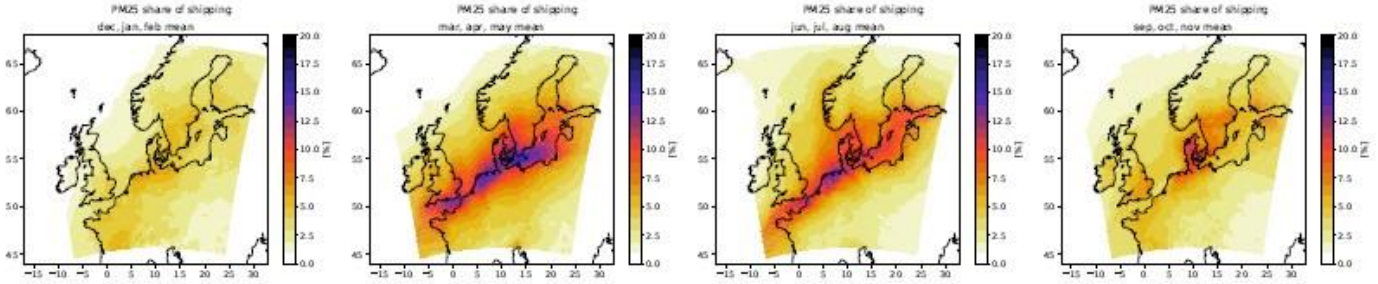

Figure S21. Seasonally averaged, modeled percentage share of ships on $PM_{2.5}$ concentrations in the ground layer in Europe.

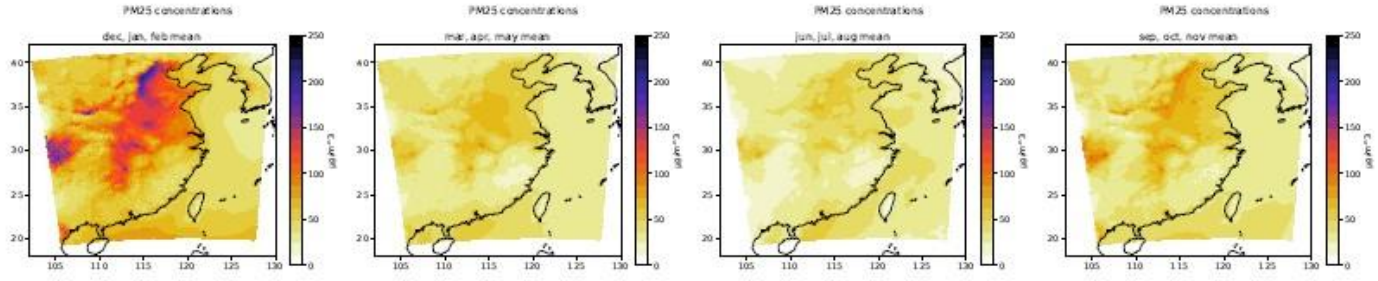

Figure S22. Seasonally averaged, modeled $PM_{2.5}$ concentrations in the ground layer from all sources in China.

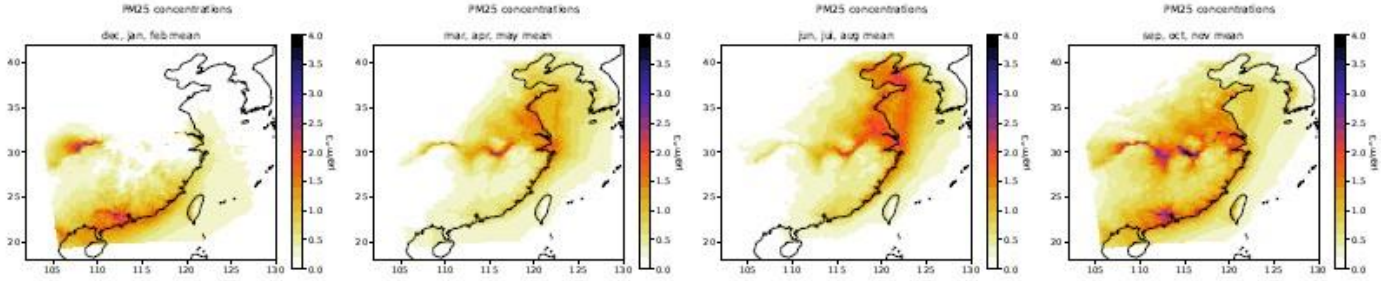

Figure S23. Seasonally averaged, modeled $PM_{2.5}$ concentrations in the ground layer from ships in China.

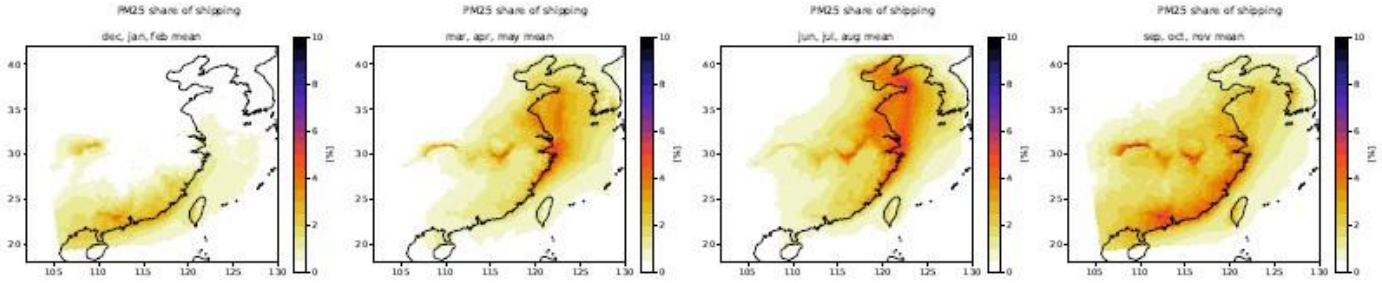

Figure S24. Seasonally averaged, modeled percentage share of ships on $PM_{2.5}$ concentrations in the ground layer in China.

3.5. NH4

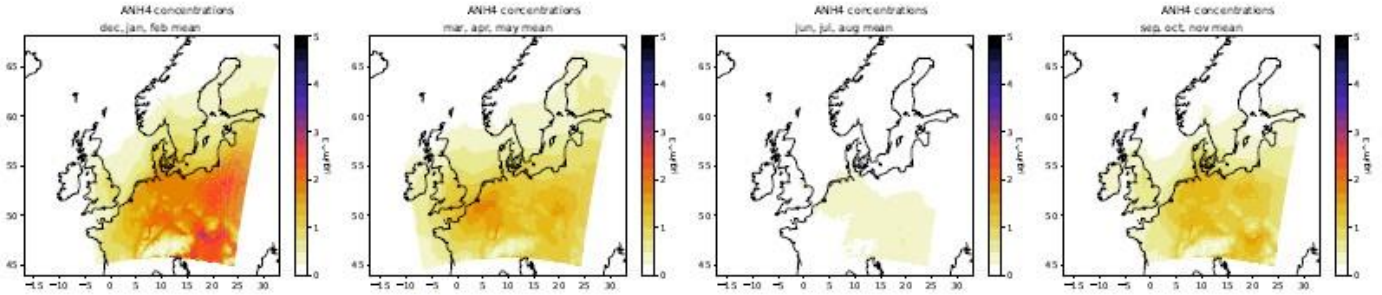

Figure S25. Seasonally averaged, modeled NH_4 concentrations in the ground layer from all sources in Europe.

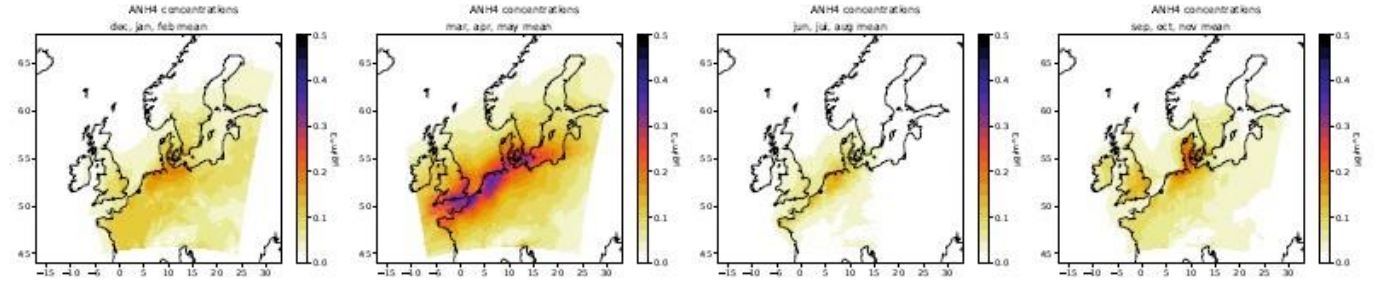

Figure S26. Seasonally averaged, modeled NH_4 concentrations in the ground layer from ships in Europe.

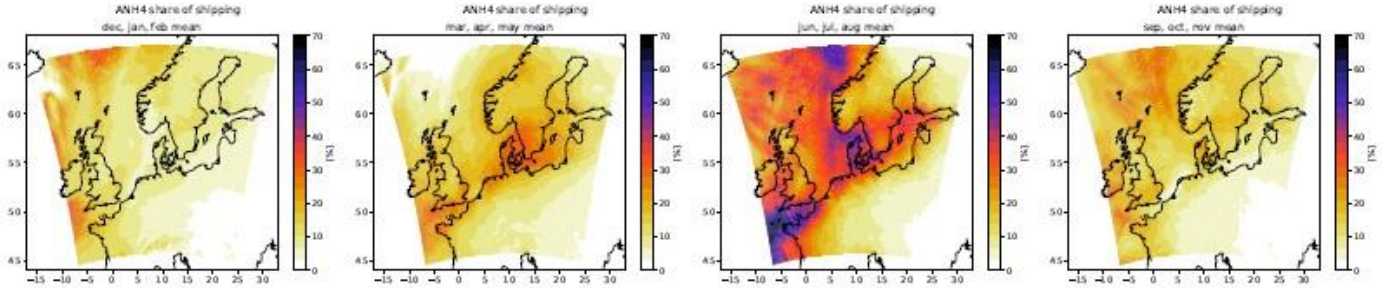

Figure S27. Seasonally averaged, modeled percentage share of ships on NH_4 concentrations in the ground layer in Europe.

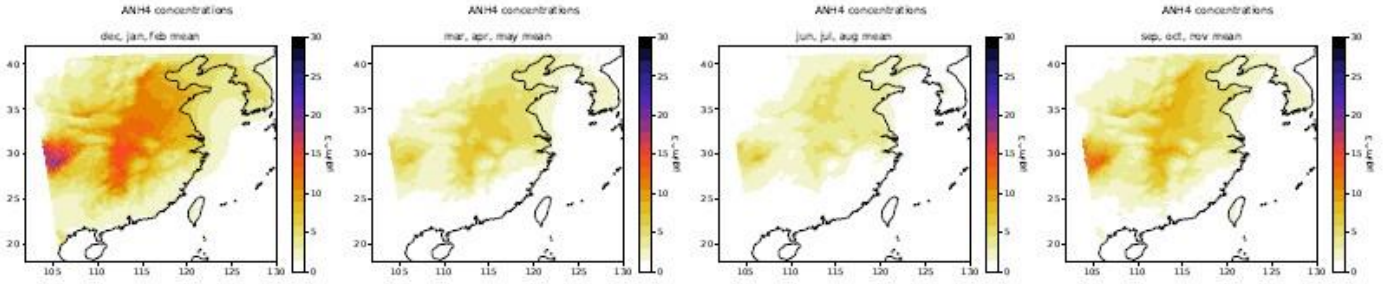

Figure S28. Seasonally averaged, modeled NH_4 concentrations in the ground layer from all sources in China.

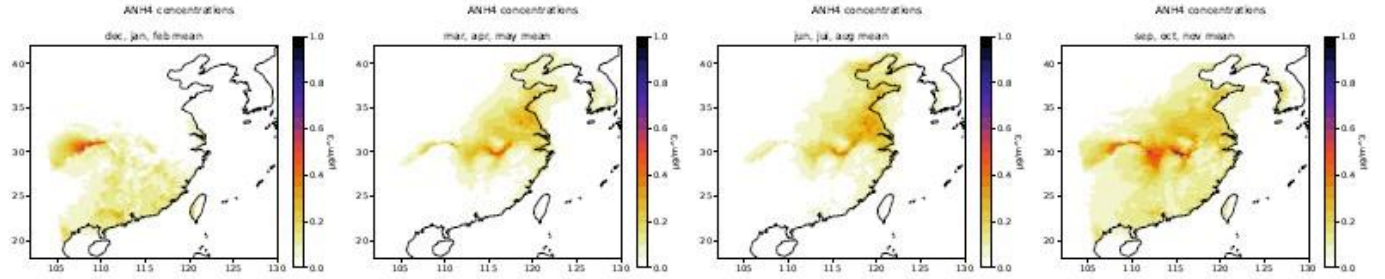

Figure S29. Seasonally averaged, modeled NH_4 concentrations in the ground layer from ships in China.

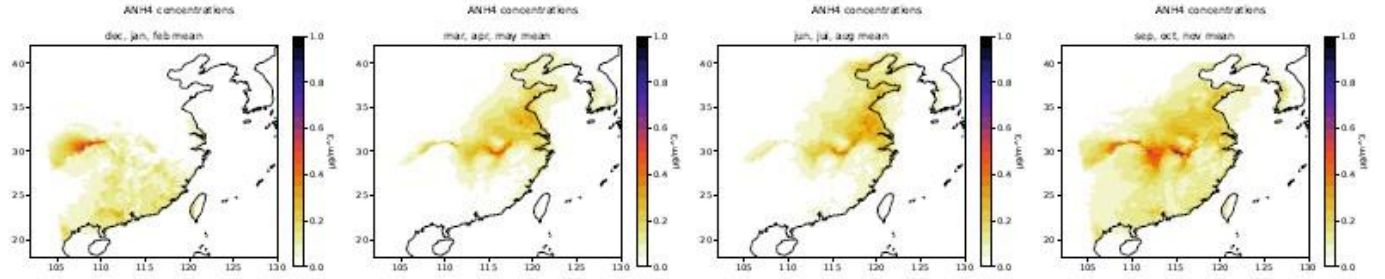

Figure S30. Seasonally averaged, modeled percentage share of ships on NH_4 concentrations in the ground layer in China.

3.6. NH_3 emissions

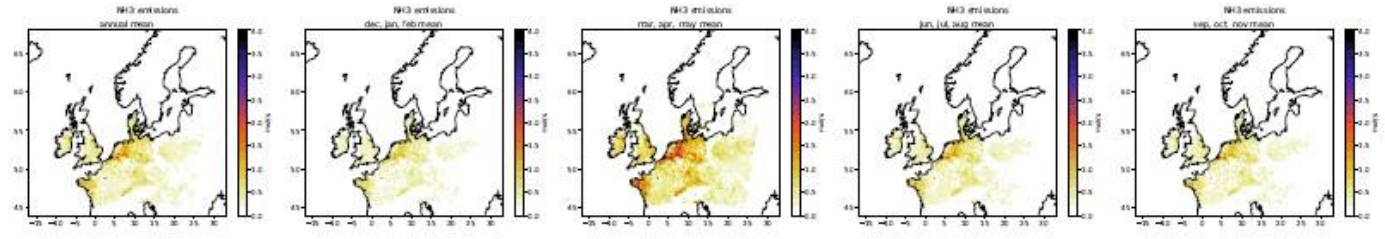

Figure S31. Seasonally averaged, modeled NH_3 emissions in the ground layer in the Europe.

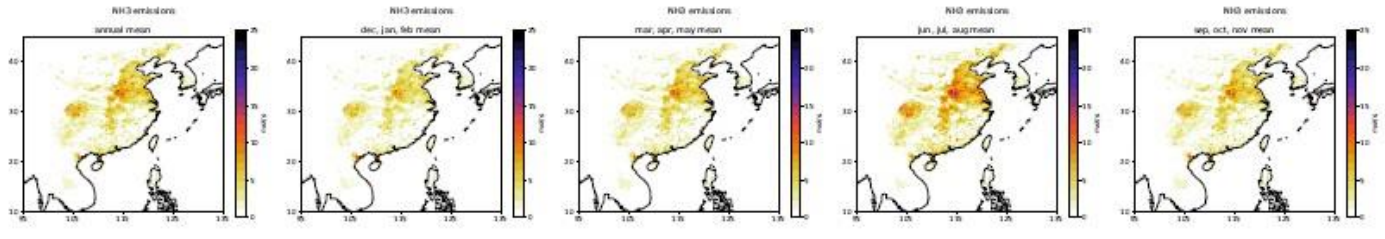

Figure S32. Seasonally averaged, modeled NH_3 emissions in the ground layer in China.

3.7. NO_3

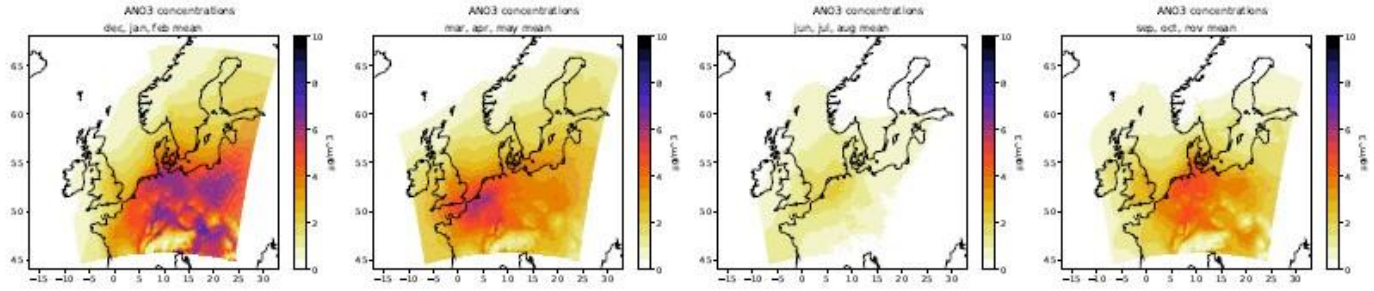

Figure S33. Seasonally averaged, modeled NO_3 concentrations in the ground layer from all sources in Europe.

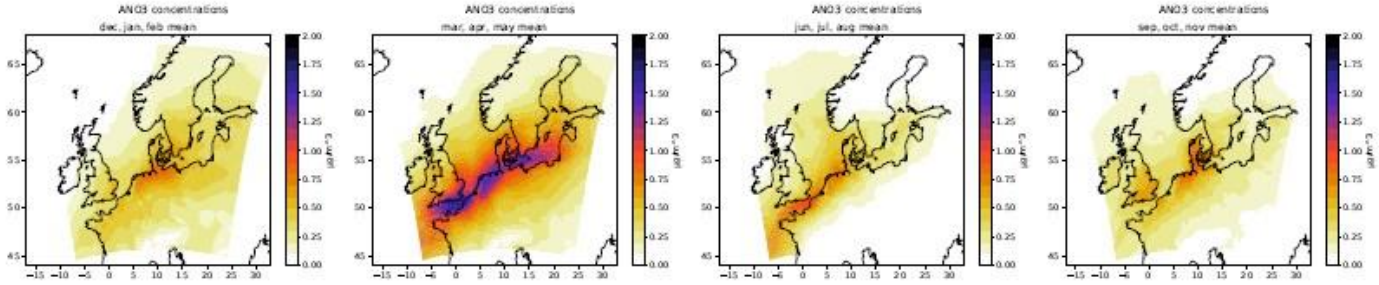

Figure S34. Seasonally averaged, modeled NO_3 concentrations in the ground layer from ships in Europe.

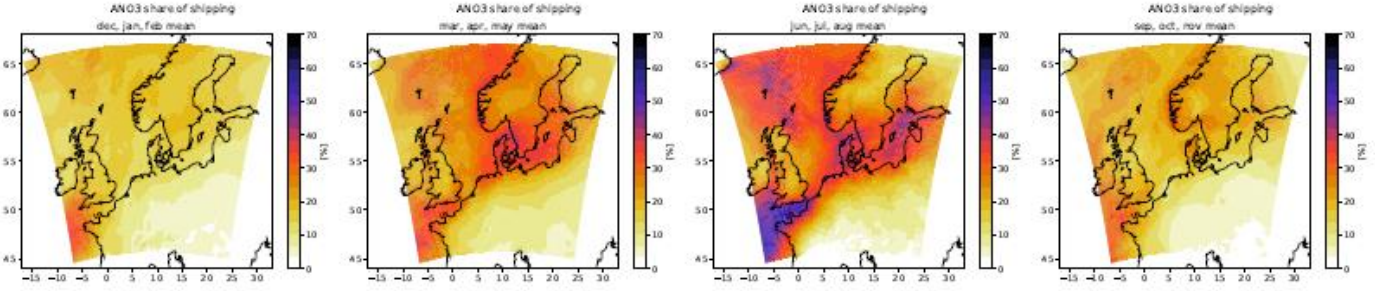

Figure S35. Seasonally averaged, modeled percentage share of ships on NO_3 concentrations in the ground layer in Europe.

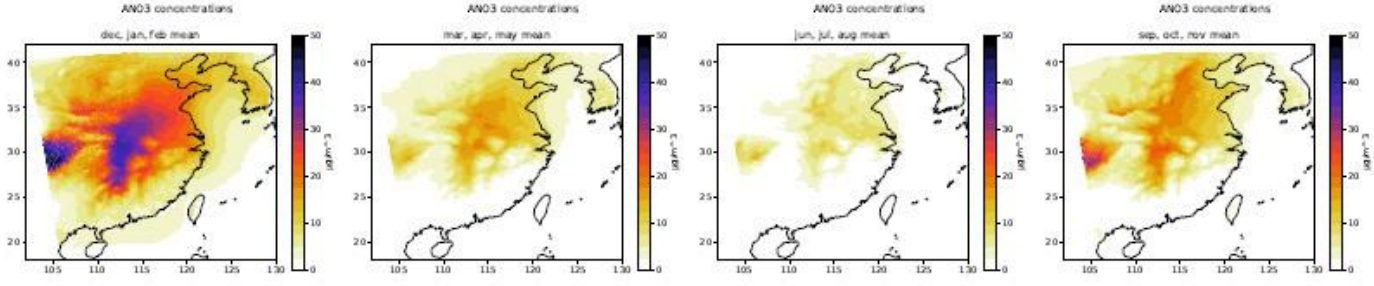

Figure S36. Seasonally averaged, modeled NO_3 concentrations in the ground layer from all sources in China.

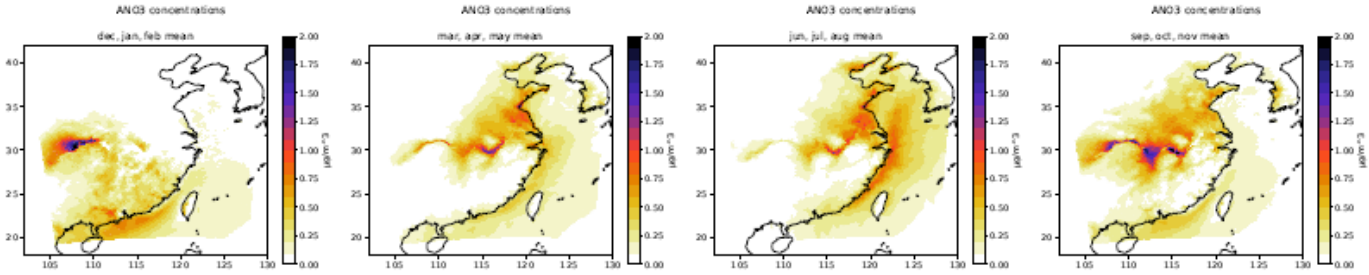

Figure S37. Seasonally averaged, modeled NO_3 concentrations in the ground layer from ships in China.

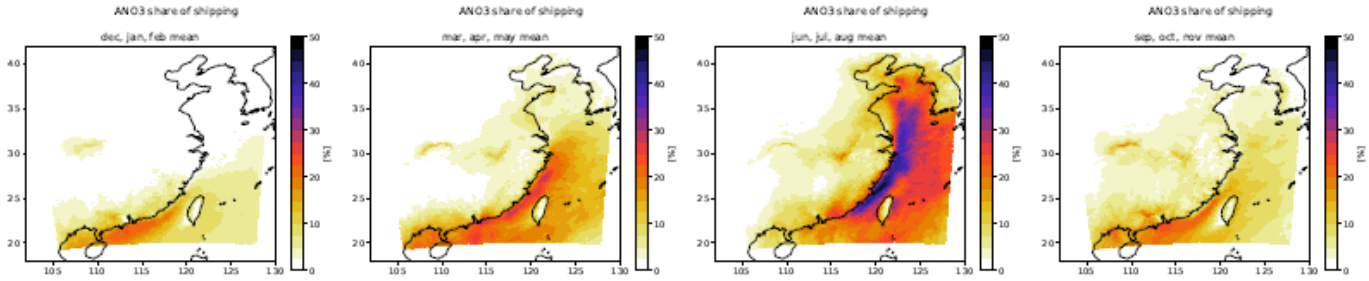

Figure S38. Seasonally averaged, modeled percentage share of ships on NO_3 concentrations in the ground layer in China.

3.8. SO_4

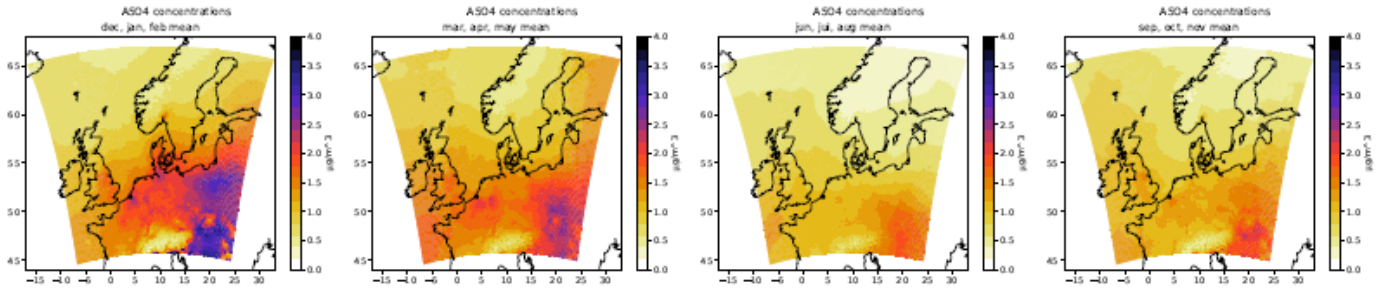

Figure S39. Seasonally averaged, modeled SO_4 concentrations in the ground layer from all sources in Europe.

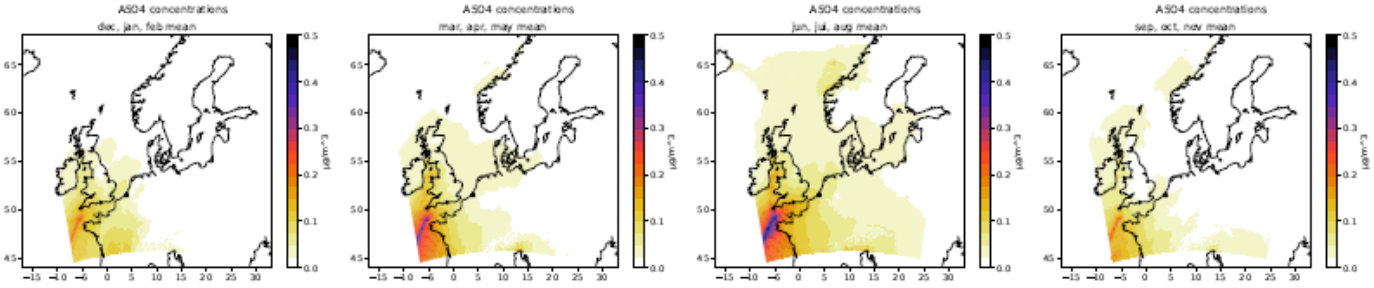

Figure S40. Seasonally averaged, modeled SO_4 concentrations in the ground layer from ships in Europe.

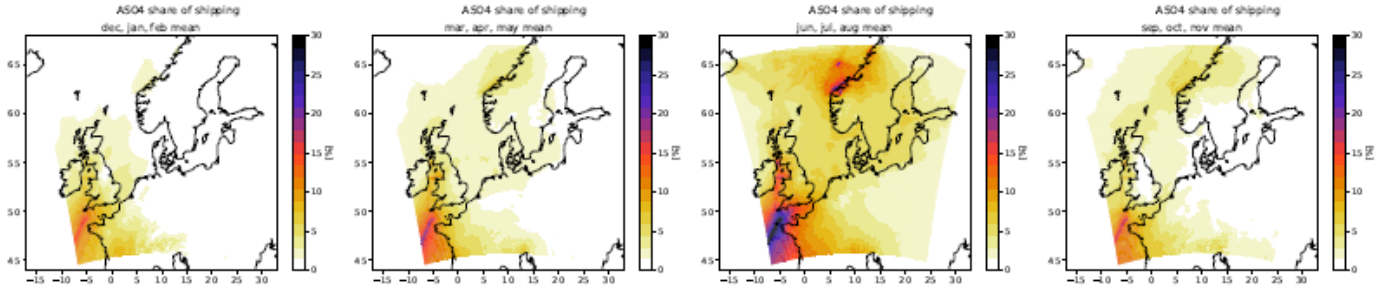

Figure S41. Seasonally averaged, modeled percentage share of ships on SO_4 concentrations in the ground layer in Europe.

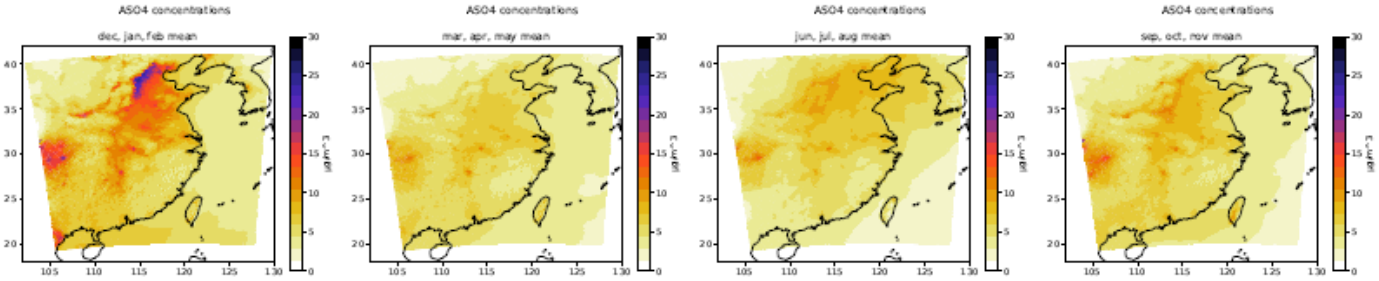

Figure S42. Seasonally averaged, modeled SO_4 concentrations in the ground layer from all sources in China.

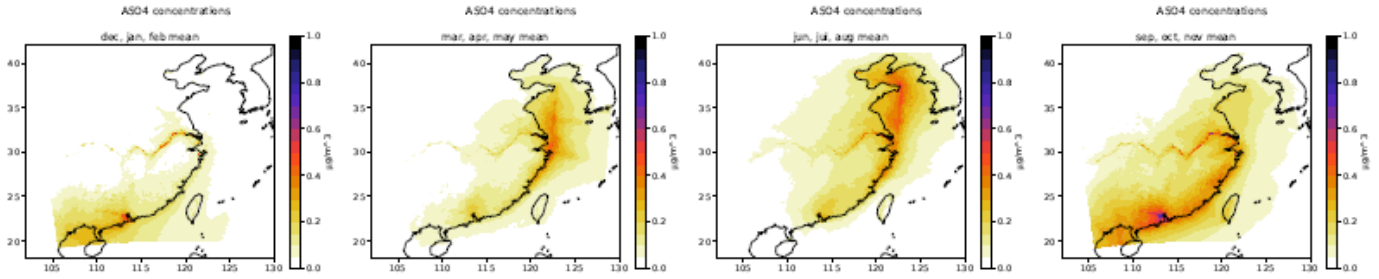

Figure S43. Seasonally averaged, modeled SO_4 concentrations in the ground layer from ships in China.

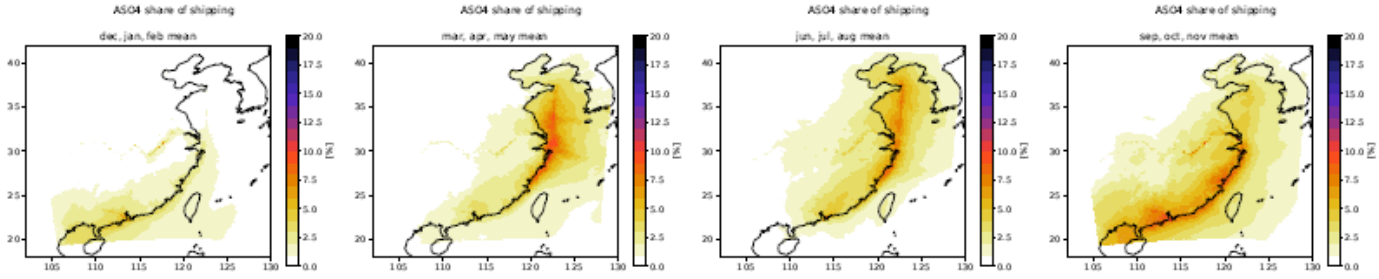

Figure S44. Seasonally averaged, modeled percentage share of ships on SO_4 concentrations in the ground layer in China.