

Supplementary

Global sensitivities of reactive N and S gas and particle concentrations and deposition to precursor emissions reductions

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Table S1: The allocation of IPCC reference regions (Iturbide et al., 2020) in the 4 world regions used in this study.

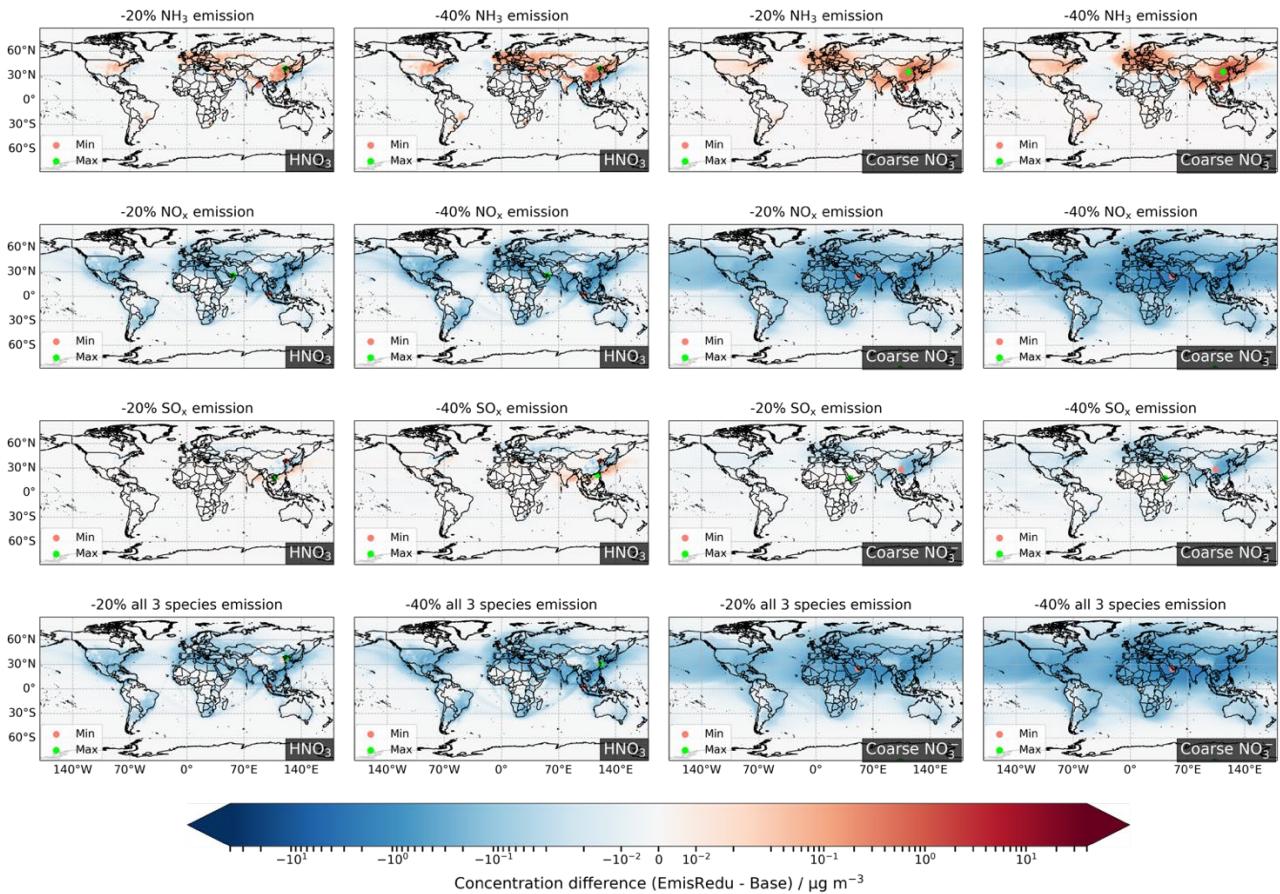
World regions in this paper	IPCC region numbers (0-57)
East Asia	35
South Asia	37
Euro_Medi	16, 17, 19
North America	3, 4, 5

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Table S2: Global and regional sensitivities of NH₃ and NH₄⁺ surface concentrations to individual emission reductions.

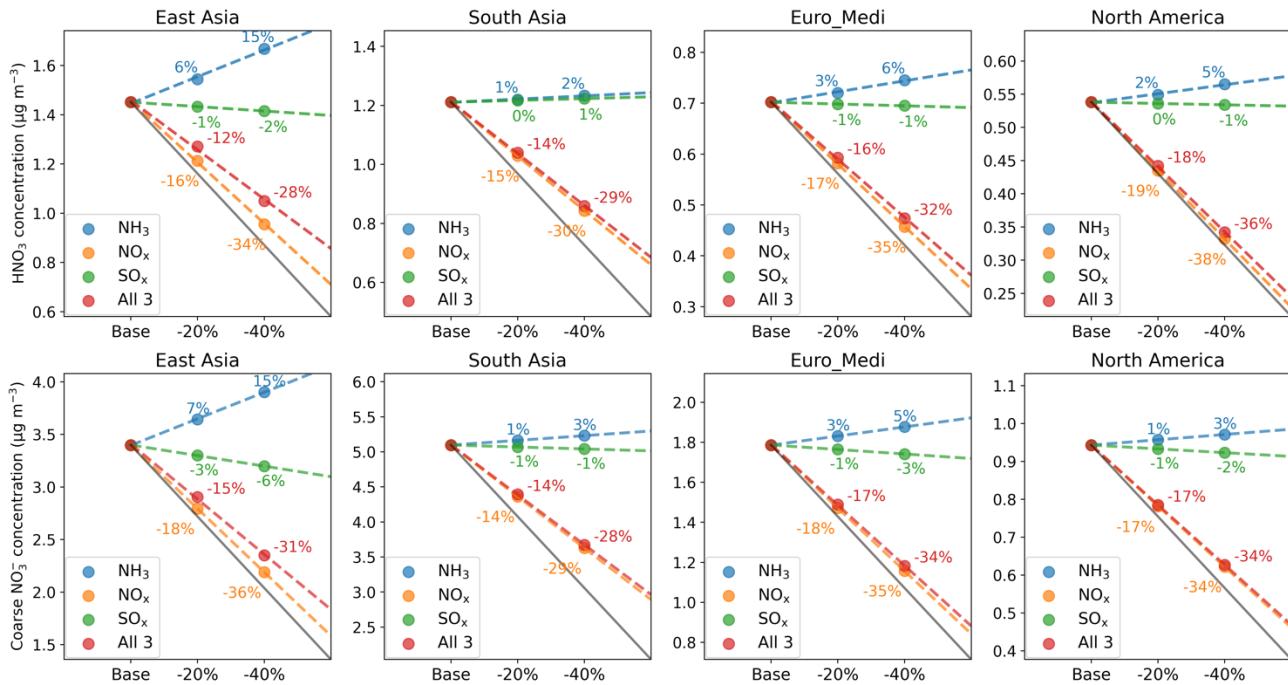
25 **Absolute difference (AD, $\mu\text{g m}^{-3}$) = Emission reduction – Baseline. Relative difference (RD, %) = $\frac{\text{AD}}{\text{Baseline}} \times 100\%$.** Entries in the table are shaded as follows: light blue represents ‘negative difference’; light red represents ‘positive difference’; no colour represents negligible differences (i.e., $|\text{RD}| \leq 3\%$).

Scenario	-20% NH ₃		-20% NO _x		-20% SO _x		-20% All-3		-40% NH ₃		-40% NO _x		-40% SO _x		-40% All-3	
	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD
NH ₃																
East Asia	-1.03	-25%	0.10	2%	0.14	3%	-0.82	-20%	-2.04	-49%	0.24	6%	0.28	7%	-1.62	-39%
NH ₄ ⁺																
East Asia	-0.22	-6%	-0.17	-5%	-0.32	-9%	-0.67	-19%	-0.51	-15%	-0.42	-12%	-0.64	-19%	-1.39	-40%
NH ₃																
South Asia	-1.23	-24%	0.04	1%	0.19	4%	-1.01	-19%	-2.47	-47%	0.09	2%	0.38	7%	-2.02	-39%
NH ₄ ⁺																
South Asia	-0.05	-2%	-0.10	-4%	-0.42	-17%	-0.54	-22%	-0.11	-4%	-0.21	-8%	-0.85	-34%	-1.07	-43%
NH ₃																
Euro_M edi	-0.27	-25%	0.03	2%	0.05	4%	-0.21	-19%	-0.53	-49%	0.06	5%	0.10	9%	-0.42	-38%
NH ₄ ⁺																
Euro_M edi	-0.08	-8%	-0.06	-6%	-0.10	-10%	-0.22	-22%	-0.18	-18%	-0.14	-13%	-0.21	-20%	-0.44	-43%
NH ₃																
North America	-0.24	-24%	0.03	3%	0.03	3%	-0.19	-19%	-0.48	-48%	0.06	6%	0.06	6%	-0.38	-38%
NH ₄ ⁺																
North America	-0.03	-5%	-0.06	-8%	-0.07	-11%	-0.15	-23%	-0.08	-12%	-0.12	-18%	-0.14	-22%	-0.30	-46%
NH ₃																
Globe	-0.09	-24%	0.00	1%	0.02	4%	-0.07	-19%	-0.17	-48%	0.01	3%	0.03	9%	-0.13	-38%
NH ₄ ⁺																
Globe	-0.02	-6%	-0.01	-4%	-0.04	-13%	-0.06	-21%	-0.04	-14%	-0.02	-8%	-0.08	-28%	-0.12	-42%



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Figure S1: Changes in HNO_3 and coarse NO_3^- annual surface concentrations for 20% and 40% emissions reductions in NH_3 , NO_x , and SO_x individually and collectively. Red and green dots in each map locate the minimum and maximum difference, respectively.



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Figure S2: The absolute and relative sensitivities of regionally-averaged annual mean surface concentrations of HNO_3 (upper row) and coarse NO_3^- (lower row) to 20% and 40% emissions reductions in NH_3 (blue), NO_x (orange) and SO_x (green) individually, and collectively (red), for the four regions defined in Fig. 1. The solid grey line in each panel illustrates the one-to-one relative response to emissions reductions, whilst the coloured dashed lines are the linear regressions through each set of three model simulations and illustrate the actual responses to emissions reductions of a given precursor. The numbers show the corresponding relative responses to each emissions reduction (with respect to baseline).

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Table S3: Global and regional sensitivities of NO_x, HNO₃, fine NO₃⁻ and coarse NO₃⁻ surface concentrations to individual emission reductions. Absolute difference (AD, $\mu\text{g m}^{-3}$) = Emission reduction – Baseline. Relative difference (RD, %) = $\frac{\text{AD}}{\text{Baseline}} \times 100\%$. Entries in the table are shaded as follows: light blue represents ‘negative difference’; light red represents ‘positive difference’; no colour represents negligible differences (i.e., $|\text{RD}| \leq 3\%$).

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Scenario	-20% NH ₃		-20% NO _x		-20% SO _x		-20% All-3		-40% NH ₃		-40% NO _x		-40% SO _x		-40% All-3	
	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD
NO _x																
East Asia	-0.03	-0%	-2.54	-24%	0.00	0%	-2.57	-24%	-0.08	-1%	-4.76	-45%	0.01	0%	-4.79	-45%
	0.09	6%	-0.24	-16%	-0.02	-1%	-0.18	-12%	0.22	15%	-0.50	-34%	-0.04	-2%	-0.40	-28%
	-0.72	-14%	-0.72	-14%	0.20	4%	-1.10	-22%	-1.62	-32%	-1.65	-33%	0.40	8%	-2.26	-45%
	0.25	7%	-0.60	-18%	-0.10	-3%	-0.49	-15%	0.51	15%	-1.21	-36%	-0.20	-6%	-1.05	-31%
HNO ₃																
South Asia	-0.00	-0%	-0.80	-11%	-0.01	0%	-0.81	-11%	-0.01	-0%	-1.57	-22%	-0.02	-0%	-1.59	-23%
	0.01	1%	-0.18	-15%	0.01	0%	-0.17	-14%	0.02	2%	-0.37	-30%	0.01	1%	-0.35	-29%
	-0.15	-18%	-0.19	-23%	0.03	4%	-0.28	-33%	-0.33	-39%	-0.38	-45%	0.07	8%	-0.51	-60%
	0.07	1%	-0.73	-14%	-0.03	-1%	-0.70	-14%	0.13	3%	-1.47	-29%	-0.06	-1%	-1.42	-28%
Fine NO ₃ ⁻																
Euro_M edi	-0.00	-0%	-0.80	-20%	0.00	0%	-0.80	-20%	-0.01	-0%	-1.55	-38%	0.01	0%	-1.55	-38%
	0.02	3%	-0.12	-17%	-0.00	0%	-0.11	-15%	0.04	6%	-0.24	-35%	-0.01	-1%	-0.23	-32%
	-0.17	-15%	-0.22	-19%	0.04	4%	-0.31	-27%	-0.37	-33%	-0.47	-41%	0.09	8%	-0.61	-53%
	0.04	3%	-0.32	-18%	-0.02	-1%	-0.30	-17%	0.09	5%	-0.63	-35%	-0.05	-3%	-0.60	-34%
Coarse NO ₃ ⁻																
North America	-0.00	-0%	-0.75	-19%	0.00	0%	-0.75	-18%	-0.01	-0%	-1.47	-36%	0.01	0%	-1.47	-36%
	0.01	2%	-0.10	-19%	-0.00	0%	-0.10	-18%	0.03	5%	-0.21	-38%	-0.00	-1%	-0.20	-36%
	-0.10	-12%	-0.18	-20%	0.02	2%	-0.24	-27%	-0.23	-26%	-0.37	-42%	0.04	4%	-0.46	-53%
	0.01	2%	-0.16	-17%	-0.01	-1%	-0.16	-17%	0.03	3%	-0.32	-34%	-0.02	-2%	-0.32	-34%
NO _x																
Globe	-0.00	-0%	-0.16	-15%	0.00	0%	-0.16	-15%	-0.00	-0%	-0.31	-30%	0.00	0%	-0.31	-30%
	0.00	1%	-0.03	-15%	-0.00	0%	-0.03	-15%	0.01	3%	-0.06	-31%	-0.00	-1%	-0.05	-30%
	-0.03	-14%	-0.03	-16%	0.01	5%	-0.05	-22%	-0.06	-30%	-0.07	-35%	0.02	10%	-0.09	-44%
	0.01	1%	-0.10	-14%	-0.01	-1%	-0.10	-14%	0.02	2%	-0.21	-28%	-0.01	-2%	-0.21	-28%

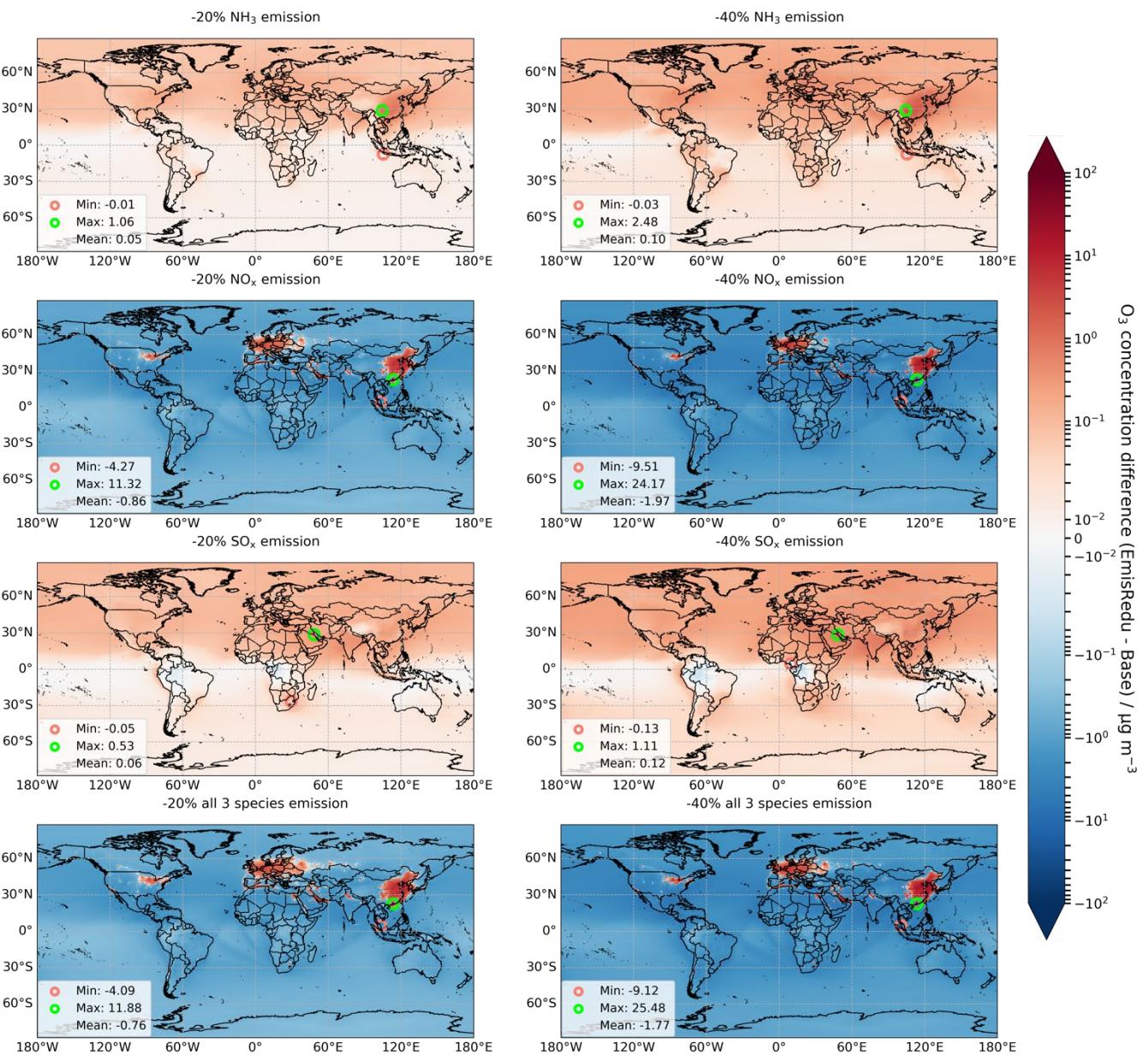


Figure S3: Changes in O₃ annual surface concentrations for 20% and 40% emissions reductions in NH₃, NO_x, and SO_x individually and collectively. Red and green dots in each map locate the minimum and maximum difference, respectively.

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Table S4: Global and regional sensitivities of SO₂, and SO₄²⁻ surface concentrations to individual emission reductions.
Absolute difference (AD, $\mu\text{g m}^{-3}$) = Emission reduction – Baseline. **Relative difference (RD, %) = $\frac{\text{AD}}{\text{Baseline}} \times 100\%$** .
Entries in the table are shaded as follows: light blue represents ‘negative difference’; light red represents ‘positive difference’; no colour represents negligible differences (i.e., $|\text{RD}| \leq 3\%$).

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Scenario	-20% NH ₃		-20% NO _x		-20% SO _x		-20% All-3		-40% NH ₃		-40% NO _x		-40% SO _x		-40% All-3	
	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD
SO ₂																
East Asia	0.31	7%	-0.10	-2%	-1.01	-24%	-0.87	-20%	0.71	16%	-0.21	-5%	-1.95	-45%	-1.75	-41%
SO ₄ ²⁻																
South Asia	0.02	0%	0.10	2%	-1.06	-19%	-0.97	-17%	0.07	1%	0.17	3%	-2.12	-38%	-2.01	-36%
SO ₂																
Euro_M edi	0.10	4%	0.02	1%	-0.52	-22%	-0.46	-19%	0.34	14%	0.05	2%	-1.01	-43%	-0.92	-39%
	0.05	1%	-0.11	-2%	-1.18	-19%	-1.25	-20%	0.14	2%	-0.27	-4%	-2.37	-38%	-2.50	-41%
SO ₂																
North America	0.03	5%	-0.00	-1%	-0.12	-22%	-0.10	-20%	0.07	14%	-0.01	-1%	-0.23	-43%	-0.20	-39%
	0.00	0%	-0.01	-1%	-0.22	-19%	-0.23	-19%	0.01	1%	-0.03	-3%	-0.44	-37%	-0.46	-39%
SO ₂																
Globe	0.01	3%	-0.00	-0%	-0.07	-19%	-0.06	-17%	0.03	8%	-0.00	-0%	-0.13	-36%	-0.12	-33%
	0.00	0%	-0.00	-1%	-0.14	-16%	-0.14	-17%	0.01	1%	-0.01	-2%	-0.29	-33%	-0.29	-34%

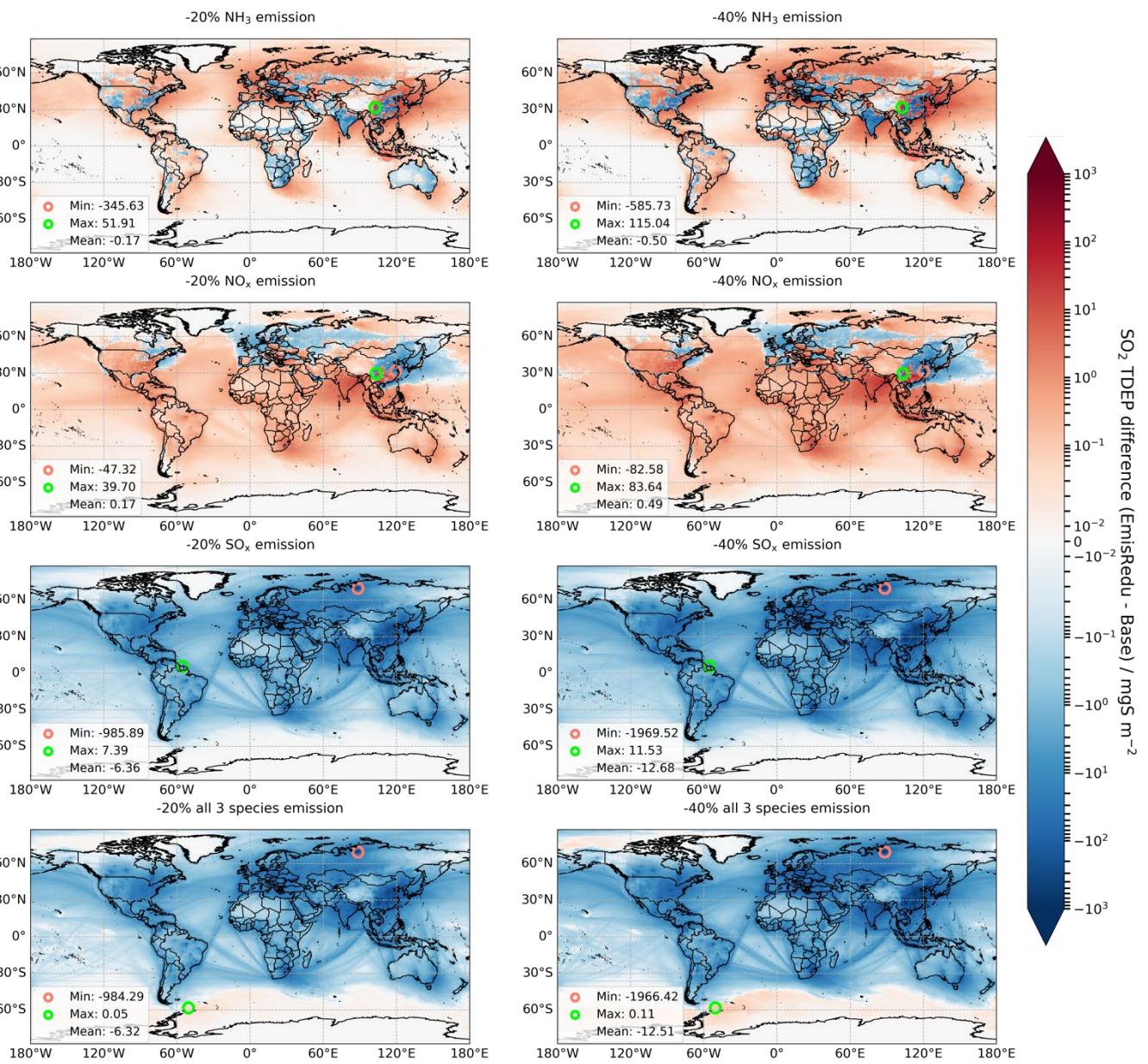
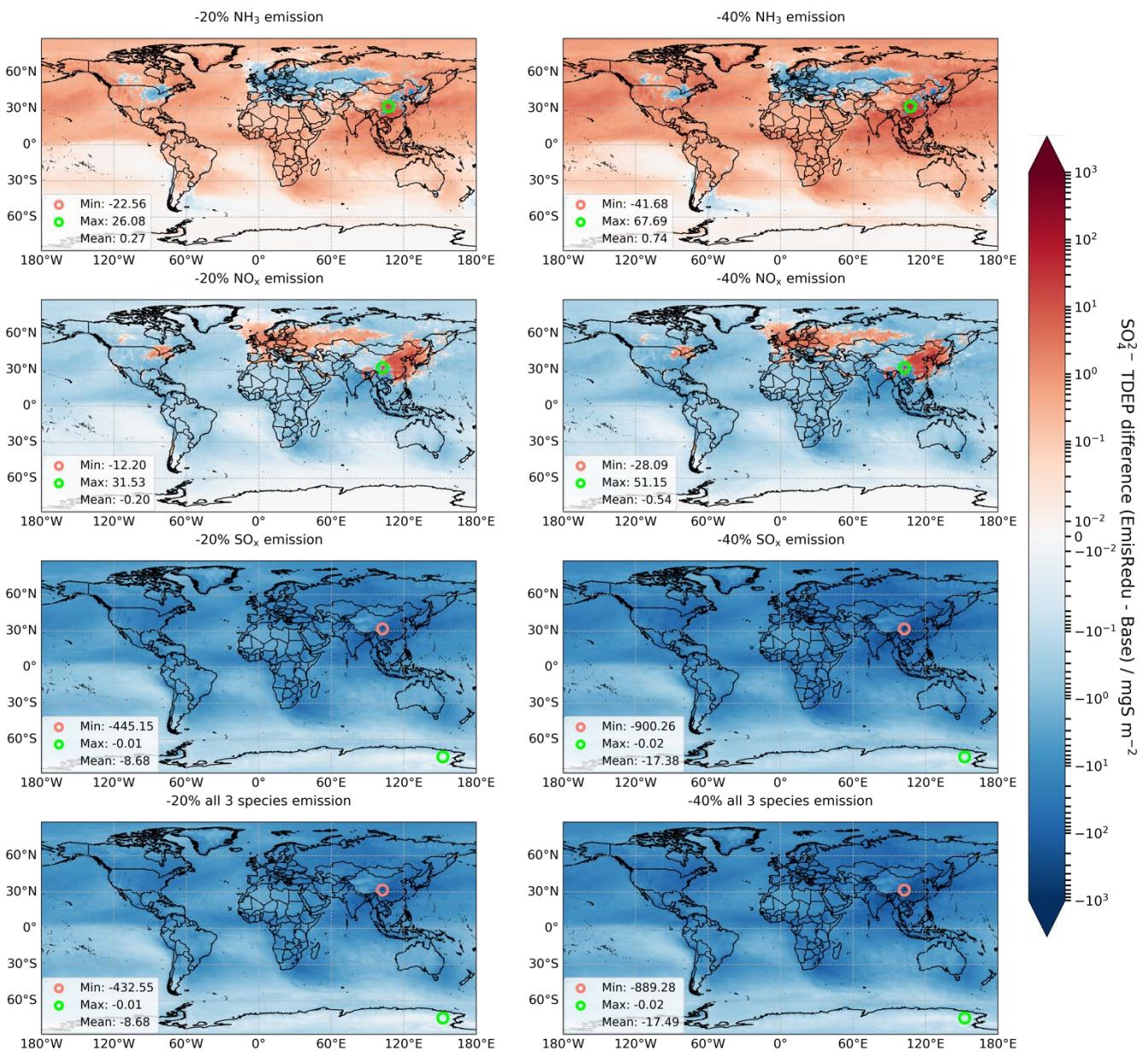


Figure S4: Changes in SO₂ total deposition (wet + dry; abbreviated as TDEP) for 20% and 40% emissions reductions in NH₃, NO_x, and SO_x individually and collectively. Red and green dots in each map locate the minimum and maximum difference, respectively.

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75 **Figure S5: Changes in SO_4^{2-} total deposition (wet + dry; abbreviated as TDEP) annual surface concentrations for 20% and 40% emissions reductions in NH_3 , NO_x , and SO_x individually and collectively. Red and green dots in each map locate the minimum and maximum difference, respectively.**

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Table S5: Global and regional sensitivities of PM_{2.5} surface concentrations to individual emission reductions.
Absolute difference (AD, $\mu\text{g m}^{-3}$) = Emission reduction – Baseline. **Relative difference (RD, %) = $\frac{\text{AD}}{\text{Baseline}} \times 100\%$** .
Entries in the table are shaded as follows: light blue represents ‘negative difference’; light red represents ‘positive difference’; no colour represents negligible differences (i.e., $|\text{RD}| \leq 3\%$).

Scenario	-20% NH ₃		-20% NO _x		-20% SO _x		-20% All-3		-40% NH ₃		-40% NO _x		-40% SO _x		-40% All-3	
PM _{2.5}	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD	AD	RD
East Asia	-0.90	-3%	-0.77	-3%	-1.15	-4%	-2.70	-10%	-2.03	-7%	-1.89	-7%	-2.33	-8%	-5.59	-20%
South Asia	-0.15	0%	-0.45	-1%	-1.54	-5%	-2.09	-7%	-0.29	-1%	-0.97	-3%	-3.10	-10%	-4.13	-13%
Euro_M edi	-0.25	-2%	-0.28	-3%	-0.41	-4%	-0.89	-9%	-0.55	-5%	-0.62	-6%	-0.82	-8%	-1.78	-17%
North America	-0.13	-2%	-0.29	-4%	-0.27	-3%	-0.65	-8%	-0.29	-4%	-0.63	-8%	-0.54	-7%	-1.31	-17%
Globe	-0.04	-1%	-0.05	-1%	-0.17	-3%	-0.25	-4%	-0.09	-1%	-0.12	-2%	-0.34	-5%	-0.51	-8%

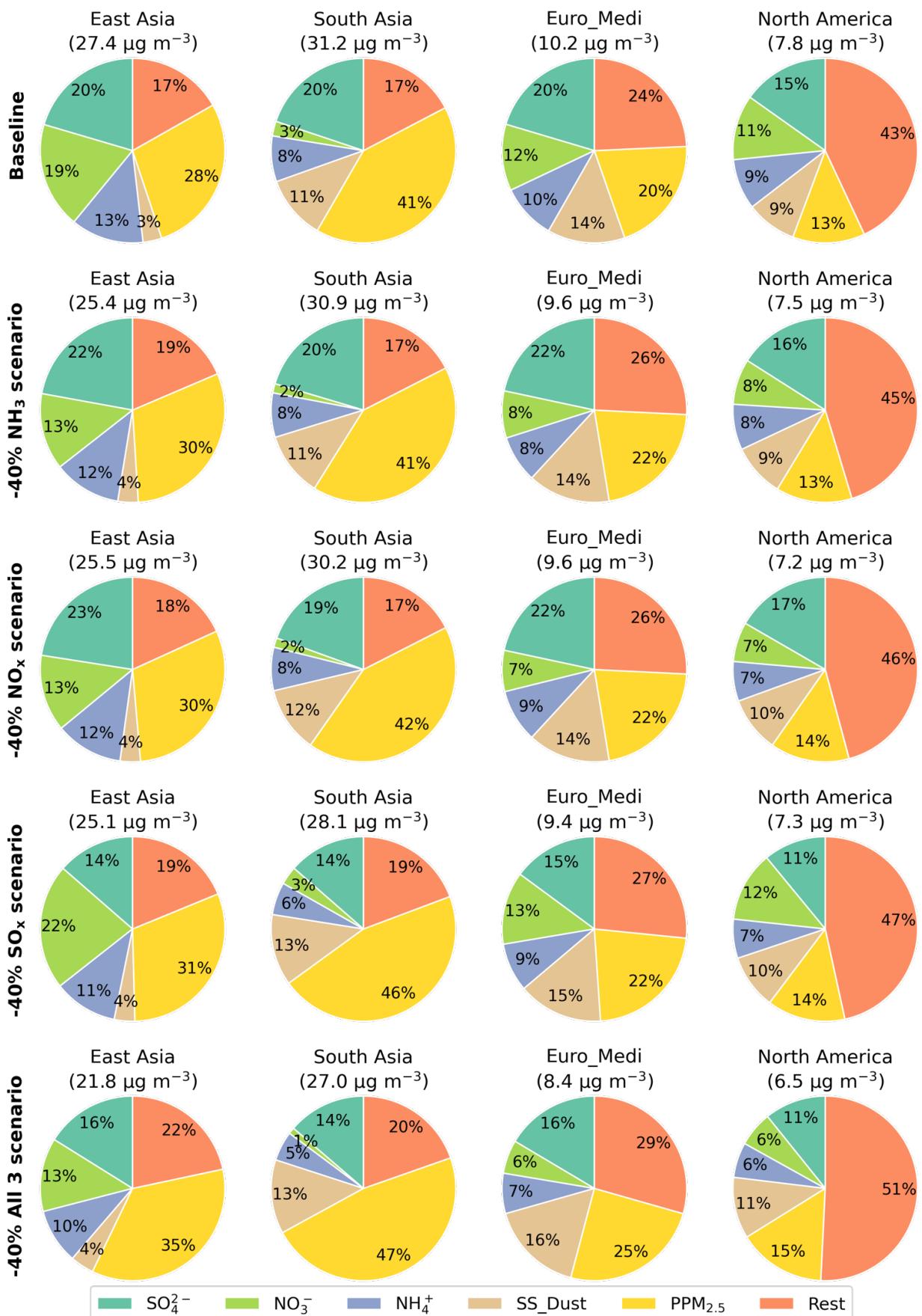


Figure S6: The percentage contributions of individual PM_{2.5} components to regionally-averaged annual mean surface concentrations of PM_{2.5} in baseline (top row) and scenarios of 40% emissions reductions in NH₃ (2nd row), NO_x (3rd row), and SO_x (4th row) individually, and collectively (bottom row), for the four regions defined in Fig. 1. The numbers labelled below each region show the corresponding absolute PM_{2.5} concentrations .

100 **Table S6: The percentage contributions of individual species total deposition (wet + dry) to RDN ($\text{NH}_3 + \text{NH}_4^+$) and OXN ($\text{NO}_x + \text{HNO}_3 + \text{TNO}_3^-$ (fine and coarse NO_3^-) + Rest OXN) total deposition (TgN yr^{-1}), in baseline and scenarios of 20% and 40% emissions reductions in NH_3 , NO_x , and SO_x individually and collectively, for the four regions defined in Fig. 1.**

		Baseline	-20%	-20%	-20%	-20%	-40%	-40%	-40%	-40%
			NH ₃	NO _x	SO _x	All 3	NH ₃	NO _x	SO _x	All 3
East Asia	RDN	12.0	9.66	12.0	12.0	9.69	7.30	12.1	12.1	7.34
	NH ₃	59%	54%	61%	61%	59%	47%	64%	65%	61%
	NH ₄ ⁺	41%	46%	39%	39%	41%	53%	36%	35%	39%
	OXN	8.33	8.36	6.87	8.32	6.88	8.39	5.40	8.31	5.42
	NO _x	12%	11%	11%	12%	11%	11%	11%	12%	11%
	HNO ₃	30%	33%	29%	28%	31%	37%	29%	27%	32%
	TNO ₃ ⁻	54%	51%	54%	55%	53%	47%	54%	57%	51%
	Rest	4%	5%	6%	5%	5%	5%	6%	4%	6%
South Asia	RDN	5.46	4.34	5.47	5.50	4.39	3.22	5.48	5.55	3.32
	NH ₃	76%	71%	77%	80%	77%	64%	78%	84%	77%
	NH ₄ ⁺	24%	29%	23%	20%	23%	36%	22%	16%	23%
	OXN	3.08	3.09	2.68	3.08	2.69	3.09	2.28	3.08	2.29
	NO _x	12%	12%	13%	12%	12%	12%	13%	12%	12%
	HNO ₃	29%	30%	29%	29%	29%	30%	29%	29%	29%
	TNO ₃ ⁻	54%	53%	53%	54%	53%	53%	54%	54%	53%
	Rest	5%	5%	5%	5%	6%	5%	5%	5%	6%
Euro_Medi	RDN	3.76	2.99	3.77	3.78	3.02	2.23	3.79	3.80	2.28
	NH ₃	64%	60%	67%	67%	66%	55%	69%	70%	67%
	NH ₄ ⁺	36%	40%	33%	33%	34%	45%	31%	30%	33%
	OXN	4.01	4.02	3.29	4.00	3.30	4.04	2.57	4.00	2.58
	NO _x	14%	14%	14%	14%	14%	14%	14%	14%	14%
	HNO ₃	31%	33%	31%	31%	32%	34%	31%	31%	33%
	TNO ₃ ⁻	48%	47%	48%	48%	47%	45%	47%	49%	45%
	Rest	7%	6%	7%	7%	7%	7%	8%	6%	8%
North America	RDN	3.25	2.61	3.26	3.25	2.62	1.98	3.26	3.26	1.99
	NH ₃	61%	57%	63%	65%	63%	51%	66%	68%	64%
	NH ₄ ⁺	39%	43%	37%	35%	37%	49%	34%	32%	36%
	OXN	3.73	3.74	3.08	3.73	3.08	3.75	2.43	3.72	2.44
	NO _x	15%	15%	15%	15%	15%	15%	15%	15%	15%
	HNO ₃	38%	39%	36%	36%	37%	41%	35%	35%	36%
	TNO ₃ ⁻	38%	36%	38%	39%	37%	34%	38%	40%	36%
	Rest	9%	10%	11%	10%	11%	10%	12%	10%	13%

Table S7: The percentage contributions of SO₂ and SO₄²⁻ total deposition (wet + dry) to OXS total deposition (TgN yr⁻¹), in baseline and scenarios of 20% and 40% emissions reductions in NH₃, NO_x, and SO_x individually and collectively, for the four regions defined in Fig. 1.

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		Baseline	-20%	-20%	-20%	-20%	-40%	-40%	-40%	-40%
		NH ₃	NO _x	SO _x	All 3	NH ₃	NO _x	SO _x	All 3	
East Asia	OXS	8.30	8.28	8.30	6.68	6.66	8.24	8.31	5.06	5.04
	SO ₂	56%	56%	56%	56%	56%	55%	56%	56%	55%
	SO ₄ ²⁻	44%	44%	44%	44%	44%	45%	44%	44%	45%
South Asia	OXS	2.78	2.77	2.79	2.25	2.25	2.73	2.80	1.71	1.71
	SO ₂	49%	49%	50%	49%	50%	48%	51%	49%	50%
	SO ₄ ²⁻	51%	51%	50%	51%	50%	52%	49%	51%	50%
Euro_Medi	OXS	3.51	3.49	3.52	2.93	2.92	3.48	3.52	2.34	2.33
	SO ₂	58%	58%	58%	58%	58%	58%	58%	57%	57%
	SO ₄ ²⁻	42%	42%	42%	42%	42%	42%	42%	43%	43%
North America	OXS	2.12	2.13	2.13	1.74	1.73	2.12	2.13	1.34	1.33
	SO ₂	44%	44%	45%	44%	45%	43%	45%	44%	44%
	SO ₄ ²⁻	56%	56%	55%	56%	55%	57%	55%	56%	56%

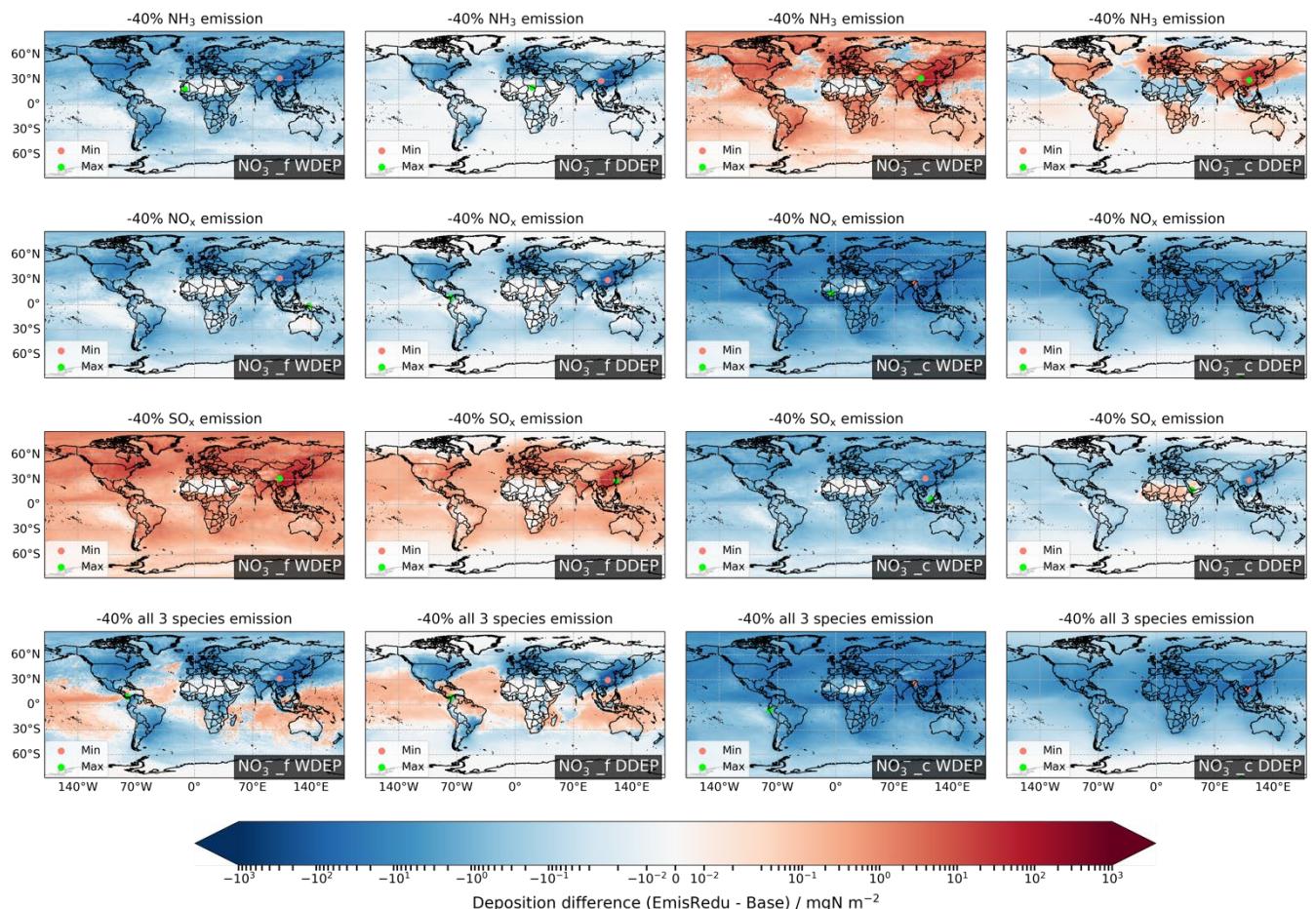


Figure S7: Changes in wet (WDEP) and dry deposition (DDEP) of fine (NO₃⁻_f) and coarse NO₃⁻ (NO₃⁻_c) for 40% emissions reductions in NH₃, NO_x, and SO_x individually and collectively. Red and green dots in each map locate the minimum and maximum difference, respectively.

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