Supporting Information

Effect of regional precursor emission controls on long-range ozone transport:

1. Short-term changes in ozone air quality

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Table S1 shows the annual average change in ozone, spatially-weighted over the receptor region, due to 10% anthropogenic NO_x emission reductions in each source region. Table S2 shows these results for experiments where NO_x, NMVOCs and CO are reduced simultaneously from three source regions. Comparing with the three-month population-weighted indicators in Tables 2 and 4 of the main paper, the strongest source-receptor pairs are generally the same, but there are important quantitative differences, suggesting that the quantification of long-range transport can vary strongly with the ozone concentration metric used.

Tables S3-S5 compare our results with the multi-model ensemble results from the HTAP model intercomparison exercise (Fiore et al., 2009). Here we use the receptor regions defined by Fiore et al. (2009), but source regions from Figure 1, and the same annual average spatially-weighted indicator of Fiore et al. (2009). In general, the results of this study are smaller than the multi-model mean, indicating a lower sensitivity in our modeling, both within the source regions and for long-range transport; this is also the case in Table S4, where we normalize for the change in

NO_x emissions. Results in Table S3 also differ from those in S1, which uses receptor regions defined in Figure 1, and S5 also differs from S2, showing the relevance of how the receptor regions are defined.

Table S6 shows the regional source-receptor matrix for 10% NO_x emission reductions in the three-month period where the influence is greatest for each source-receptor pair.

Figure S1 presents the definitions of 26 metropolitan areas used in this study. Table S7 shows source-receptor relationships for the 26 metropolitan regions, per unit change in NO_x emissions. Table S8 shows the source-receptor relationships for metropolitan regions for the experiments where NO_x, CO, and NMOVC emissions are reduced by 10% in each of 3 source regions.

Table S1 - Source-receptor matrix for the annual average area-weighted change in ozone in the receptor region, resulting from 10% NO_x reductions in each source region (ppt). Values underlined indicate the effect of a reduction in one region on itself (the diagonal). The nine highest inter-regional values are in bold.

		Receptor Region								
		NA	EU	FSU	AF	IN	EA	SA	SE	AU
Source Region	NA	-143	**-69**	**-50**	**-39**	-27	**-46**	-10	-3	0
	EU	-8	136	26	**-52**	-10	-22	0	0	0
	FSU	-10	8	65	-12	-17	**-45**	0	0	0
	AF	-16	-30	-25	-161	-33	-25	-8	-3	-14
	IN	-12	-9	-10	-13	-425	**-48**	-1	-19	0
	EA	**-39**	-27	-38	-9	-19	-166	0	**-47**	0
	SA	-5	0	0	-7	-2	-1	-195	-3	-21
	SE	-3	-2	-2	-5	-32	-16	-5	-273	-11
	AU	0	0	0	-2	0	0	-11	-7	-140

Table S2 – Source-receptor matrix for the annual average area-weighted change in ozone in the receptor region, resulting from 10% combined reductions of NO_x, NMVOCs, and CO in each source region (ppt).

		Receptor Region								
		NA	EU	FSU	AF	IN	EA	SA	SE	AU
Source	NA	-240	**-125**	**-94**	**-67**	-49	**-84**	-16	-12	-3
	EU	-42	-15	-43	**-93**	-26	**-65**	-3	-7	-1
	SE	-7	-6	-5	-11	-43	-23	-10	-300	-17

Table S3 – The annual average spatially-weighted change in ozone in the HTAP receptor regions of Fiore et al. (2009), due to 10% reductions in NO_x emissions from each source region (ppb). In parenthesis are the ensemble means of many models from Fiore et al. (2009) ±1 standard deviaion, divided by 2 becuase of the 20% NO_x reductions assumed in that study. Values in bold are within one standard deviation of Fiore et al. (2009). Note that source regions defined in this paper do not match exactly the receptor regions of Fiore et al. (2009); the South Asia (SA) region of Fiore et al. (2009) corresponds to the IN region here.

		Receptor Region			
		NA	EU	SA (IN)	EA
Source Region	NA	-0.206 (-0.38±0.10)	-0.069 (-0.11±0.035)	**-0.038** (-0.05±0.015)	-0.035 (-0.06±0.015)
	EU	-0.010 (-0.04±0.015)	0.009 (-0.23±0.105)	-0.014 (-0.075±0.02)	-0.017 (-0.06±0.02)
	IN	-0.034 (-0.015±0.01)	**-0.024** (-0.02±0.01)	-0.161 (-0.535±0.105)	-0.024 (-0.05±0.015)
	EA	-0.013 (-0.055±0.02)	-0.010 (-0.04±0.015)	**-0.034** (-0.045±0.02)	**-0.254** (-0.31±0.085)

Table S4 – As Table S3, but normalized per unit change in NO_x emissions in this study and for Fiore et al. (2009) in parenthesis (ppb (TgN $yr^{-1})^{-1}$). For Fiore et al. (2009), we divide the multi-model mean and standard deviation of the change in ozone by the multi-model mean emission reduction.

		Receptor Region			
		NA	EU	SA (IN)	EA
Source Region	NA	0.259 (0.45±0.12)	0.087 (0.13±0.04)	**0.047** (0.06±0.02)	0.044 (0.07±0.02)
	EU	0.021 (0.05±0.02)	-0.019 (0.27±0.13)	0.030 (0.09±0.02)	0.035 (0.07±0.02)
	IN	0.298 (0.05±0.03)	0.206 (0.06±0.03)	**1.397** (1.62±0.32)	0.211 (0.15±0.05)
	EA	0.034 (0.08±0.03)	0.024 (0.06±0.02)	**0.085** (0.06±0.03)	0.638 (0.44±0.12)

Table S5 – The annual average spatially-weighted change in ozone in the HTAP receptor regions of Fiore et al. (2009), due to 10% combined reductions of NO_x, NMVOC and CO emissions from each source region (ppb). In parenthesis are the ensemble means of many models from Fiore et al. (2009) ±1 standard deviaion, divided by 2 becuase of the 20% combined reductions assumed in that study. Values in bold are within one standard deviation of Fiore et al. (2009). Note that source regions defined in this paper do not match exactly the receptor regions of Fiore et al. (2009); the South Asia (SA) region of Fiore et al. (2009) corresponds to the IN region here.

		Receptor Region			
		NA	EU	SA (IN)	EA
Source Region	NA	-0.329 (-0.52±0.115)	-0.123 (-0.185±0.05)	**-0.072** (-0.085±0.02)	-0.060 (-0.11±0.025)
	EU	-0.041 (-0.095±0.03)	-0.118 (-0.41±0.145)	-0.051 (-0.12±0.04)	-0.039 (-0.12±0.025)

Table S6 - Source-receptor matrix for the three-month period where the 10% NO_x reduction in each source region causes the greatest surface ozone decrease in each receptor region, for the 3-month population-weighted average ozone concentration (ppt).

		Receptor Region								
		NA	EU	FSU	AF	IN	EA	SA	SE	AU
Source Region	NA	-571	**-94**	**-63**	-44	-44	-40	-21	-10	-3
	EU	-14	-194	**-184**	**-101**	-13	-24	0	-3	0
	FSU	-15	**-55**	-401	-41	-21	-38	0	-2	0
	AF	-15	-37	**-63**	-222	-50	-28	-10	-8	-28
	IN	-17	-18	-23	-18	-647	-22	-2	-44	-2
	EA	-34	-48	-34	-11	-41	-930	-1	**-168**	0
	SA	-6	-2	-2	-8	-5	-1	-346	-5	-37
	SE	-7	-5	-5	-6	**-58**	**-51**	-10	-461	-12
	AU	0	0	0	-3	0	0	-15	-10	-318

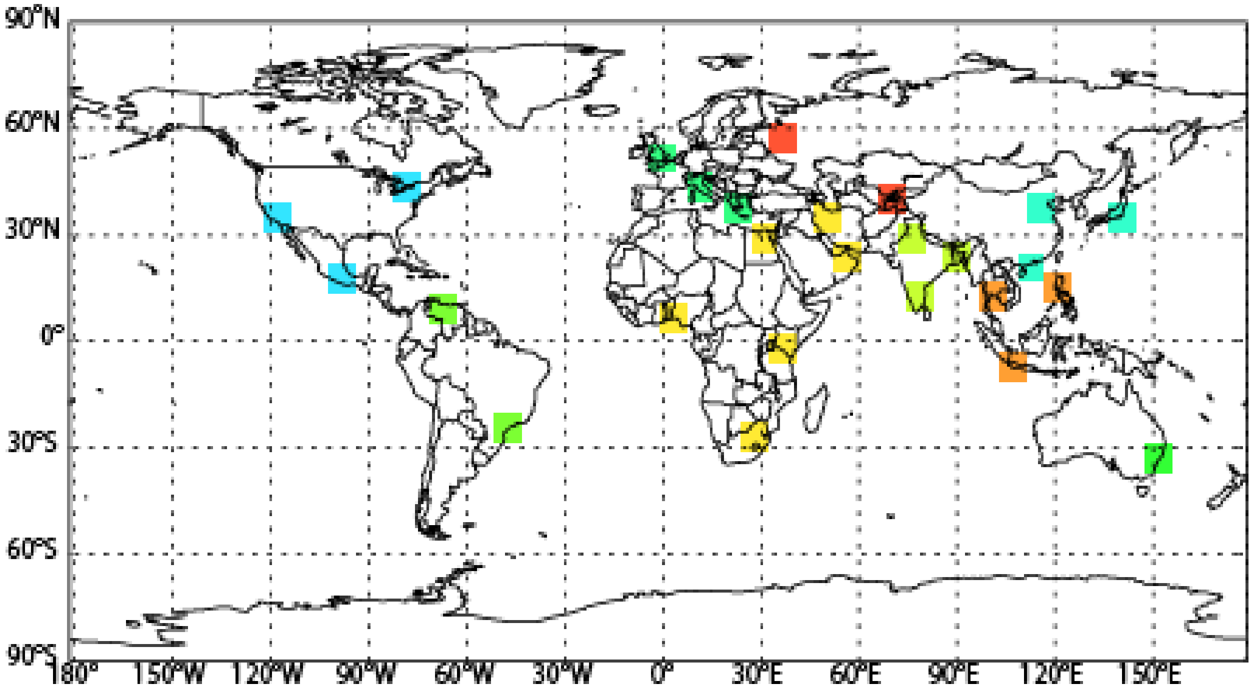

Figure S1 – Regional definitions for 26 metropolitan areas shown in Tables 6 and 7 of the main paper, and Table S1. Each region is 3x3 MOZART-2 grid cells.

Table S7 – Change in 3-month average ozone (Table 5 of main paper) per unit change in NO_x emissions in each source region (ppb $(TgN\ yr^{-1})^{-1}$).

		Receptor Region												
		Los Angeles (JJA)	Mexico City (OND)	Toronto (JJA)	London (MAM)	Rome (JJA)	Athens [a] (JAS)	Moscow (JJA)	Tashkent (JJA)	Lagos (JFM)	Johannesburg (SON)	Cairo (MJJ)	Nairobi (DJF)	Tehran [b] (MJJ)
Source Region	NA	0.52	0.78	0.72	0.15	0.06	0.06	0.05	0.10	0.02	0.00	0.07	0.00	0.10
	EU	0.03	0.01	0.02	-1.67	1.72	1.37	**0.53**	0.21	0.03	0.00	**0.55**	0.00	0.23
	FSU	0.09	0.01	0.09	0.00	0.08	0.35	1.60	1.69	0.00	0.00	0.14	0.00	**1.31**
	AF	0.01	0.04	0.00	0.12	0.05	**0.68**	0.00	0.09	0.65	0.95	2.58	0.37	0.99
	IN	0.07	0.19	0.01	0.07	0.00	0.01	0.00	0.09	0.01	0.00	0.04	0.36	0.05
	EA	0.11	0.07	0.04	0.07	0.02	0.03	0.02	0.08	0.00	0.00	0.02	0.00	0.03
	SA	0.00	0.04	-0.01	0.00	-0.02	-0.02	-0.01	-0.01	0.07	0.26	-0.01	0.05	0.00
	SE	-0.01	0.06	-0.02	0.03	-0.02	-0.02	-0.02	-0.01	0.05	0.07	-0.02	0.15	-0.01
	AU	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.30	-0.01	-0.01	-0.01

Source Region		Dubai (AMJ)	Delhi (MAM)	Chennai (DJF)	Dhaka (FMA)	Hong Kong (OND)	Beijing (JAS)	Tokyo (FMA)	Caracas (MAM)	Sao Paulo (ASO)	Bangkok (DJF)	Jakarta (JAS)	Manila (DJF)	Sydney (ASO)
		Receptor Region												
	NA	0.09	0.09	0.02	0.03	0.03	0.02	0.08	0.12	0.00	0.02	0.00	0.04	0.00
	EU	0.14	0.05	0.00	0.01	0.03	0.04	0.08	0.01	0.00	0.01	0.00	0.02	0.00
	FSU	0.27	0.15	0.00	0.01	0.04	0.25	0.11	0.00	0.00	0.00	0.00	0.00	0.00
	AF	1.79	0.42	0.03	0.09	0.07	0.01	0.20	0.05	0.04	0.04	0.02	0.08	0.08
	IN	0.24	3.16	2.78	6.64	0.21	0.06	0.13	0.04	0.01	0.18	0.02	0.32	0.01
	EA	0.03	0.03	0.11	0.01	1.46	2.03	-0.44	0.01	0.00	**0.58**	0.00	0.34	0.00
	SA	0.03	0.04	0.09	0.05	0.00	-0.01	0.02	2.43	2.63	0.04	0.14	0.07	0.39
	SE	0.03	0.07	**1.62**	**0.52**	0.11	0.07	0.09	0.07	0.12	3.72	3.49	1.36	0.15
	AU	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	**0.60**	-0.01	**0.68**	-0.01	7.86

[a] The region defined for Athens lies mainly in EU, and partly in AF. [b] The region defined for Tehran lies mainly in AF, and partly in FSU.

Table S8 – As Table 5, but for the simulations where anthropogenic emissions of NO_x, NMVOCs, and CO are all reduced.

		Receptor Region												
		Los Angeles (JJA)	Mexico City (OND)	Toronto (JJA)	London (MAM)	Rome (JJA)	Athens [a] (JAS)	Moscow (JJA)	Tashkent (JJA)	Lagos (JFM)	Johannesburg (SON)	Cairo (MJJ)	Nairobi (DJF)	Tehran [b] (MJJ)
Source	NA	<u>-662</u>	<u>-765</u>	<u>-728</u>	**-210**	-98	-84	-69	-112	-49	-4	-107	-21	-130
	EU	-34	-30	-29	<u>593</u>	<u>-1107</u>	<u>-823</u>	**-311**	-144	-50	-1	**-389**	-12	**-172**
	SE	-5	-10	-1	-7	-2	-2	-1	-3	-9	-11	-4	-20	-4

		Receptor Region												
		Dubai (AMJ)	Delhi (MAM)	Chennai (DJF)	Dhaka (FMA)	Hong Kong (OND)	Beijing (JAS)	Tokyo (FMA)	Caracas (MAM)	Sao Paulo (ASO)	Bangkok (DJF)	Jakarta (JAS)	Manila (DJF)	Sydney (ASO)
Source	NA	-118	-113	-38	-53	-60	-28	-144	-119	-6	-45	-8	-70	-6
	EU	-117	-57	-19	-20	-52	-32	-136	-18	-1	-38	-2	-46	-1
	SE	-9	-12	-135	-47	-13	-11	-14	-9	-14	<u>-270</u>	<u>-258</u>	<u>-103</u>	-16

[a] The region defined for Athens lies mainly in EU, and partly in AF. [b] The region defined for Tehran lies mainly in AF, and partly in FSU.