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Impacts of emission changes in China from 2010 to 2017 on domestic and intercontinental air quality and health effect

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Supporting information

Table S1. The annual $PM_{2.5}$ changes at China provinces from 2011 to 2017 (CEDS_MEIC – CEDS_MEIC_ChinaFix; unit of μg m^{-3}).

Provinces	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Anhui	7.32	5.64	2.19	-4.24	-12.14	-17.56	-22.84
Beijing	3.99	6.19	5.66	3	-1.87	-5.65	-9.07
Chongqing	4.11	2.74	0.92	-6.32	-11.63	-16.62	-21.13
Fujian	1.89	2.66	0.9	-3.5	-4.9	-7.44	-9.02
Gansu	0.92	0.77	0.35	-1.75	-3.26	-4.33	-5.76
Guangdong	4.18	3.66	1.84	-2.32	-4.76	-7.7	-10.24
Guangxi	4.73	4.85	2.73	-1.46	-4.7	-8.88	-11.24
Guizhou	3.37	4.21	5.91	3.06	-0.18	-3.85	-6.54
Hainan	1.48	1.77	2.1	-1.07	-1.77	-4.24	-6.54
Hebei	5.85	7.04	5.61	0.39	-5.85	-10.81	-15.4
Heilongjiang	1.96	2.1	0.57	-0.49	-2.02	-3.29	-3.83
Henan	9.77	6.09	0.45	-9.28	-23.24	-30.96	-37.58
Hubei	6.82	4.43	0.5	-9.34	-16.31	-20.76	-25.82
Hunan	4.67	4.33	3.1	-3.4	-5.8	-10.65	-14.67
Jiangsu	6.54	4.25	-1.26	-4.14	-11.08	-15.51	-19.87
Jiangxi	2.66	2.53	1.66	-3.04	-4.73	-9.4	-12.97
Jilin	2.65	3.39	1.73	-1.54	-4.13	-5.79	-6.48
Liaoning	2.95	1.71	-0.88	-4.06	-6.95	-9.31	-10.58
Nei Mongol	1.32	0.14	-0.58	-1.12	-1.91	-2.77	-3.36
Ningxia Hui	2.36	1.85	1.06	-2.3	-4.94	-6.89	-9.57
Qinghai	0.18	0.15	-0.05	-0.53	-0.84	-1.14	-1.67
Shaanxi	4.08	4.73	3.25	-4.28	-10.6	-13.99	-17.33
Shandong	6.94	6.74	1.04	-6.6	-13.91	-19.62	-23.98
Shanghai	2.36	1.13	-1.02	-2.67	-4.88	-5.74	-8.1
Shanxi	4.83	3.71	1.9	-2.5	-8.13	-12.32	-16.84
Sichuan	1.47	2.14	1.64	-2.76	-6.16	-9.48	-12.16
Tianjin	4.97	5.93	6.32	2.61	-2.36	-5.96	-10.18
Xinjiang Uygur	0.53	1.66	2.11	1.92	1.65	1.3	1.06
Xizang	0.03	0.06	0.03	-0.02	0.01	-0.01	-0.04
Yunnan	0.75	1.25	2.12	1.14	-0.14	-1.91	-2.7
Zhejiang	2.65	1.79	0.4	-4.49	-7.6	-9.21	-12.17

Table S2. The same as Table S1 but for MDA8 ozone (unit of ppbv).

Provinces	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Anhui	-0.34	-0.41	-0.08	0.6	1.34	1.63	1.83
Beijing	-0.92	-0.75	0.24	3.16	5.27	6.15	6.43
Chongqing	0.53	0.48	0.84	1.03	0.96	1.2	1.73
Fujian	0.26	0.28	0.26	0.28	0.28	0.2	0.2
Gansu	0.47	0.58	0.71	0.89	0.85	0.85	0.73
Guangdong	0.1	0.14	0.47	0.33	0.12	0.08	-0.01
Guangxi	0.42	0.53	0.73	0.32	0.19	-0.11	-0.15
Guizhou	0.33	0.11	0.22	0.3	0.17	0.1	0.24
Hainan	0.34	0.48	0.35	0.18	0.15	0.02	-0.13
Hebei	-0.72	-0.81	-0.22	2.22	4.09	4.83	5.07
Heilongjiang	0.05	-0.14	0	-0.3	0	0.01	0.09
Henan	-0.39	0.06	0.66	2.08	3.57	3.96	4.37
Hubei	0.03	0.32	1.1	2.09	2.38	2.49	2.92
Hunan	0.32	0.38	0.51	0.56	0.4	0.44	0.69
Jiangsu	-0.7	-1.16	0.19	1.3	2.26	2.65	3.04
Jiangxi	0.09	0.49	0.43	0.72	0.77	0.82	0.97
Jilin	0	-0.17	0	0.34	0.54	0.54	0.69
Liaoning	-0.07	-0.16	0.1	0.69	0.97	1.05	1.27
Nei Mongol	-0.17	-0.04	0.07	0.44	0.54	0.48	0.5
Ningxia Hui	0.16	0.1	0.59	1.5	2.23	2.22	2.11
Qinghai	0.41	0.6	0.49	0.14	-0.01	-0.2	-0.52
Shaanxi	-0.04	-0.15	0.4	1.84	2.61	2.95	3.38
Shandong	-0.2	-0.9	0.03	0.7	1.75	2.51	3.16
Shanghai	-0.37	-0.28	0.59	1.53	2.17	2.36	2.57
Shanxi	-0.89	-0.78	-0.41	2.36	3.96	4.73	5.08
Sichuan	0.5	0.66	0.74	0.48	0.34	0.41	0.58
Tianjin	-1.32	-1.12	0.59	2.42	5.81	7.11	7.25
Xinjiang Uygur	0.16	0.32	-0.02	-0.08	-0.11	-0.06	0.01
Xizang	0.15	0.26	0.19	0	0.02	-0.09	-0.23
Yunnan	0.26	0.31	0.23	0.18	0.13	0.1	0.09
Zhejiang	-0.13	-0.22	0.15	0.93	1.41	1.58	1.75

Table S3. The annual $PM_{2.5}$ mortality burden changes at China provinces from 2011 to 2017 (CEDS_MEIC – CEDS_MEIC_ChinaFix; unit of deaths yr^{-1}).

Provinces	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Anhui	1261	1072	463	-831	-2490	-3997	-4944
Beijing	341	508	450	180	-196	-503	-840
Chongqing	505	390	136	-594	-1217	-2007	-2545
Fujian	581	689	234	-1277	-1742	-2761	-3237
Gansu	371	370	94	-587	-1133	-1602	-2121
Guangdong	2652	2626	1245	-1437	-3529	-5962	-7481
Guangxi	1466	1741	830	-756	-1950	-3712	-4607
Guizhou	721	1055	1285	686	27	-854	-1493
Hainan	83	117	123	-65	-115	-283	-441
Hebei	1270	1611	1237	-34	-1397	-2448	-3787
Heilongjiang	738	914	297	-17	-540	-1052	-1362
Henan	1988	1408	274	-1872	-4703	-6820	-8645
Hubei	1473	1190	452	-1836	-3448	-5040	-6146
Hunan	1319	1365	979	-1017	-1785	-3557	-4791
Jiangsu	1488	1058	-452	-1431	-3485	-5038	-6286
Jiangxi	719	788	532	-976	-1579	-3334	-4269
Jilin	491	671	338	-244	-714	-1105	-1314
Liaoning	568	263	-246	-798	-1360	-1936	-2282
Nei Mongol	500	12	-248	-431	-753	-1170	-1460
Ningxia Hui	134	76	0	-117	-231	-364	-507
Qinghai	70	50	-14	-157	-267	-373	-476
Shaanxi	895	1161	584	-731	-1753	-2462	-3261
Shandong	1499	1575	159	-1831	-3850	-5434	-6833
Shanghai	251	134	-148	-417	-753	-960	-1227
Shanxi	650	537	204	-353	-1041	-1641	-2351
Sichuan	973	1385	841	-1707	-3711	-6001	-7524
Tianjin	202	249	240	92	-92	-231	-409
Xinjiang Uygur	331	929	1200	1170	1082	913	778
Xizang	8	11	9	-4	11	5	-3
Yunnan	421	741	1013	544	-100	-977	-1542
Zhejiang	725	597	112	-1549	-2576	-3471	-4308

Table S4. The same as Table S3 but for ozone.

Provinces	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Anhui	126	41	221	314	324	341	375
Beijing	-55	-120	-52	252	436	510	510
Chongqing	195	204	235	161	129	106	191
Fujian	197	194	58	50	-2	-92	-36
Gansu	144	139	129	99	65	56	17
Guangdong	447	474	114	-374	-832	-980	-1038
Guangxi	256	331	316	-9	-145	-336	-393
Guizhou	240	348	459	276	144	13	-6
Hainan	35	59	74	10	26	0	-26
Hebei	-67	-322	-154	641	1184	1473	1476
Heilongjiang	82	38	68	-31	-8	-21	1
Henan	107	279	531	1028	1323	1461	1650
Hubei	332	283	412	338	327	269	351
Hunan	261	372	403	273	302	177	257
Jiangsu	-99	-153	352	726	861	934	904
Jiangxi	249	166	181	53	57	-59	-76
Jilin	68	41	49	46	40	20	42
Liaoning	64	16	-8	114	114	109	164
Nei Mongol	-77	-63	-36	93	87	88	112
Ningxia Hui	35	30	27	21	22	12	-3
Qinghai	31	29	19	15	2	-2	-16
Shaanxi	168	150	247	403	435	423	521
Shandong	161	-176	348	307	692	1103	1420
Shanghai	-16	-1	77	149	176	181	163
Shanxi	-64	-20	61	402	566	634	665
Sichuan	476	728	829	508	367	339	526
Tianjin	-61	-162	-15	163	369	486	516
Xinjiang Uygur	22	38	-41	-42	-47	-30	8
Xizang	4	5	4	0	5	3	1
Yunnan	162	309	292	155	30	-43	-69
Zhejiang	56	72	239	291	365	342	330

Fig S1. The anthropogenic emission trends in China from 2000 to 2017 reported by MEIC and CEDS. Note that the CEDS did not report emissions after year 2014 (Hoesly et al., 2018).

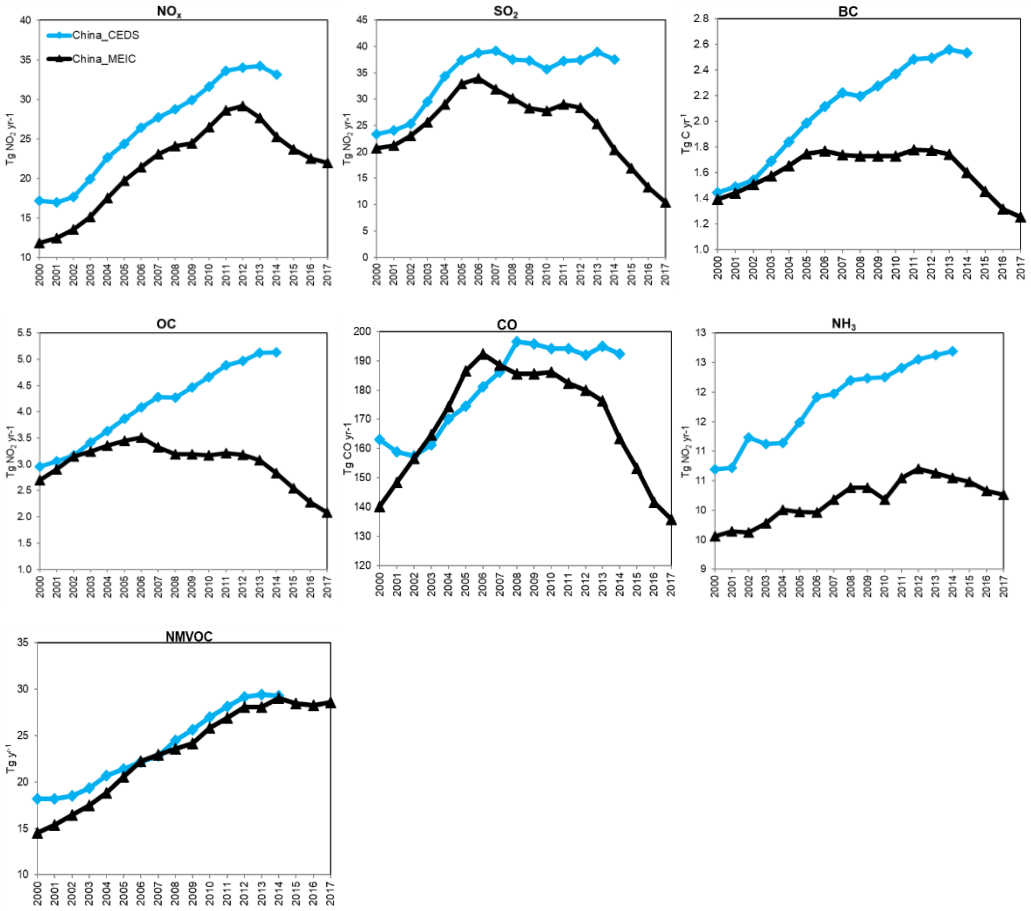

Fig S2. The spatial distribution for emission relative differences between CEDS and MEIC in 2014 for (a) NO_x, (b) SO_2, (c) BC, (d) OC and (e) CO. Red colors means emissions from CEDS are higher than that in MEIC, and blue colors means lower in CEDS. The relative differences are calculated as (CEDS-MEIC)/MEIC×100.

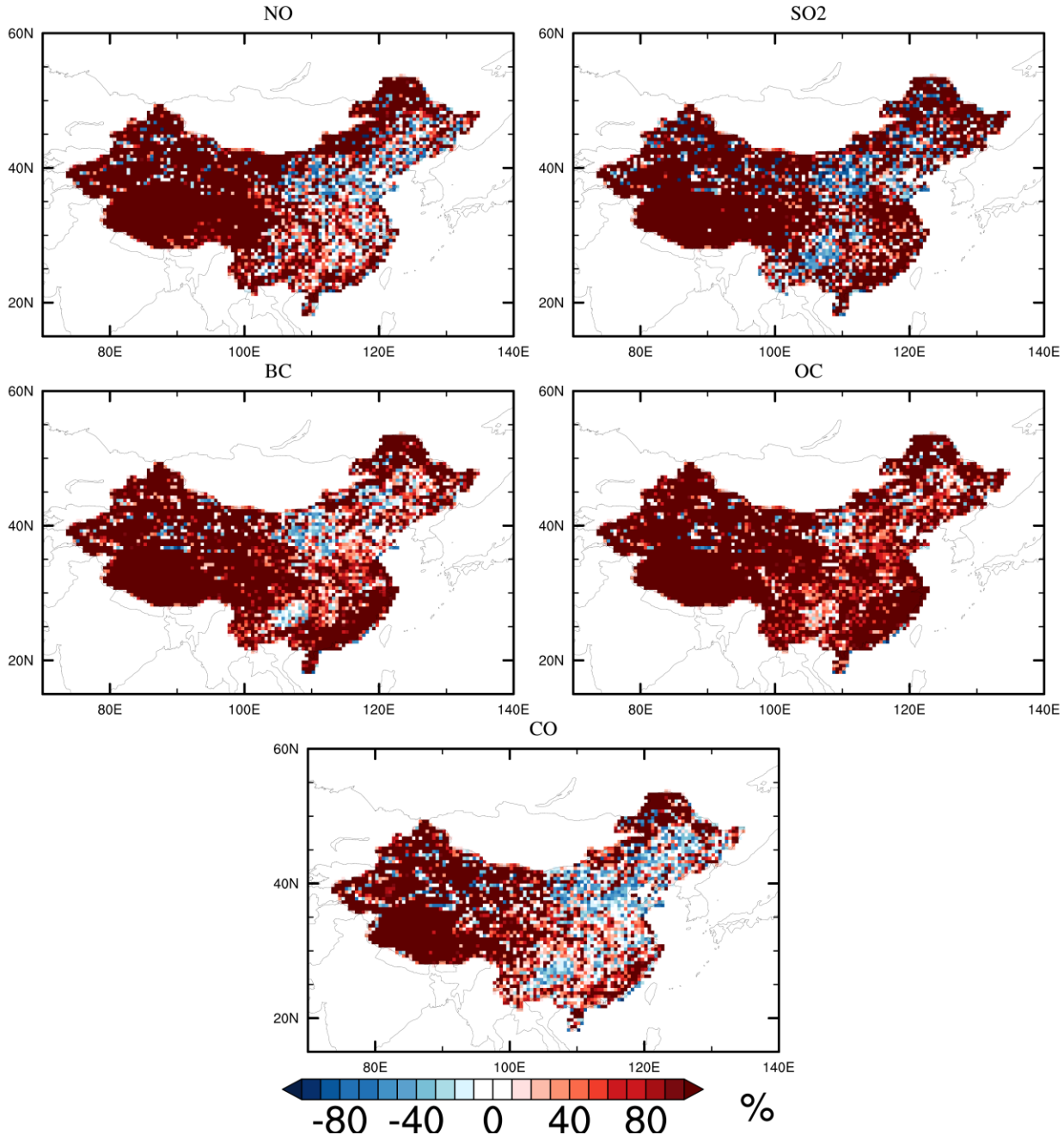

Fig. S3. Simulated annual $PM_{2.5}$ concentration differences between applying CEDS and MEIC emission inventory in China from 2010 to 2014. The differences are calculated between CEDS_MEIC and CEDS_Global for each year.

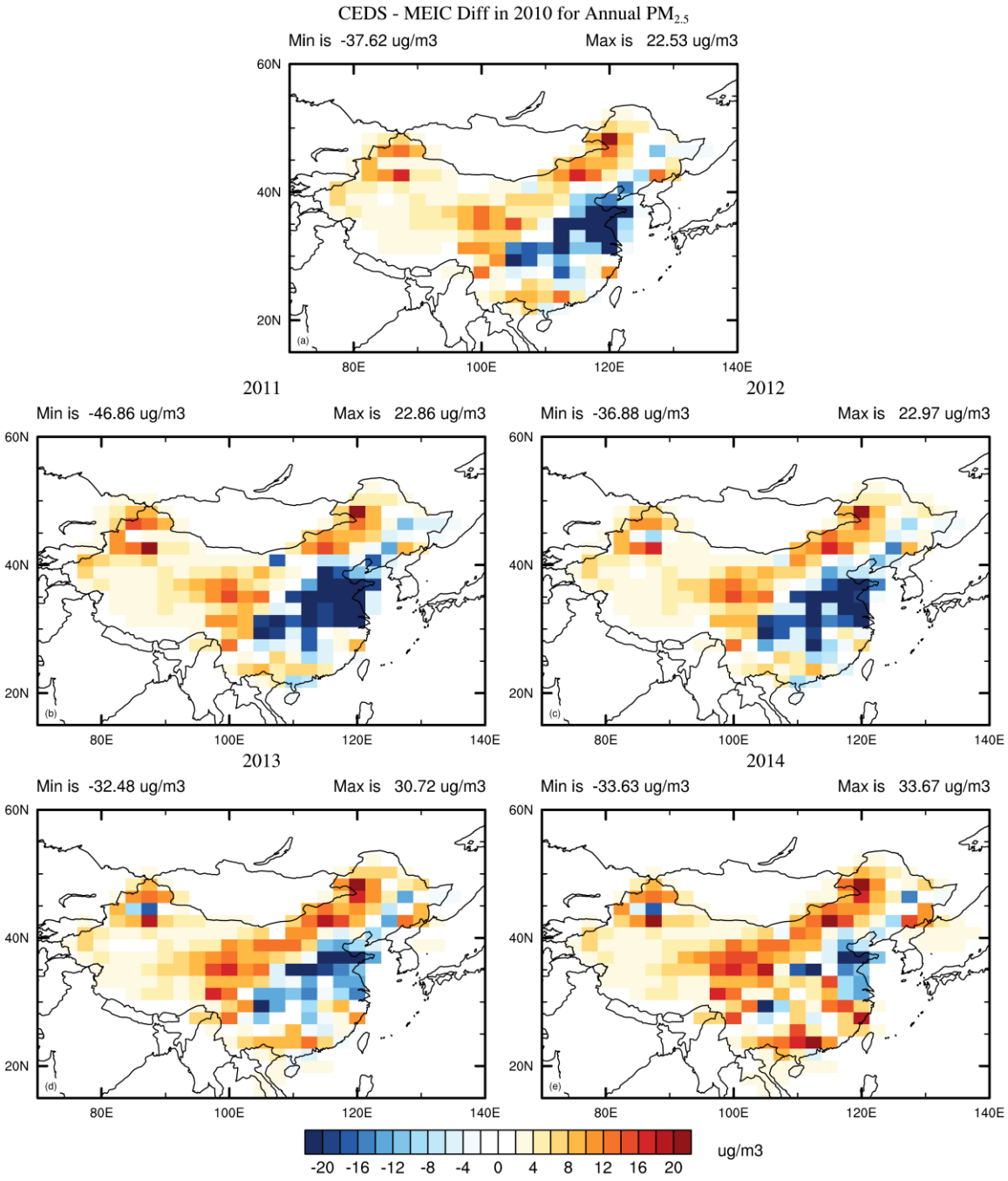

Fig. S4. As Fig. S3 but for annual average MDA8 O_3 changes.

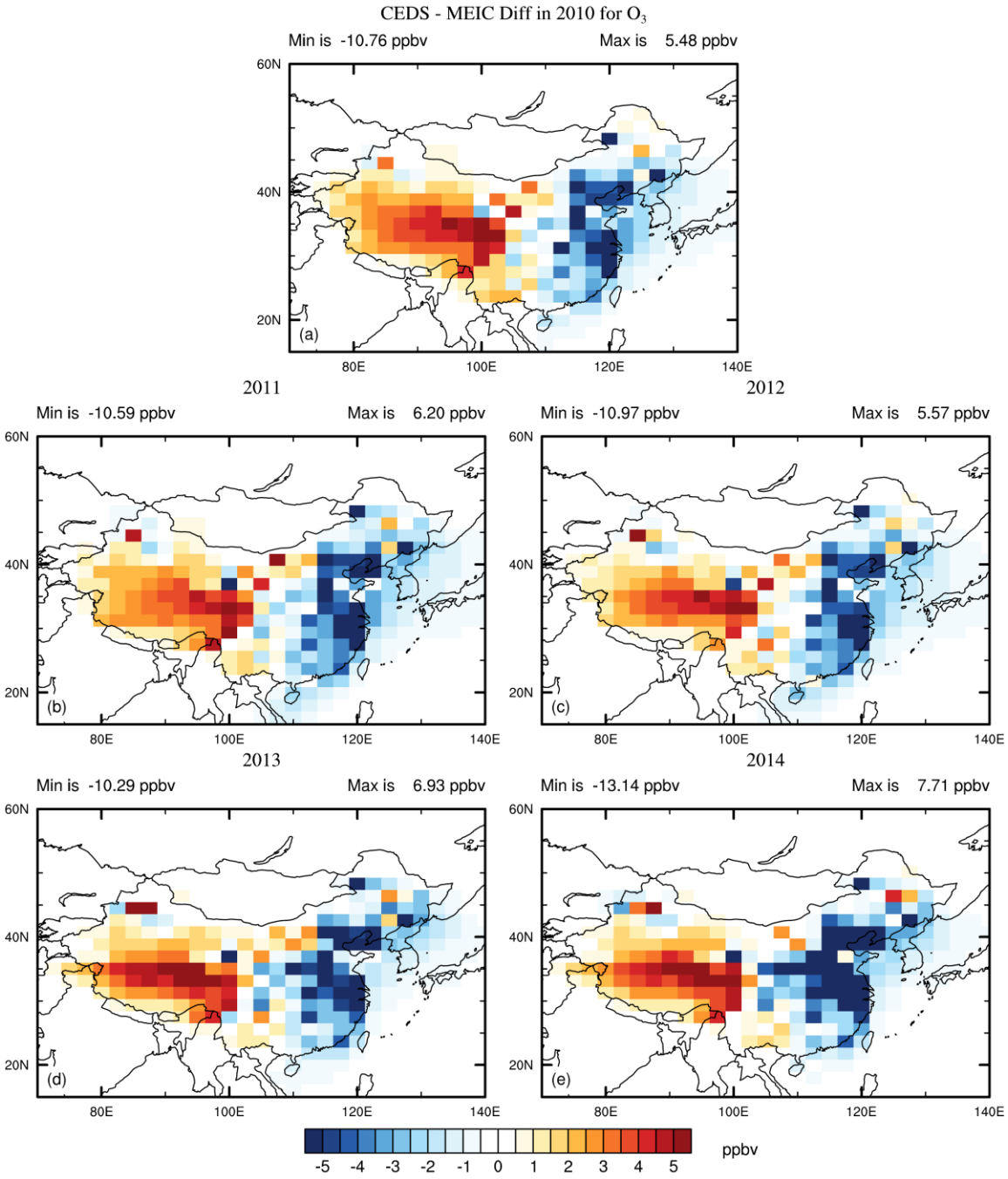

Fig. S5. Evaluation of simulated annual $PM_{2.5}$ concentration against surface $PM_{2.5}$ observations. The circles depict 249 locations of continued valid $PM_{2.5}$ observations from 2013 to 2017 (normalized mean bias(NMB), horizontal colorbar), overlaying on the 5-yr average of model simulated annual $PM_{2.5}$ concentration (μg m^{-3}, vertical colorbar).

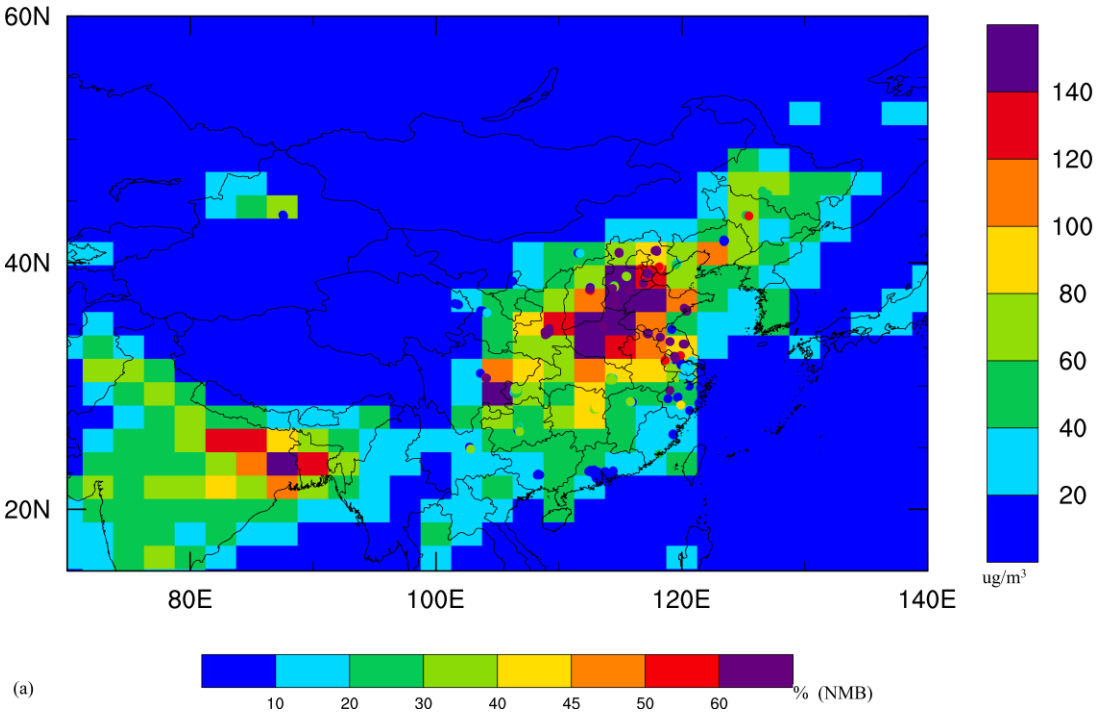

Fig. S6. Evaluation of simulated annual MDA8 ozone concentration against surface observations. The circles depict 700 locations of continued valid ozone observations from 2013 to 2017 (normalized mean bias(NMB), horizontal colorbar), overlaying on the 5-yr average of model simulated concentration ppbv, vertical colorbar).

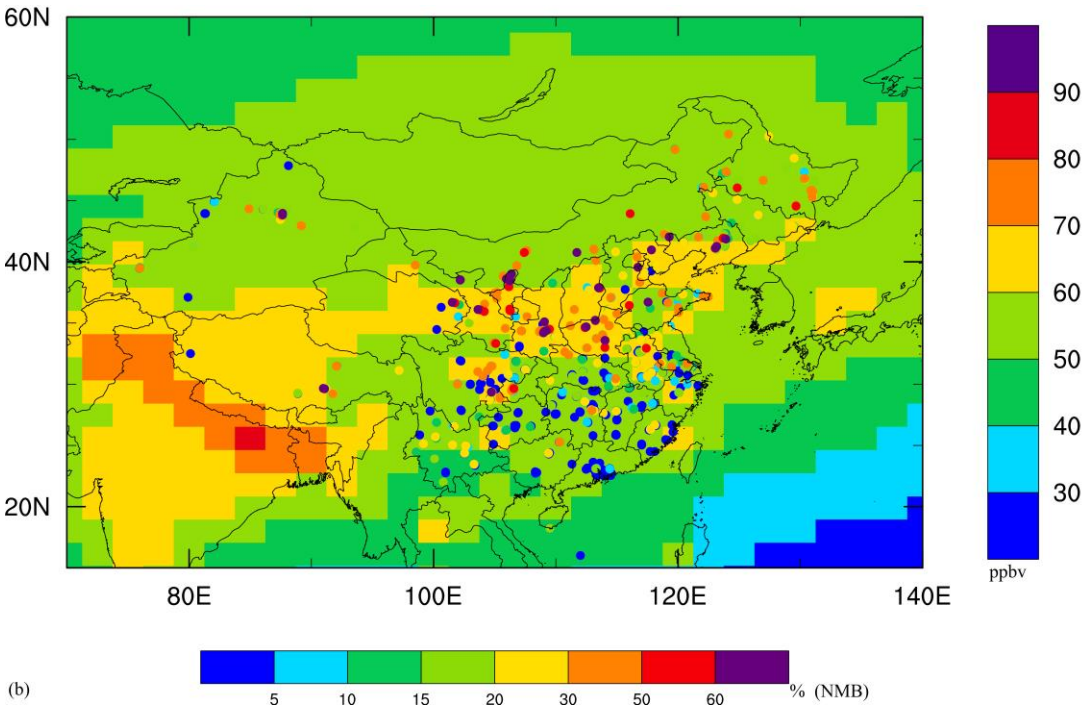

Fig. S7. Seasonal population-weighted $PM_{2.5}$ changes in China (a), Japan (b), South Korea (c), and U.S. (d) from 2010 to 2017 (CEDS_MEIC – CEDS_MEIC_ChinaFix).

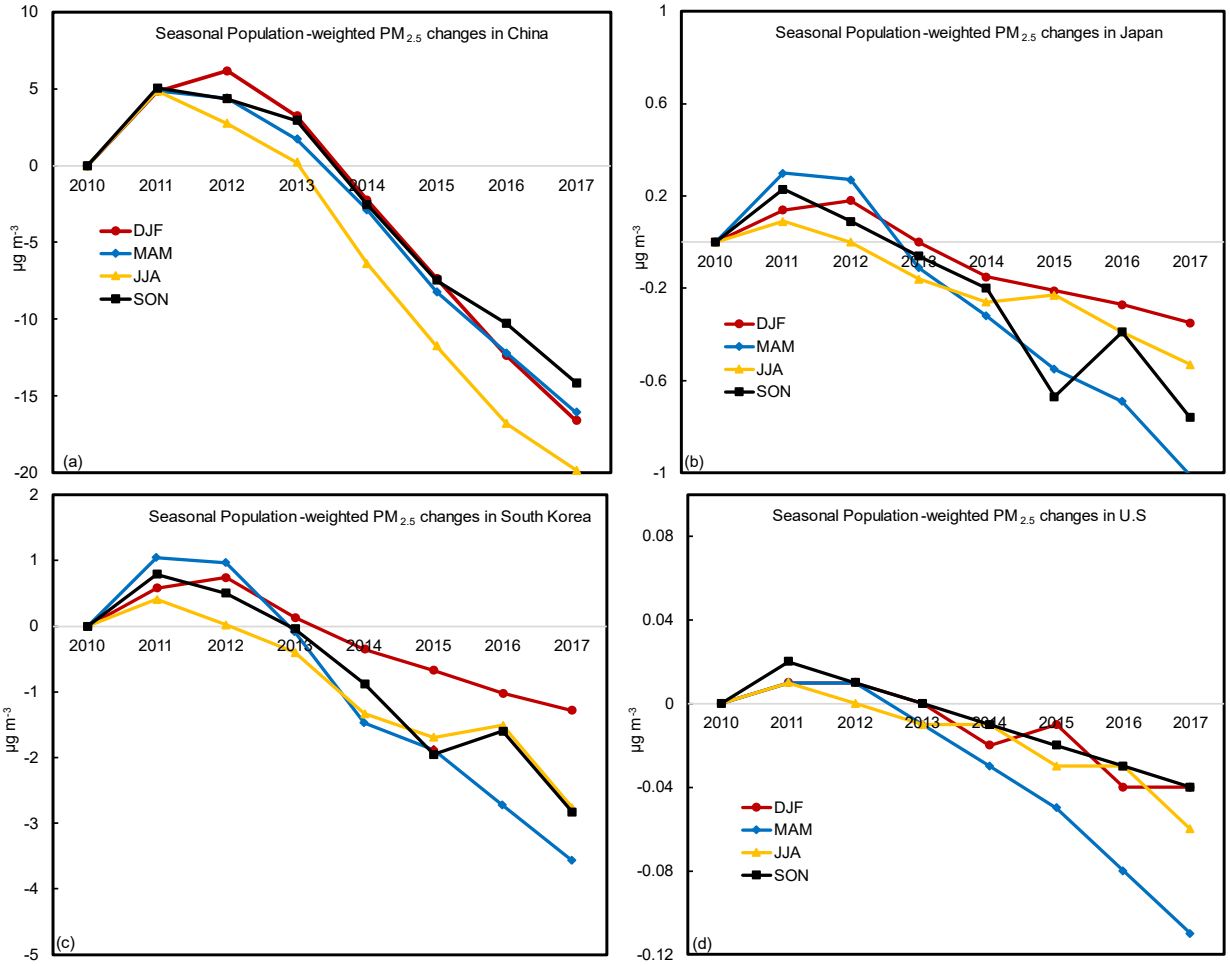

Fig. S8. Same as S7 but for MDA8 O_3 changes.

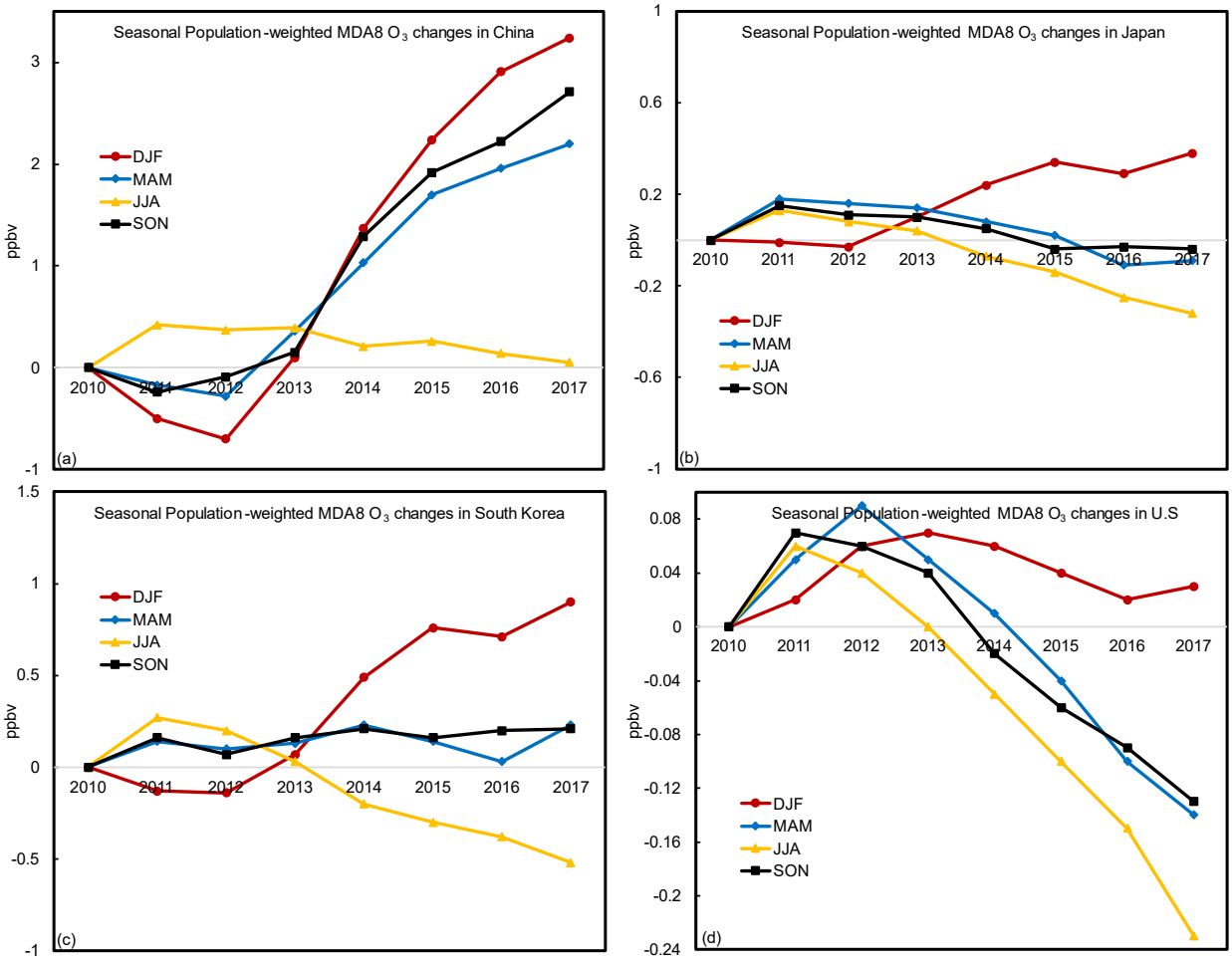

Fig. S9. Summertime MDA8 O_3 changes from 2011 to 2017 from emission changes in China. The results are calculated as the differences between CEDS_MEIC and CEDS_MEIC_ChinaFix for each year.

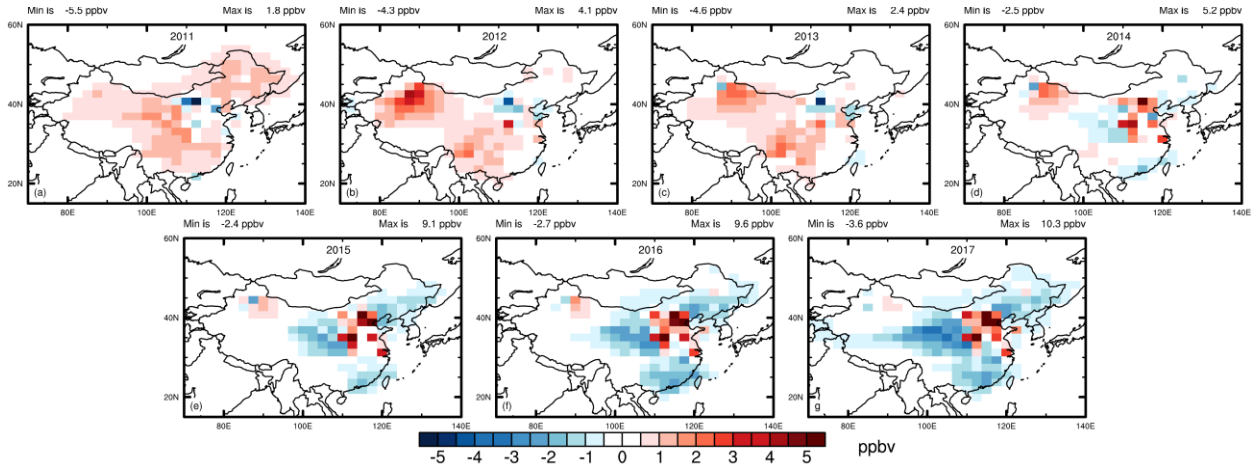

Fig. S10. Global zonal average O_3 changes from 2010 to 2017. The differences are calculated as the differences between each year (from 2011 to 2017) and 2010.