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Supplement of

Evaluation of tropospheric ozone and ozone precursors in simulations from the HTAPII and CCMI model intercomparisons – a focus on the Indian subcontinent

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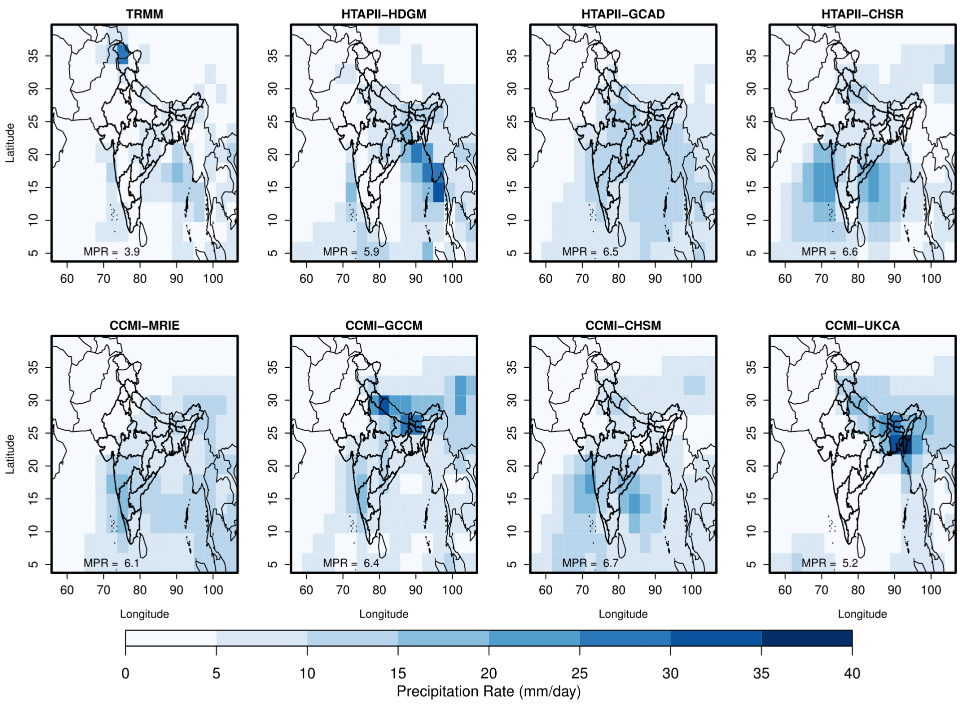
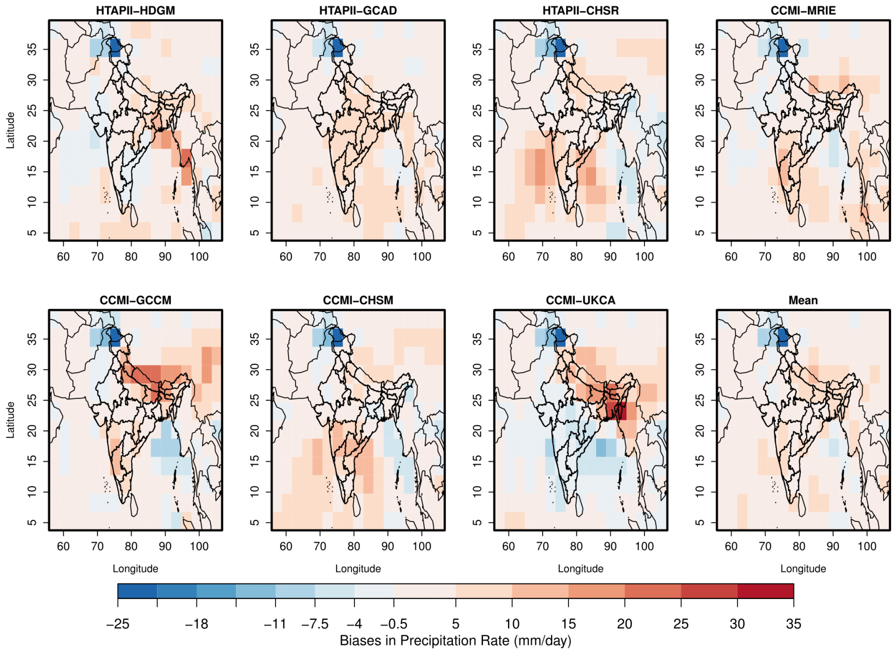
S1: India receives nearly 70% of its annual rainfall from the southwest monsoon, 5% during winter and 25% during pre and post monsoon seasons combined. During winter, most of the rainfall is in the northern part of India due to western disturbances (Yadav et al., 2010). Precipitation during winter is not included in this analysis. The spatial spread of precipitation is very less during the pre and post monsoon season. In this study we have considered precipitation rates during the monsoon season only. Earlier studies have shown that TRMM overestimates the rainfall over higher mean rainfall regimes against the gridded gauge-based data over India, except for the orographic regions of Western ghats on the western coast of India and the foothills of Himalayas (Prakash et al., 2015). Figure S1.b shows the magnitude of bias in model simulated precipitation rates with respect to TRMM data for the monsoon season. Models in general overestimate surface precipitation over this region. High biases are observed in the northeastern part of India. This can be attributed to the higher uncertainty in the satellite based precipitation estimates in the mountainous regions reported in several studies (Aghakouchak et al., 2012). The annual area average of surface precipitation as simulated by the models show a positive bias of 15-30 over land when compared to surface precipitation rates from TRMM. However, CCMI-UKCA shows a negative bias of -0.5 to -7.5 over central and southern part of India. Since, TRMM overestimates surface precipitation over this region, models must also overestimate surface precipitation over this region.

S1.a) TRMM mean precipitation rates for June, July, August, September (JJAS), monsoon months, for the years 2008-2010 and Model simulated mean surface precipitation for JJAS for the year 2009.

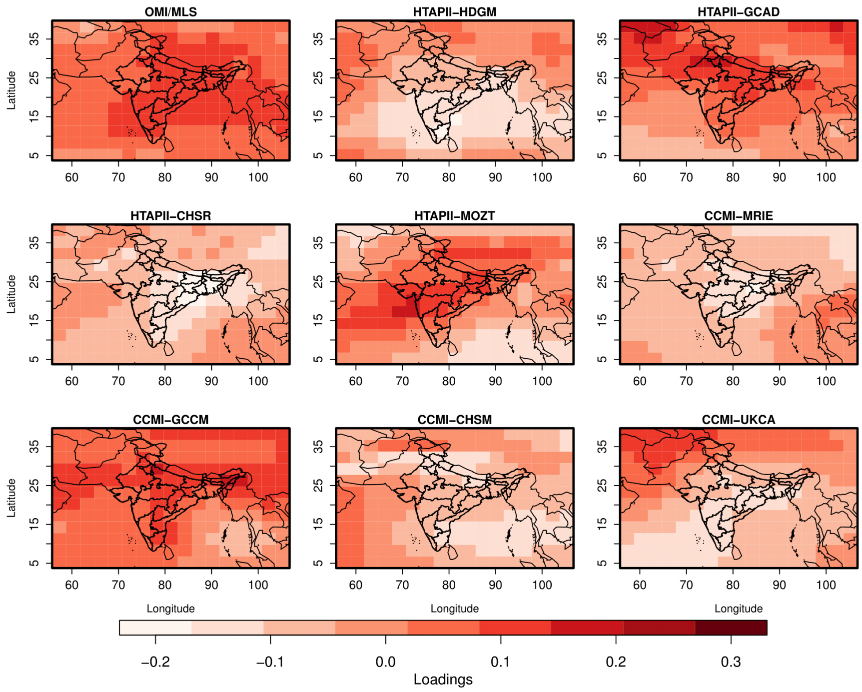


S1.b) Biases in precipitation rates as simulated by the models w.r.t. the precipitation rates determined by TRMM.

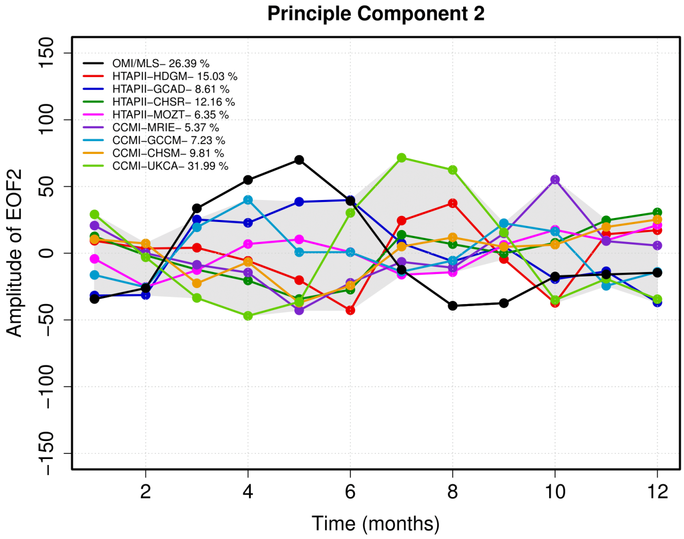


S2: EOF Analysis:

S2.a) Second dominant Spatial pattern (i.e. Emperical Orthogonal Function 2), which explains the second maximum variance in the tropospheric ozone column.

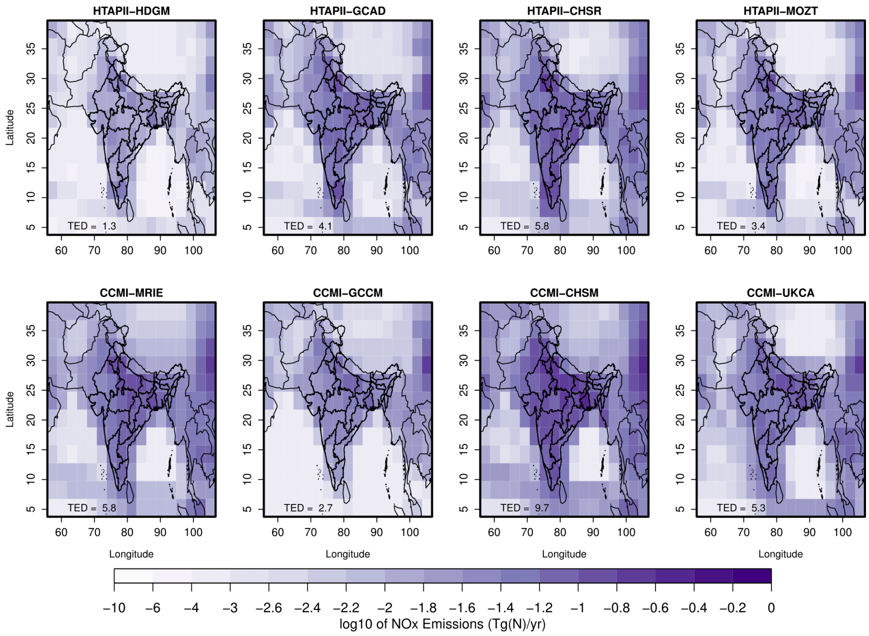


S2.b) Time series of the amplitude of the EOF2 (Principle component 2)

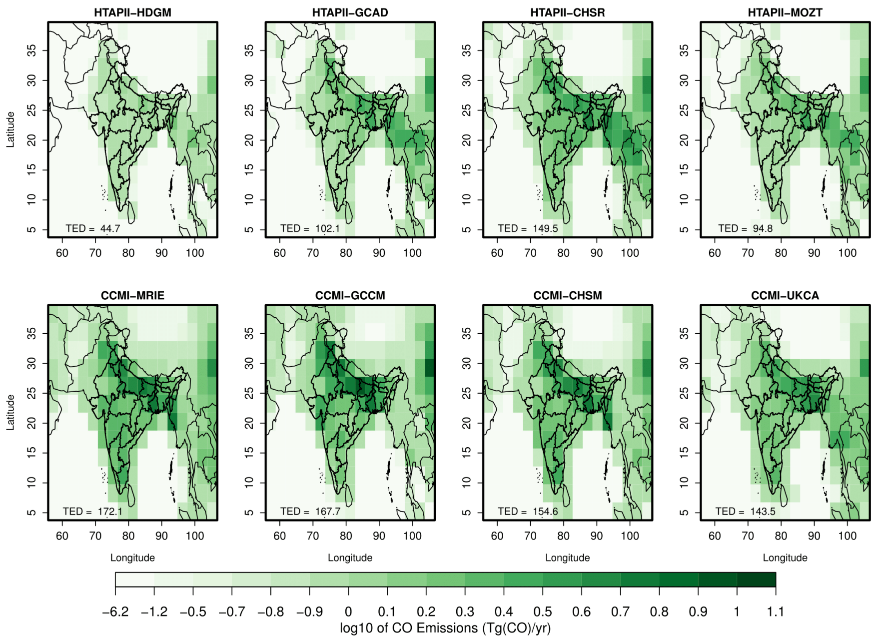


S3: Models show a standard deviation of +-6.699 Tg(N)/yr and +-116.165 Tg(CO)/yr for global emissions of NOx and CO, respectively. Figure S2.a and S2.b show the spatial distribution of annual average surface NOx emissions and CO emissions, as simulated by the models, along with values of Total Emissions in the Domain (TED). High emissions are simulated over the IGP region, western coast and the central part of India. The IGP region is a densely populated region and the numbers of ports on the western coast of India are higher than the eastern coast of India. High emissions in these regions and the neighbouring regions are associated with high anthropogenic activities. CCMI-MRIE and HTAPII-CHSR (TED = 5.8 Tg(N)/yr) and HTAPII-HDGM (TED = 1.3 Tg(N)/yr) act as outliers for NOx emissions, one giving high and other giving low NOx emissions in the domain, respectively. CCMI-MRIE (TED = 172.1 Tg(CO)/yr) and HTAPII-HDGM (TED = 44.7 Tg(CO)/yr) act as outliers for CO emissions, with the highest and lowest emissions in the domain, respectively. NOx and CO emissions are very different for HTAPII-CHSR (TED = 5.8 Tg(N)/yr, 149.5 Tg(CO)/yr) and CCMI-CHSM (TED = 9.7 Tg(N)/yr, 154.6 Tg(CO)/yr). They have the same chemistry scheme, but belong to different MIPs.

S3.a) Model simulated annual average surface NOx Emissions in units of Teragrams of Nitrogen per year. Values in the left bottom corner indicate the total emissions in the domain (TED) as simulated by the models.



S3.b) Model simulated annual average surface CO Emissions in units of Teragrams of Carbon Monoxide per year. Values in the left bottom corner indicate the total emissions in the domain (TED) as simulated by the models.



S4: Annual averages of NO, NO_2, NOx from the eight model simulations contributing to the HTAPII and CCMI MIP's at the ground based MAPAN – stations. Observations for NO and NO2 are available only at Delhi. NO_2 is much higher in the models as compared to NO in NOx, while observations at Delhi show higher NO values as compared to NO_2 in NOx

	Observations			HTAPII-HDGM			HTAPII-GCAD			HTAPII-CHSR			HTAPII-MOZT		
	NO	NO_2	NOx	NO	NO_2	NOx	NO	NO_2	NOx	NO	NO_2	NOx	NO	NO_2	NOx
Delhi	61.7	30.7	92	2.25	22.41	24.65	0.28	5.56	5.84	1.52	16.16	17.68	0.47	17.91	18.37
Patiala				14.84	32.08	46.92	0.07	0.91	0.99	0.15	3.43	3.57	0.03	7.57	7.6
Udaipur				0.13	2.88	3.01	0.1	1.88	1.98	0.17	3.72	3.89	0.01	3.57	3.57
Jabalpur				0.13	4.44	4.57	0.34	6.64	6.98	0.13	2.91	3.03	0.01	3.51	3.52
Pune				0.2	4.92	5.11	0.09	1.69	1.78	0.13	3.35	3.47	0.01	4.08	4.1
Hyderabad				0.62	9.82	10.44	0.17	3.94	4.12	0.21	5.16	5.37	0.03	6.52	6.54
Guwahati				0.25	5.07	5.32	0.14	2.36	2.5	0.05	1.03	1.08	0.04	1.78	1.82
Chennai				0.06	1.47	1.53	0.06	0.92	0.97	0.07	1.82	1.9	0.01	2.73	2.74

	Observations			CCMI-MRIE			CCMI-GCCM			CCMI-CHSM			CCMI-UKCA		
	NO	NO_2	NOx	NO	NO_2	NOx	NO	NO_2	NOx	NO	NO_2	NOx	NO	NO_2	NOx
Delhi	61.7	30.7	92	1.37	4.87	6.23	0.23	5.18	5.41	0.45	5.64	6.09	0.1	4.07	4.17
Patiala				1.37	4.87	6.23	0.06	0.83	0.89	0.25	4.83	5.08	0.05	1	1.05
Udaipur				0.47	2.66	3.13	0.09	1.74	1.82	0.1	1.83	1.94	0.03	1.32	1.35
Jabalpur				2.09	9.36	11.45	0.18	4.01	4.19	0.09	1.76	1.85	0.09	3.79	3.88
Pune				0.59	3.3	3.88	0.08	1.7	1.79	0.08	1.7	1.79	0.04	3.12	3.15
Hyderabad				0.77	4.47	5.24	0.15	3.87	4.02	0.16	3.04	3.2	0.07	3.2	3.27
Guwahati				0.23	1.11	1.34	0.09	1.75	1.84	0.04	1.28	1.31	0.11	1.38	1.49
Chennai				0.02	0.12	0.14	0.05	0.88	0.94	0.07	1.44	1.51	0.02	1.49	1.51

S5: Pearson's correlation coefficient (R) values for model simulated CO against observations at the eight ground based MAPAN stations.

Stations	HTAPII-HDGM	HTAPII-GCAD	HTAPII-CHSR	HTAPII-MOZT	CCMI-MRIE	CCMI-GCCM	CCMI-CHSM	CCMI-UKCA	MMM
Delhi	0.63	0.56	0.58	0.71	0.66	0.48	0.56	0.62	0.69
Patiala	0.63	0.61	0.44	0.65	0.03	0.58	0.3	0.45	0.49
Jabalpur	0.24	0.14	0.29	0.18	0.37	0.3	0.29	0.23	0.28
Udaipur	0.93	0.94	0.86	0.95	0.93	0.95	0.94	0.93	0.96
Pune	0.7	0.78	0.89	0.86	0.86	0.7	0.91	0.82	0.8
Hyderabad	-0.2	-0.14	-0.22	-0.13	-0.1	-0.07	-0.16	-0.08	-0.15
Guwahati	0.81	0.47	0.65	0.81	0.92	0.93	0.91	0.88	0.83
Chennai	0.8	0.83	0.76	0.46	0.65	0.76	0.81	0.54	0.74

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