

Table S1: Model performance statistics for meteorological parameters

	Bangalore	Delhi	Guwahati	Kolkata	Mumbai	Patna
Temperature						
RMSE (°C)	2.58	2.23	2.88	4.02	2.61	1.89
IOA	0.91	0.94	0.75	0.79	0.80	0.95
ME (°C)	-2.32	-0.34	-1.97	-3.16	-1.99	-0.74
Relative humidity						
RMSE (%)	9.33	8.71	11.21	15.68	10.49	11.63
IOA	0.97	0.92	0.79	0.79	0.85	0.91
ME (%)	0.06	0.53	3.09	12.09	3.99	5.98
Wind speed						
RMSE (m s ⁻¹)	1.47	1.91	1.84	1.90	1.44	2.11
IOA	0.49	0.59	0.40	0.48	0.83	0.55
ME (m s ⁻¹)	0.51	-0.22	-0.35	0.07	-0.71	1.22
Wind direction						
RMSE (°)	44.06	108.48	146.95	64.29	76.91	104.87
IOA	0.79	0.72	0.47	0.43	0.68	0.75
ME (°)	-18.48	10.28	6.07	22.41	14.23	-26.17

Table S2: Model performance statistics for chemical species

NOR-I						
	BC					
	BANGALORE	DELHI	KOLKATA	MUMBAI	PATNA	GUWAHATI
RMSE (µg m ⁻³)	1.49	20.03	27.31	47.12	7.12	1.04
IOA	0.44	0.13	0.03	0.01	0.28	0.48
ME (µg m ⁻³)	0.74	13.81	21.71	32.84	3.81	0.00
Dust						
RMSE (µg m ⁻³)	18.85	122.19	32.02	82.17	64.17	33.40
IOA	0.41	0.33	0.35	0.35	0.35	0.26
ME (µg m ⁻³)	-15.13	-76.40	-30.09	-76.21	-50.50	-31.91
Organic Carbon						
RMSE (µg m ⁻³)	2.57	34.63	49.02	87.04	12.12	4.64
IOA	0.71	0.24	0.07	0.02	0.51	0.50
ME (µg m ⁻³)	0.73	24.55	38.29	60.88	3.87	-1.41
Sulfate						
RMSE (µg m ⁻³)	1.66	4.36	2.43	3.34	7.48	4.12
IOA	0.42	0.56	0.68	0.36	0.35	0.30
ME (µg m ⁻³)	-0.16	3.19	0.58	2.87	5.11	-2.22
NOR						

	BC					
	BANGALORE	DELHI	KOLKATA	MUMBAI	PATNA	GUWAHATI
RMSE ($\mu\text{g m}^{-3}$)	0.69	7.13	15.14	24.16	2.86	0.77
IOA	0.64	0.29	0.06	0.02	0.51	0.61
ME ($\mu\text{g m}^{-3}$)	0.48	5.76	13.21	19.76	2.16	0.11
	Dust					
RMSE ($\mu\text{g m}^{-3}$)	18.43	120.49	29.71	74.03	57.77	20.48
IOA	0.40	0.23	0.36	0.38	0.33	0.39
ME ($\mu\text{g m}^{-3}$)	-14.52	-61.58	-26.64	-65.36	-40.90	-18.49
	Organic carbon					
RMSE ($\mu\text{g m}^{-3}$)	1.44	11.21	25.73	44.48	5.34	3.64
IOA	0.81	0.51	0.14	0.04	0.70	0.61
ME ($\mu\text{g m}^{-3}$)	0.44	8.61	22.04	36.26	0.02	-2.02
	Sulfate					
RMSE ($\mu\text{g m}^{-3}$)	1.56	3.48	1.88	3.99	3.30	3.04
IOA	0.38	0.45	0.73	0.31	0.60	0.30
ME ($\mu\text{g m}^{-3}$)	-0.30	1.63	0.12	3.61	1.27	-1.62

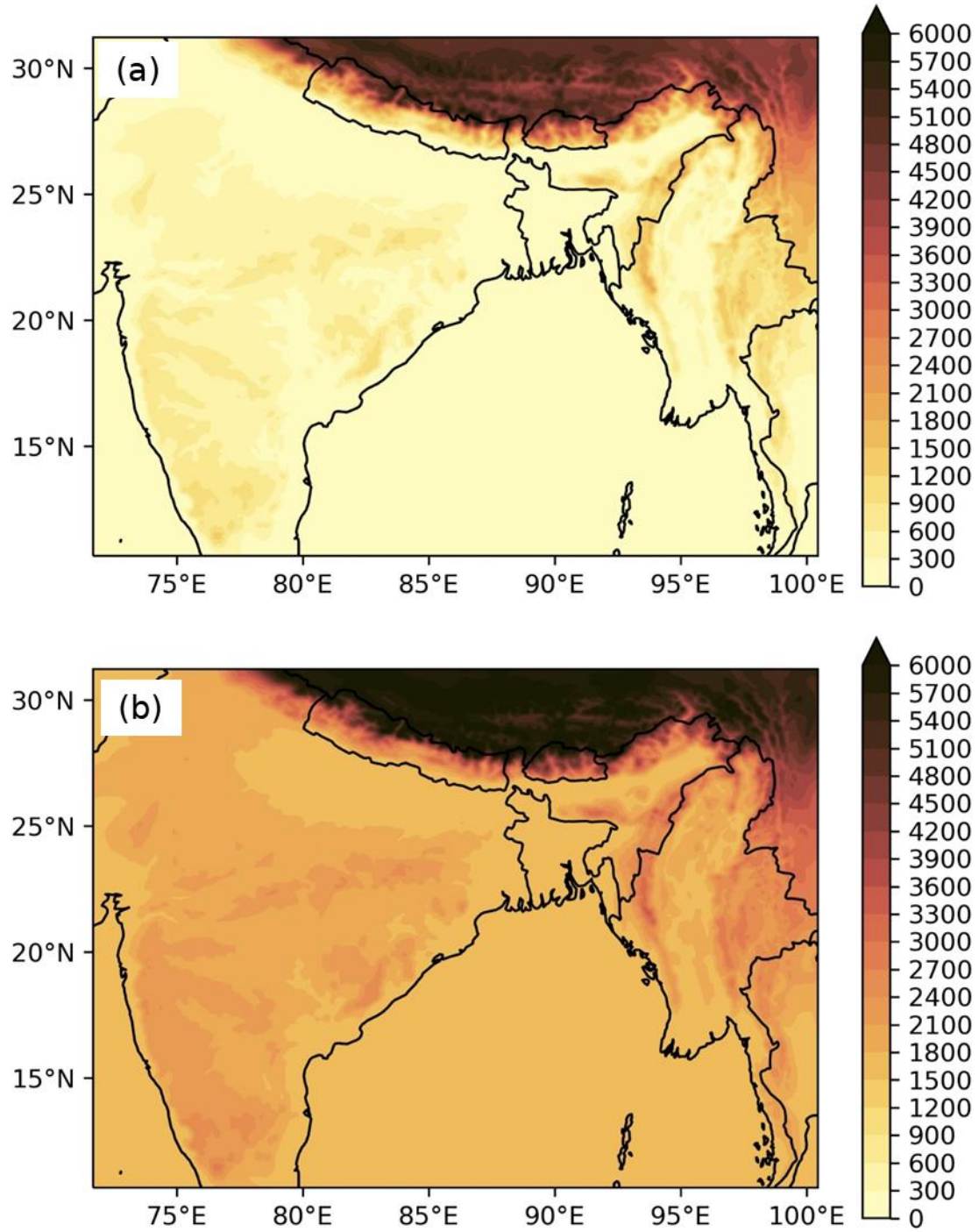


Figure S1: Spatial distributions of geopotential heights (m) of model level a) 0 (near surface) b) 15

Table S3: Region-wise PM₁₀ concentration ($\mu\text{g m}^{-3}$) in different scenarios at different atmospheric heights

	No_EMISS_NE		Only_EMISS_NE		NOR-I		(No_EMISS_NE/ (No_EMISS_NE + Only_EMISS_NE))*100%	
Model level	0	15	0	15	0	15	0	15
Region 1	18.18	32.67	6.49	1.01	30.25	42.99	73.70	97.00
Region 2	12.78	21.70	6.33	1.14	26.64	33.75	66.86	95.02
Region 3	5.25	7.33	3.43	0.90	12.69	12.39	60.48	89.03
Region 4	21.62	36.01	16.03	0.88	40.12	47.38	57.43	97.62
Average	14.46	24.43	8.07	0.98	27.43	34.13	64.18	96.14

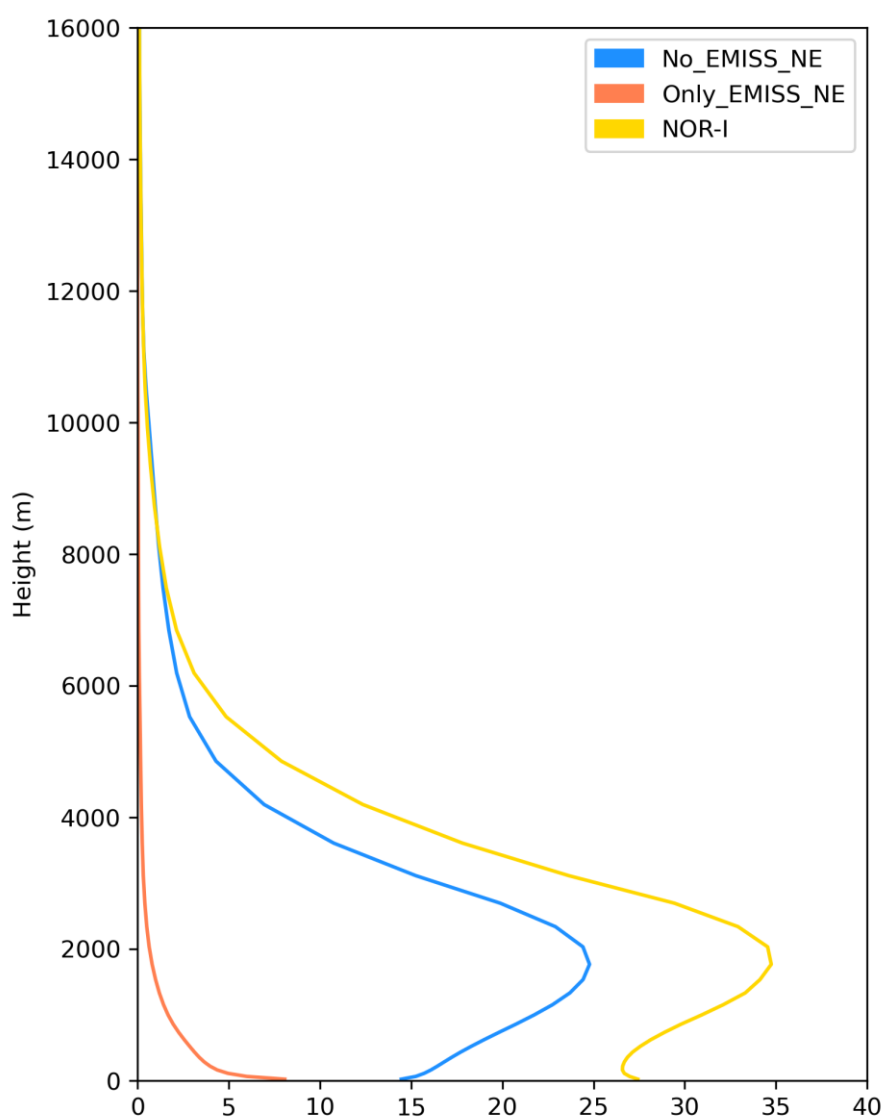


Figure S2: Regional average vertical profile of PM₁₀ concentration ($\mu\text{g m}^{-3}$) in different scenarios

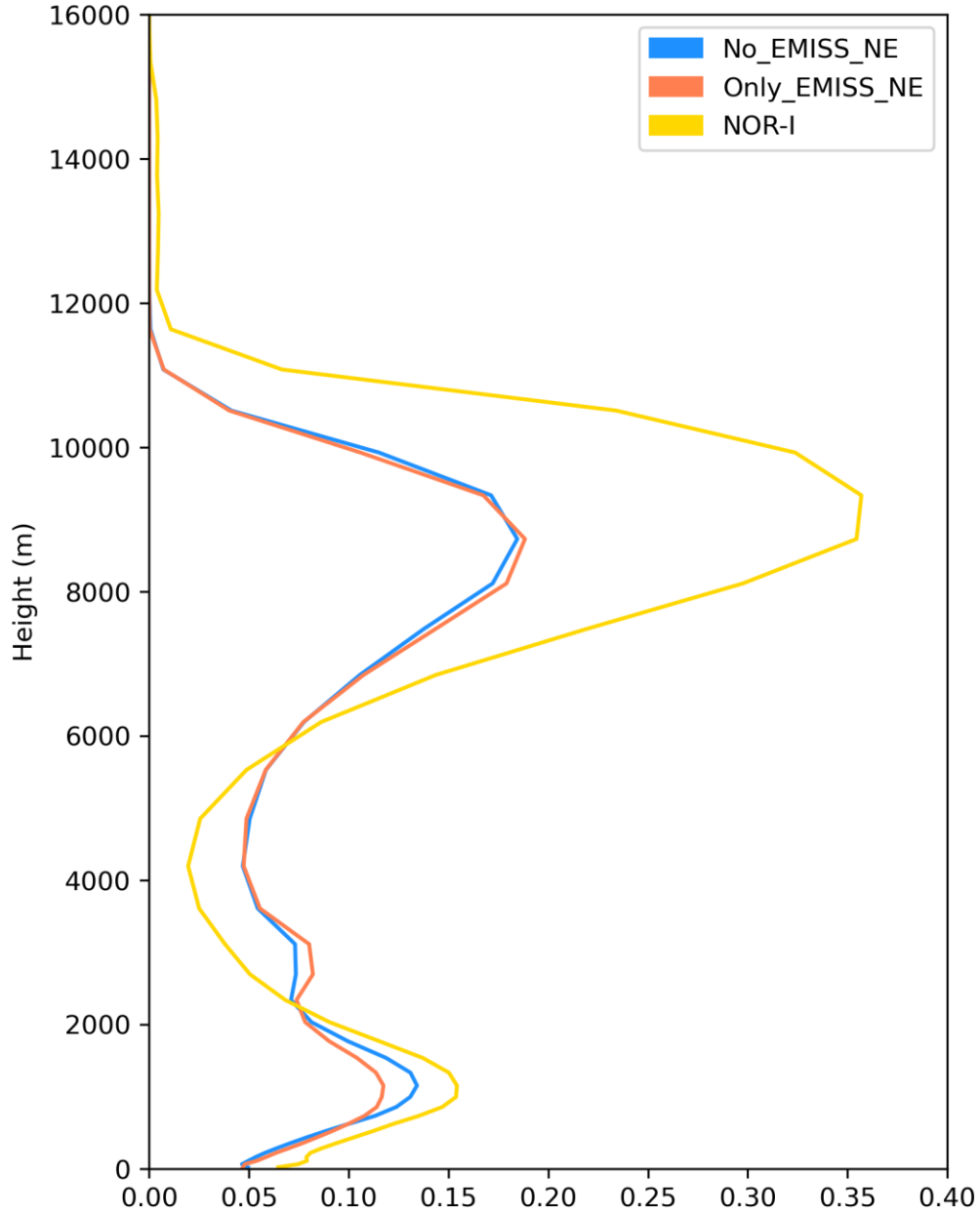


Figure S3: Regional average vertical profile of cloud cover in different scenarios

Aerosol effects of local and transported aerosols on radiative forcing

At surface,

$$\text{Net total RF} = \text{NOR-I}_{((\text{SWDNB}+\text{LWDNB})-(\text{SWUPB}+\text{LWUPB}))} - \text{NOCHEM}_{((\text{SWDNB}+\text{LWDNB})-(\text{SWUPB}+\text{LWUPB}))}$$

$$\text{Net indirect RF} = \text{NOFEED-I}_{((\text{SWDNB}+\text{LWDNB})-(\text{SWUPB}+\text{LWUPB}))} - \text{NOCHEM}_{((\text{SWDNB}+\text{LWDNB})-(\text{SWUPB}+\text{LWUPB}))}$$

$$\text{Net direct + semi-direct RF} = \text{NOR-I}_{((\text{SWDNB}+\text{LWDNB})-(\text{SWUPB}+\text{LWUPB}))} - \text{NOFEED-I}_{((\text{SWDNB}+\text{LWDNB})-(\text{SWUPB}+\text{LWUPB}))}$$

$$\text{Net direct RF} = \text{NOR-I}_{((\text{SWDNBC}+\text{LWDNBC})-(\text{SWUPBC}+\text{LWUPBC}))} - \text{NOFEED-I}_{((\text{SWDNBC}+\text{LWDNBC})-(\text{SWUPBC}+\text{LWUPBC}))}$$

$$\text{Net semi-direct RF} = (\text{Direct + semi-direct RF}) - \text{Net direct RF}$$

At TOA,

$$\text{Net total RF} = \text{NOR-I}_{((\text{SWDNT}+\text{LWDNT})-(\text{SWUPT}+\text{LWUPT}))} - \text{NOCHEM}_{((\text{SWDNT}+\text{LWDNT})-(\text{SWUPT}+\text{LWUPT}))}$$

$$\text{Net indirect RF} = \text{NOFEED-I}_{((\text{SWDNT}+\text{LWDNT})-(\text{SWUPT}+\text{LWUPT}))} - \text{NOCHEM}_{((\text{SWDNT}+\text{LWDNT})-(\text{SWUPT}+\text{LWUPT}))}$$

$$\text{Net direct + semi-direct RF} = \text{NOR-I}_{((\text{SWDNT}+\text{LWDNT})-(\text{SWUPT}+\text{LWUPT}))} - \text{NOFEED-I}_{((\text{SWDNT}+\text{LWDNT})-(\text{SWUPT}+\text{LWUPT}))}$$

$$\text{Net direct RF} = \text{NOR-I}_{((\text{SWDNTC}+\text{LWDNTC})-(\text{SWUPTC}+\text{LWUPTC}))} - \text{NOFEED-I}_{((\text{SWDNTC}+\text{LWDNTC})-(\text{SWUPTC}+\text{LWUPTC}))}$$

$$\text{Net semi-direct RF} = (\text{Direct} + \text{semi-direct RF}) - \text{Net direct RF}$$

$$\text{Thus, Net atmospheric RF} = \text{Total RF}_{\text{TOA}} - \text{Total RF}_{\text{SURFACE}}$$

Similarly, the short-wave (SW) or long-wave (LW) was similarly found by using either or SW or LW radiation instead of combined radiations. NOR-I was replaced by No_EMISS_NE or Only_EMISS_NE while NOFEED was replaced by No_EMISS_NE_NOFEED or Only_EMISS_NE_NOFEED to find contributions of local and transported emissions.

Table S4: Changes in total, convective (RAINNC) and non-convective (RAINNC) rainfall (mm) due to different aerosol effects in different scenarios

		Total aerosol effect	Direct + Semi-direct	Indirect
NOR-I	Region 1	-100.60	-13.21	-87.39
	Region 2	-71.93	-1.34	-70.59
	Region 3	-102.60	-2.49	-100.11
	Total	-275.13	-17.04	-258.09
No_EMISS_NE	Region 1	-29.81	-18.37	-11.44
	Region 2	-21.52	-5.88	-15.64
	Region 3	-21.73	0.30	-22.04
	Total	-73.06	-23.95	-49.11
Only_EMISS_NE	Region 1	-26.81	-6.23	-20.57
	Region 2	2.48	-0.17	2.65
	Region 3	-0.12	-2.01	1.89
	Total	-24.45	-8.42	-16.04

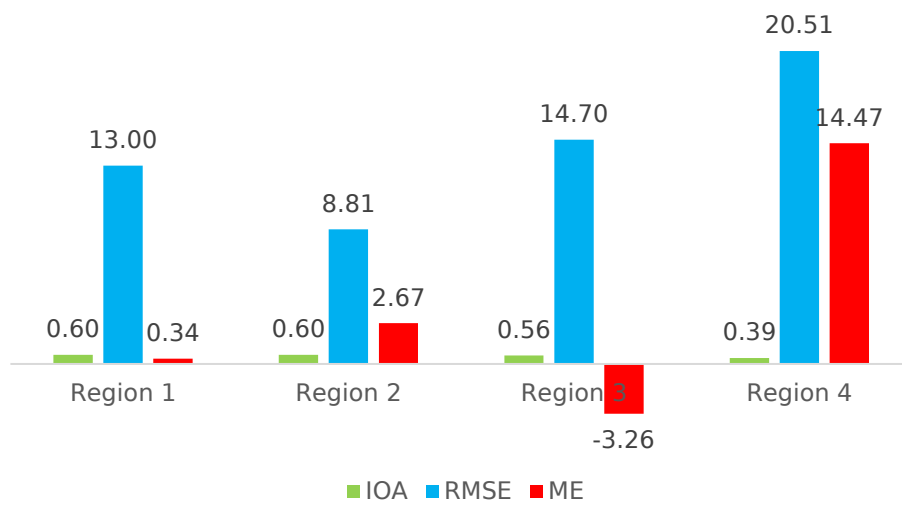


Figure S4: Region wise rainfall evaluation statistics with NOR-I. RMSE and ME in mm day⁻¹

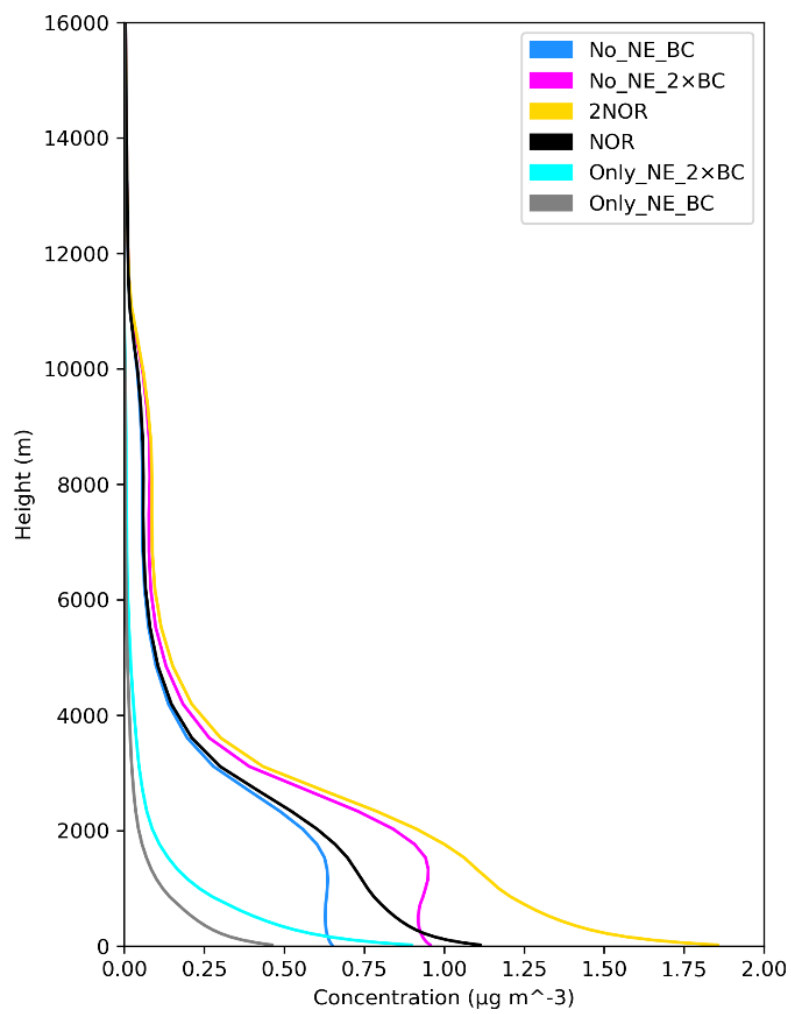


Figure S5: Regionally averaged vertical profiles of BC concentration ($\mu\text{g m}^{-3}$) in different scenarios

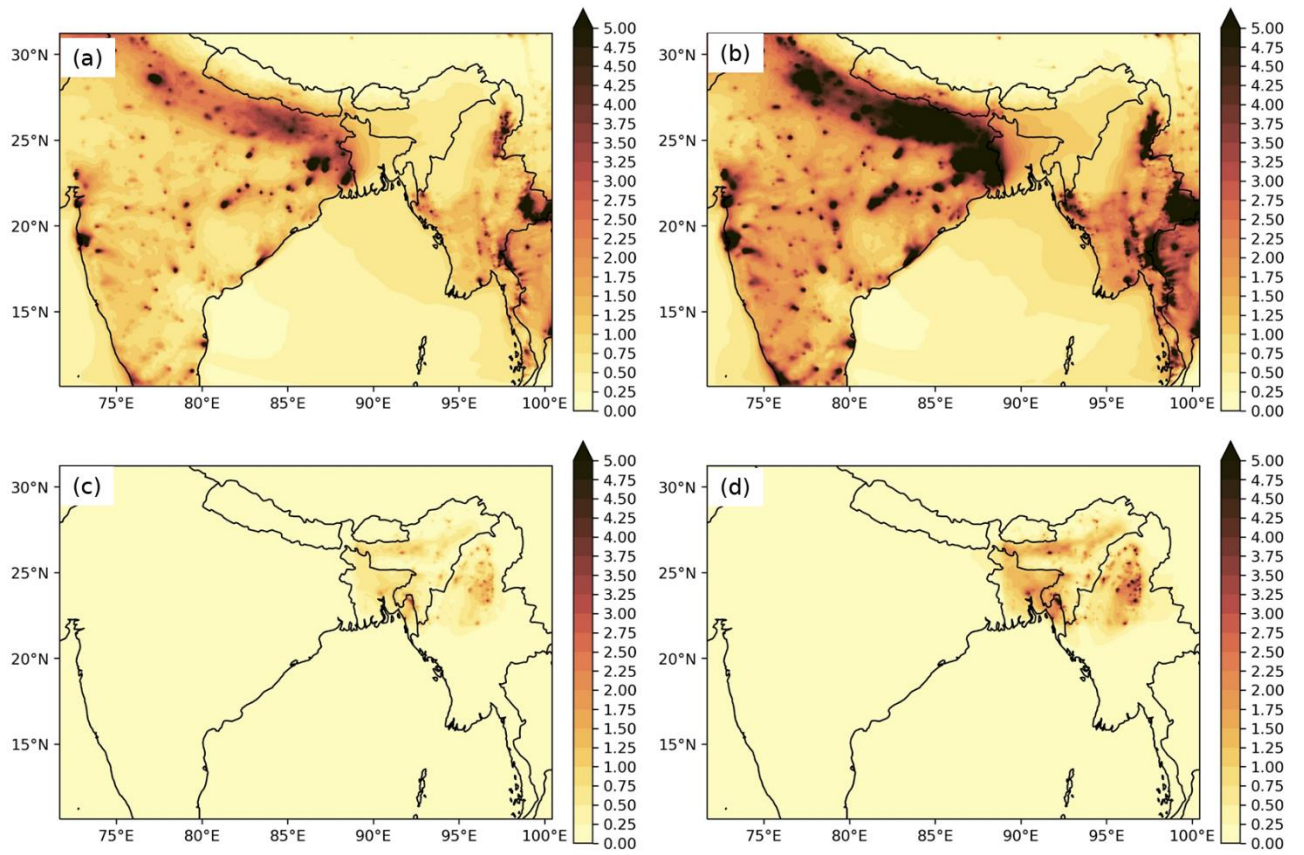


Figure S6: Spatial distributions of near surface (model level 0) BC concentration ($\mu\text{g m}^{-3}$) in a) No_NE_BC b) No_NE_2×BC c) Only_NE_BC d) Only_NE_2×BC

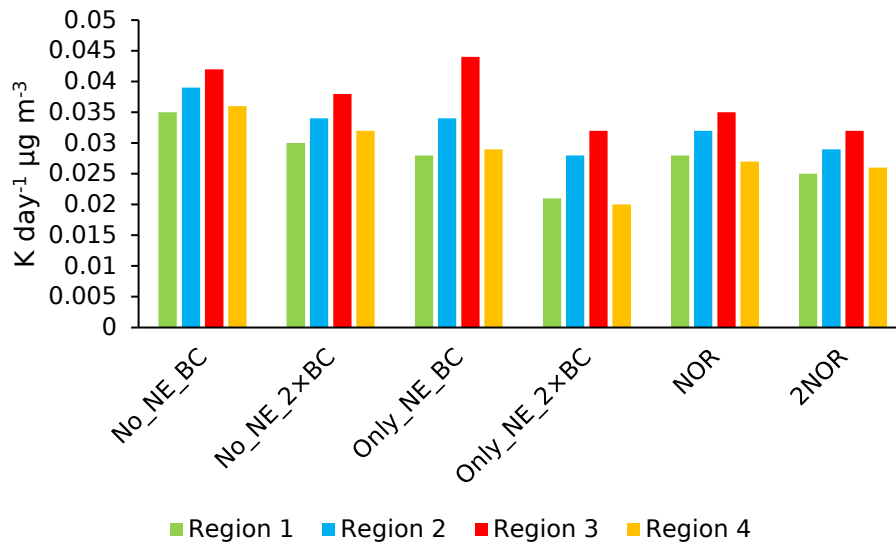


Figure S7: Region-wise HE in different scenarios

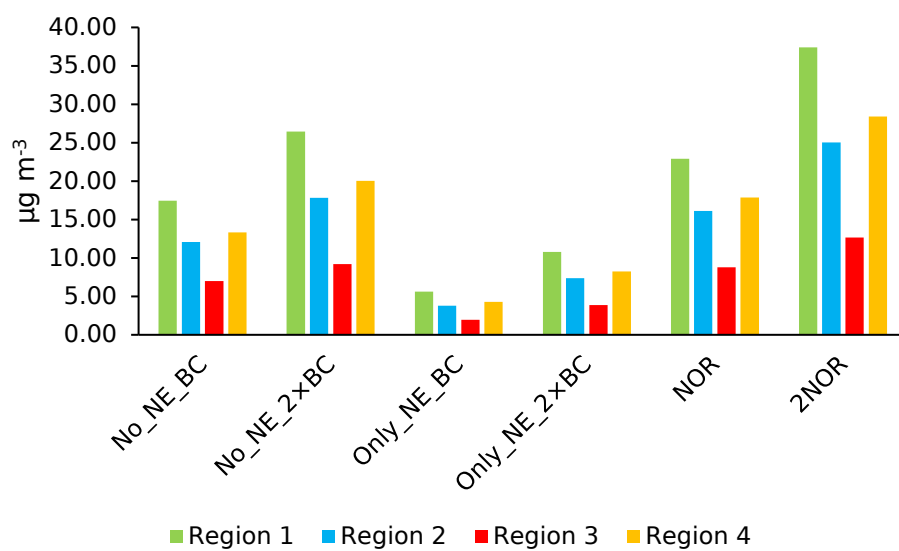


Figure S8: Column integrated BC concentration

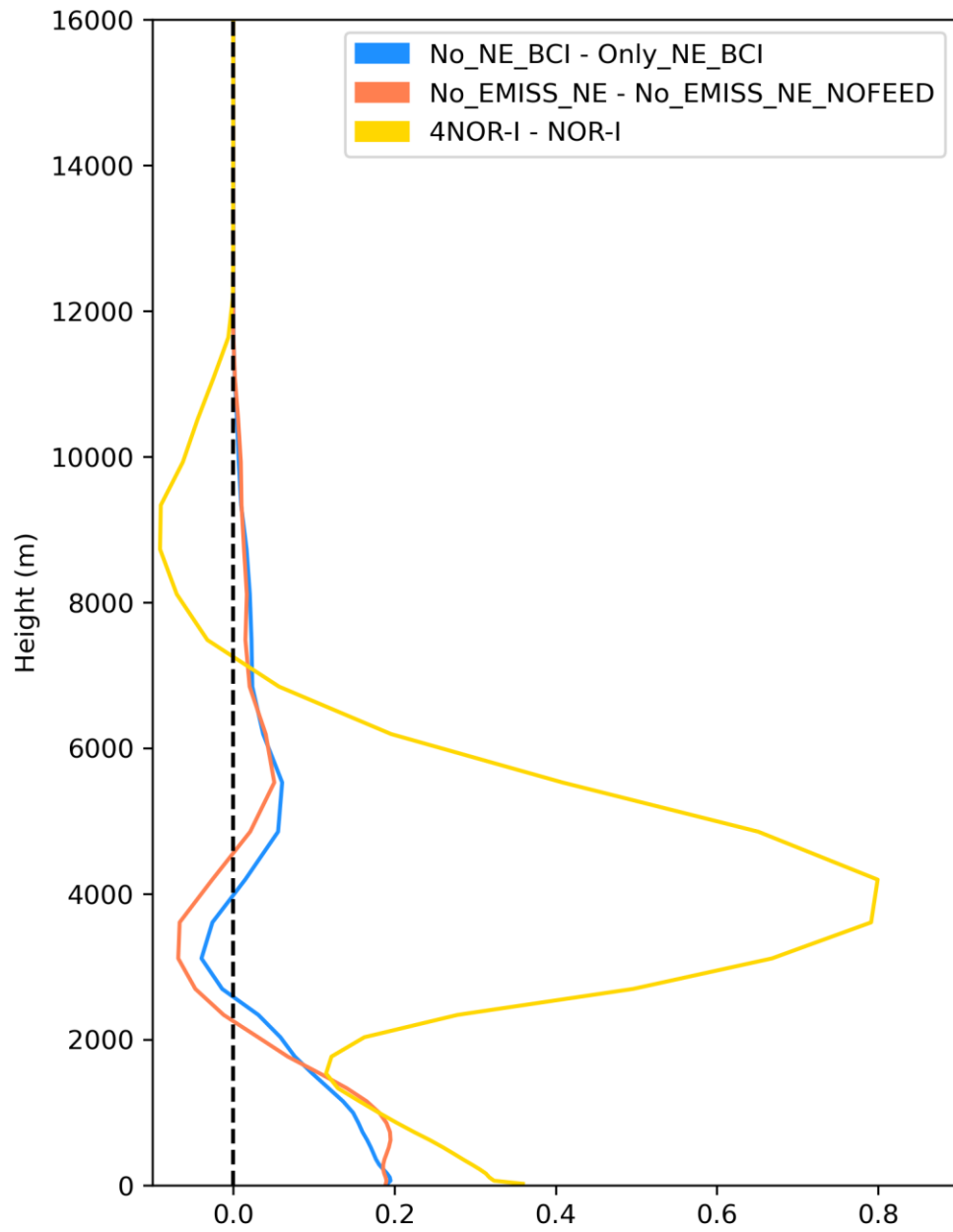


Figure S9: Regionally averaged vertical profiles of water vapor mixing ratio (g kg^{-1}) perturbations

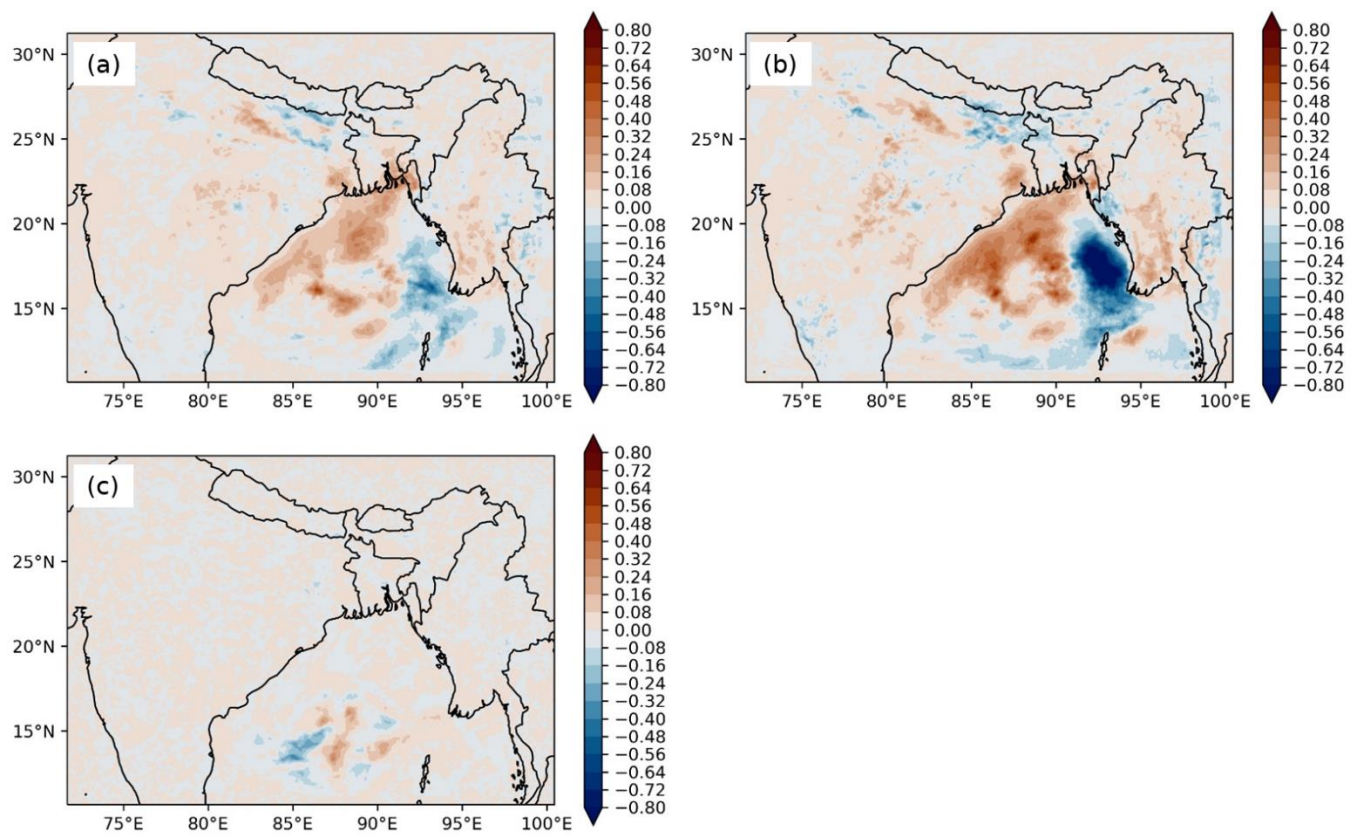


Figure S10: Spatial distributions of change in moisture flux ($\text{g s}^{-1} \text{m}^{-2}$) in a) No_NE_BC – Only_NE_BC b) No_NE_2xBC – Only_NE_BC c) Only_NE_2xBC – Only_NE_BC near surface

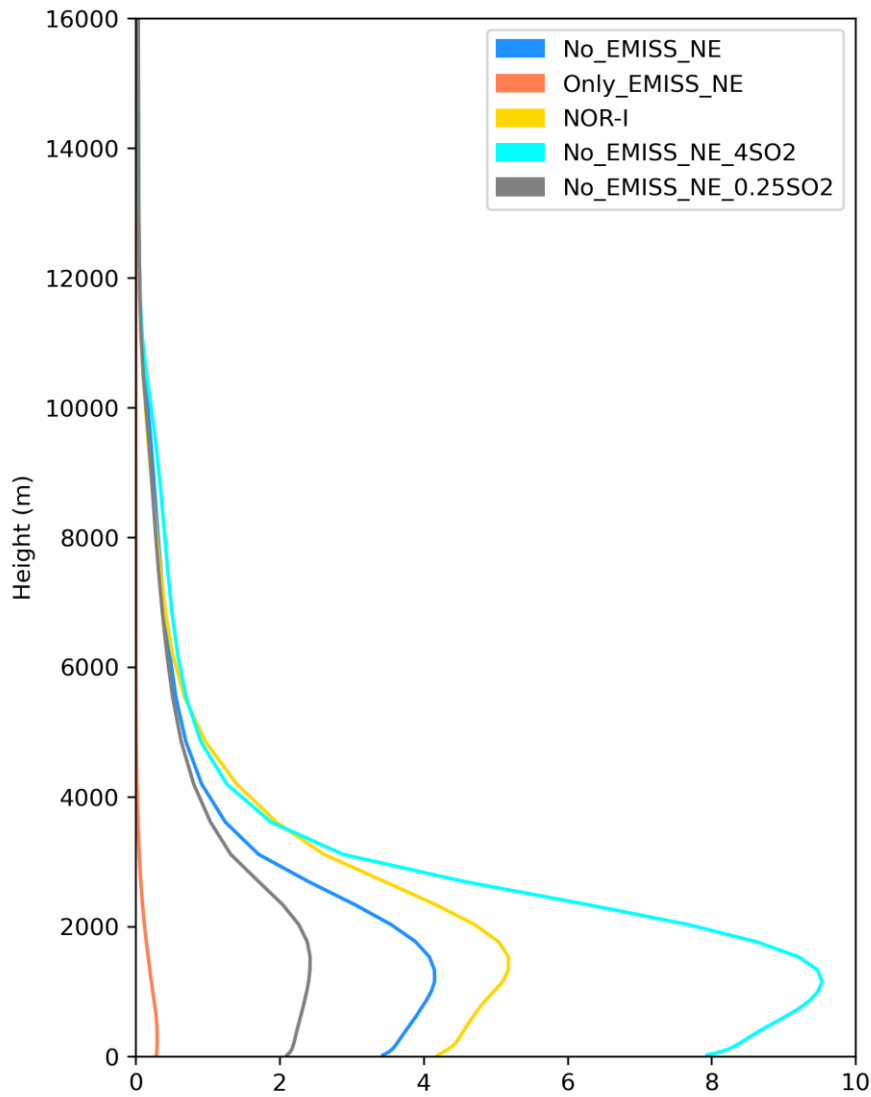


Figure S11: Regional average vertical profile of sulfate aerosol concentration ($\mu\text{g m}^{-3}$) in different scenarios

Table S5: Amount of rainfall (mm) aerosol effects increase (inc) or decrease (dec) RAIN under different rainfall intensities

	inc_0_5	inc_5_10	inc_>10	dec_0_5	dec_5_10	dec_>10
Total aerosol effect (NOR-I – NOCHEM)	6.17	9.99	137.16	-6.50	-10.61	-411.34
Direct + semi-direct effect (NOR-I – NOFEED-I)	6.62	10.17	116.92	-7.07	-10.51	-133.16
Indirect effect (NOFEED-I – NOCHEM)	6.52	10.24	141.62	-6.48	-10.57	-399.41
Total aerosol effect with BC increase (4NOR-I – NOCHEM)	5.13	8.81	275.47	-6.52	-10.10	-337.23
Direct + semi-direct effect with BC increase (4NOR-I – NOFEED-I)	5.55	9.66	339.33	-6.95	-10.78	-143.17
BC increase (4NOR-I – NOR-I)	5.63	9.73	343.76	-6.58	-10.45	-131.41

Table S6: Percentage (%) of simulation time aerosol effects increase (inc) or decrease (dec) RAIN under different rainfall intensities

	inc_0_5	inc_5_10	inc_>10	dec_0_5	dec_5_10	dec_>10
Total aerosol effect (NOR-I – NOCHEM)	21.05	4.51	12.32	21.06	4.80	19.23
Direct + semi-direct effect (NOR-I – NOFEED-I)	22.37	4.61	10.85	24.18	4.78	11.38
Indirect effect (NOFEED-I – NOCHEM)	21.44	4.63	12.38	20.58	4.78	18.85
Total aerosol effect with BC increase (4NOR-I – NOCHEM)	17.83	3.97	13.92	23.69	4.58	16.63
Direct + semi-direct effect with BC increase (4NOR-I – NOFEED-I)	17.79	4.36	16.51	24.08	4.87	12.74
BC increase (4NOR-I – NOR-I)	18.45	4.39	16.55	23.57	4.72	12.34