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Impacts of reducing scattering and absorbing aerosols on the temporal extent and intensity of South Asian summer monsoon and East Asian summer monsoon

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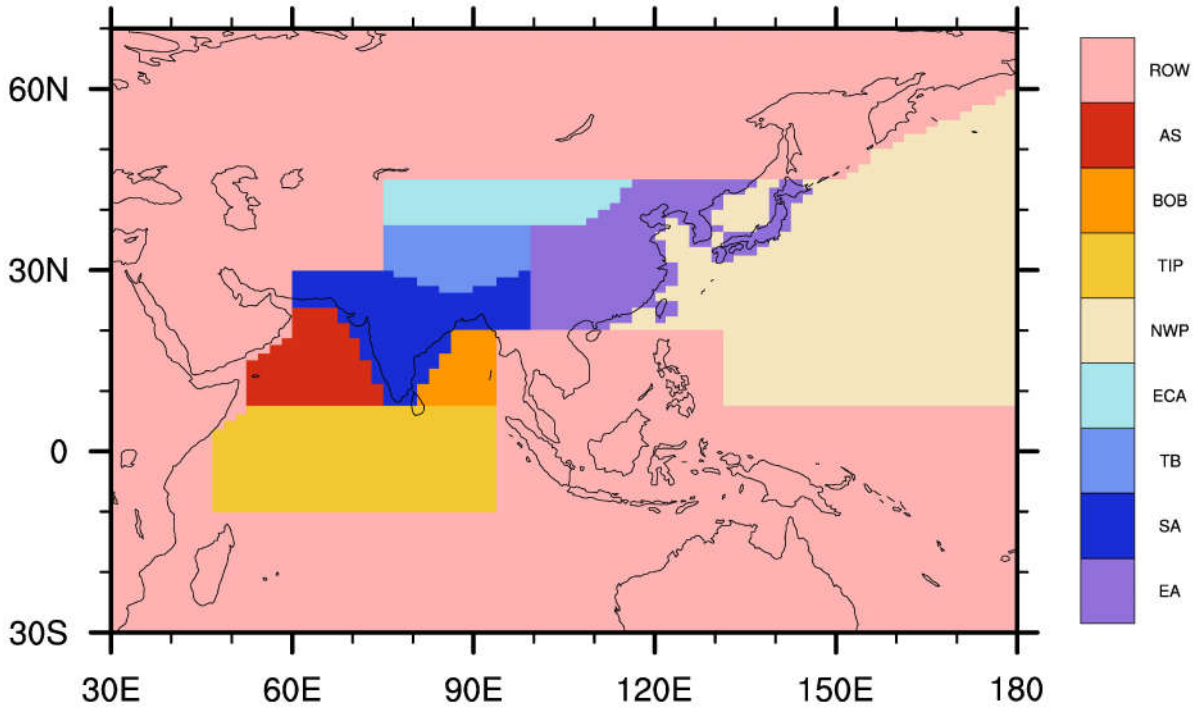

Figure S1. The division of the East Asia (EA), South Asia (SA), Tibet Plateau (TP), East-Central Asia (ECA), Northwest Pacific (NWP), Tropical Indian Ocean (TIO), Bay of Bengal (BOB), Arabian Sea (AS) and rest of the world (ROW) refers to the sixth IPCC assessment report.

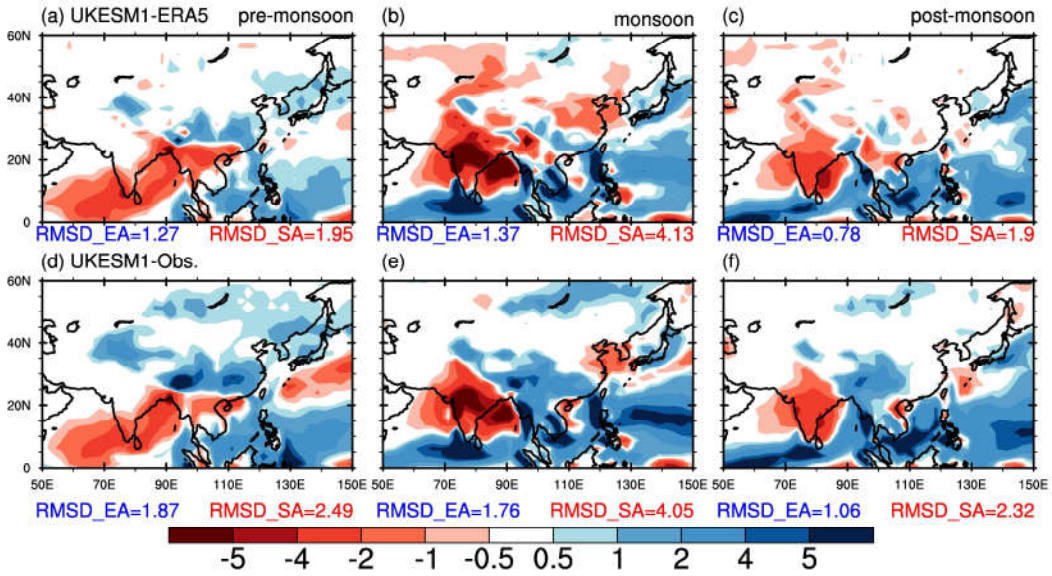

Figure S2. Spatial distributions of the climatological mean (1985-2014) difference in precipitation (unit: mm day^{-1}) between the simulations and ERA5 reanalysis (a-c) during pre-monsoon (April-May; a), monsoon (June-August; b) and post-monsoon (September-October; c) seasons. (d)-(f): Same as (a)-(c), but for the difference between the simulations and merged observations from Global Precipitation Climatology Project (GPCP) rain gauge-satellite combined precipitation dataset and Climate Prediction Center (CPC) unified gauge-based daily observations. The regional mean root-mean-square deviation (RMSD; unit: mm day^{-1}) values over EA and SA are shown in blue and red text, respectively.

Table S1. The mean values and the 25th-75th percentile ranges of the monsoon onset date (unit: pentad), withdrawal date (unit: pentad) and duration (unit: pentad) over South and East Asia in different simulations obtained based on different definitions.

		W2009[a]			N2016[b]		
		Onset (pentad)	Withdrawal (pentad)	Duration (pentad)	Onset (day)	Withdrawal (day)	Duration (day)
SASM	CTRL	30.8 (30,32)[*]	51.2 (50,52)	21.4 (19,23)	32.1 (30,33.5)	55.9 (53.5,58)	24.8 (23,27.5)
	AER-75%	30.7 (30,32)	51.2 (50,52)	21.5 (20,23)	30.9 (29,32)	56.1 (54.5,57.5)	26.3 (23.5,29)
	SCT-75%+ ABS-75%[e]	31.4 (30,33)	50.9 (50,52)	20.5 (18.5,23)	32 (31,33)	56.5 (55.5,59)	25.5 (23,29)
	SCT-75%	30.7 (29,32)	51.5 (50.5,52.5)	21.8 (20,23)	31.7 (30.5,33)	57.8 (56,59.5)	27.1 (25,29.5)
	ABS-75%	32 (30.5,33.5)	50.4 (49.5,51.5)	19.4 (17,20.5)	32.3 (31,34)	55.2 (52.5,57)	23.9 (20.5,27)
		W2016[c]			G1983[d]		
		Onset (pentad)	Withdrawal (pentad)	Duration (pentad)	Onset (pentad)	Withdrawal (pentad)	Duration (pentad)
EASM	CTRL	15.8 (14,18)	49.3 (47.5,51)	34.5 (33,37)	16.7 (15,19)	53.2 (52,54)	37.8 (36,40)
	AER-75%	15.9 (14,19)	48.9 (48,50)	34.0 (31,37)	17.1 (16,18)	52.6 (52,54)	36.4 (35,38)
	SCT-75%+ ABS-75%	15.5 (14,17)	49.4 (48,50.5)	34.9 (32,37)	16.4 (15,18)	53.2 (52,54)	37.8 (35,40.5)
	SCT-75%	15.8 (14,18)	50.1 (48,51.5))	35.4 (31.5,39.5)	16 (14.5,17)	53.7 (52.5,54))	38.8 (36,41)
	ABS-75%	15.2 (14,16)	48.8 (47.5,50)	34.6 (32,36.5)	16.8 (16,18)	52.7 (51,54)	36.9 (34.5,39)

[*]Mean value with a 25th-75th percentile range. [a] Definition from Wang et al. (2009) to obtain South Asian summer monsoon (SASM) onset and withdrawal dates, hereafter referred to as W2009. [b] Definition from Noska and Misra (2016) to obtain the SASM onset and withdrawal dates, hereafter referred to as N2016.[c] Definition from Wang, D. et al (2016) to obtain East Asian summer monsoon (EASM) onset and withdrawal dates, hereafter referred to as W2016.[d] Definition from Guo (1983) to obtain the EASM onset and withdrawal dates, hereafter referred to as G1983. [e] Linear addition of the impacts of the reductions in the SCT and ABS.

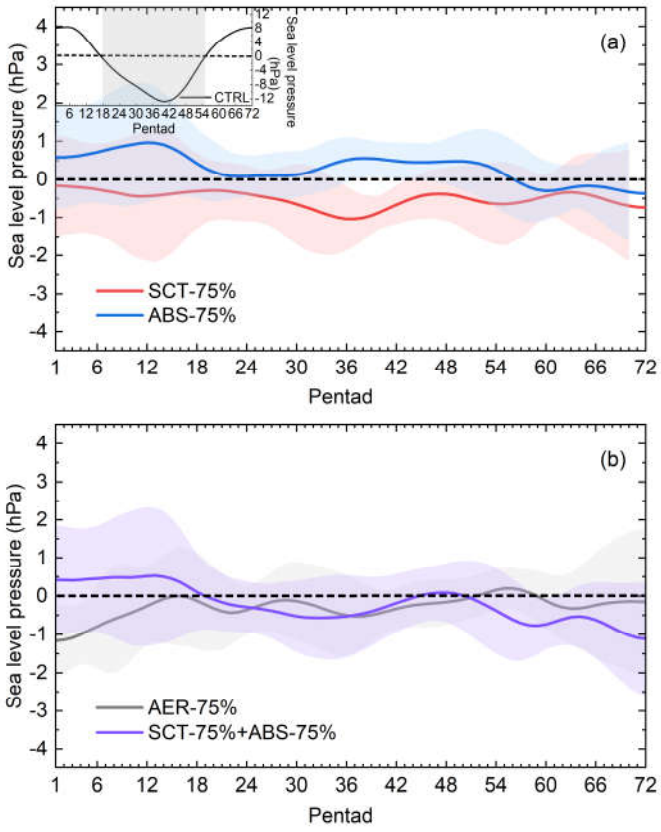

Figure S3. Time series of the anomalous land-sea sea level pressure (SLP) difference (unit: hPa) between the Asian continent part (including South Asia, East Asia, Tibet Plateau and East-Central Asia) adjacent to the ocean and its surrounding oceans and seas (including Northwest Pacific, tropical Indian Ocean, Bay of Bengal and Arabian Sea) to the reductions in total aerosols (b; gray line), SCT aerosols (a; red line) and ABS aerosols (a; blue line). The x-axis denotes the time (unit: pentad). The land-sea SLP difference responses are the difference between the aerosol-emission-perturbed and control runs. Purple line in Panel (b) represent the sum of the impacts of the reductions in the SCT and ABS. The shading area denote the standard deviation of the land-sea SLP difference anomaly. The sub-panel attached to Panel (a) gives the climatological land-sea SLP difference (unit: hPa) from control simulations. The region division used in this study refers to the sixth IPCC assessment report and is shown in Fig. S1.

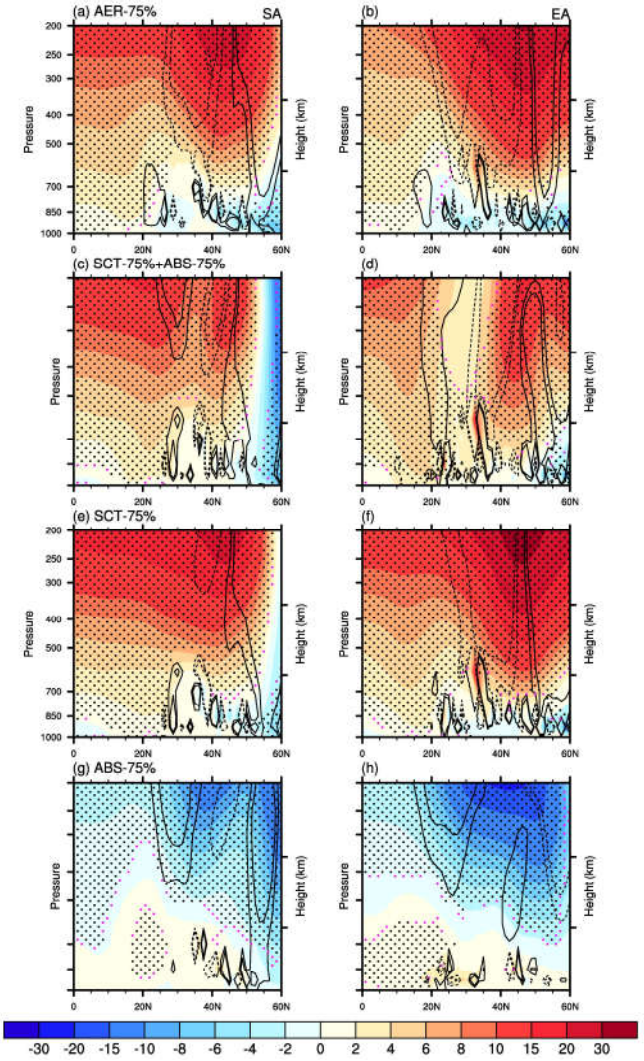

Figure S4. Zonal-mean geopotential height (unit: m) responses to the reductions in total aerosols (a and b), scattering (SCT) aerosols (e and f), and absorbing (ABS) aerosols (g and h) during monsoon season over South Asia (70-90°E; a, c, e and g) and East Asia (100-120°E; b, d, f, h). Monsoon season is analyzed and based on the definitions from N2016 over South Asia and G1983 over East Asia. Panels (c) and (d) are the sum of the impacts of the reductions in the SCT and ABS. Black lines denote the meridional gradient of GH response (unit: gpm m^{-1}; solid and dashed lines denote positive and negative values, respectively). Black and pink dotted regions denote where the geopotential height change is statistically significant at the 95% and 90% confidence level, respectively, according to a t-test.

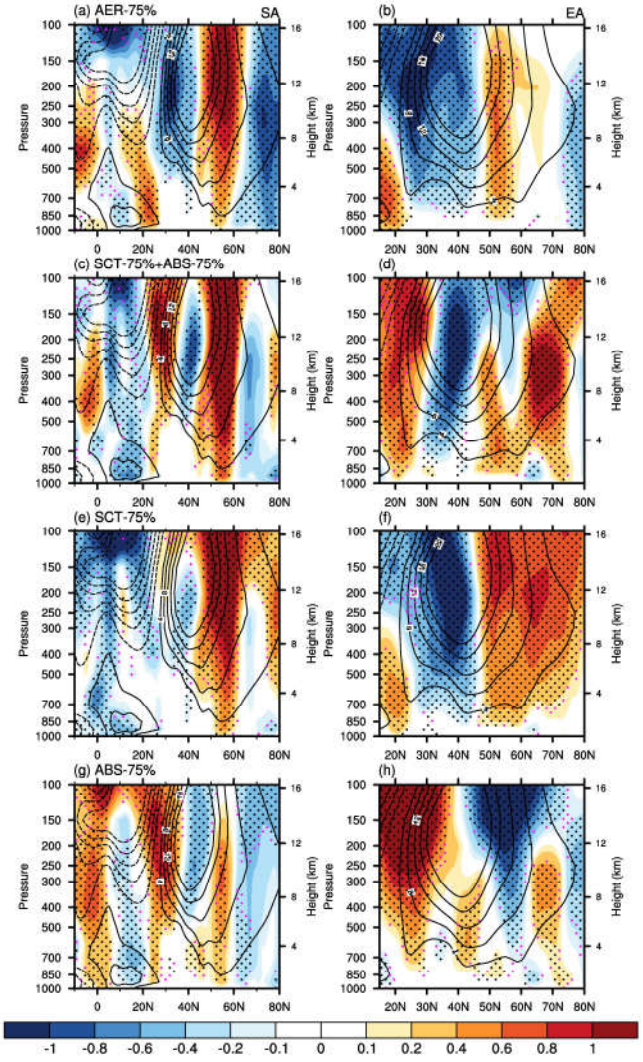

Figure S5. Same as Figure S4, but for the zonal-mean zonal wind (shading; unit: m s^{-1}; red and blue denote westerly and easterly wind, respectively) responses during monsoon season. Black lines represent the climatological zonal wind from control simulations (unit: m s^{-1}; solid and dash lines denote westerly and easterly wind, respectively).

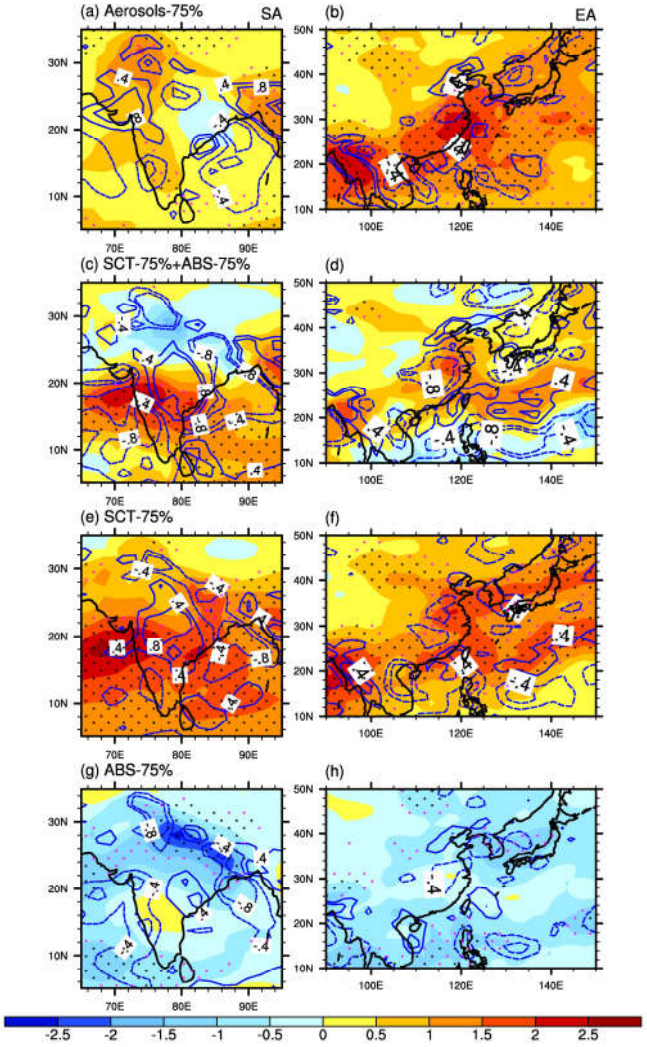

Figure S6. Spatial distributions of the total column moisture flux (shading; unit: kg m^{-2} s^{-1}; red denote moisture convergence and blue denote divergence) and 850-hPa vertical velocity (contours; unit: -100×Pa s^{-1}) responses to the reductions in total aerosols (a and b), SCT aerosols (e and f) and ABS aerosols (g and h) during monsoon season over South Asia (a, c, e and g) and East Asia (b, d, f and h). Monsoon season is analyzed and based on the definitions from N2016 over South Asia and G1983 over East Asia. Panels (c) and (d) is the sum of the impacts of the reductions in the SCT and ABS. Black and pink dotted regions denote where the total column moisture flux change is statistically significant at the 95% and 90% confidence level, respectively, according to a t-test.