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Strong intermodel differences and biases in CMIP6 simulations of $PM_{2.5}$, aerosol optical depth, and precipitation over Africa

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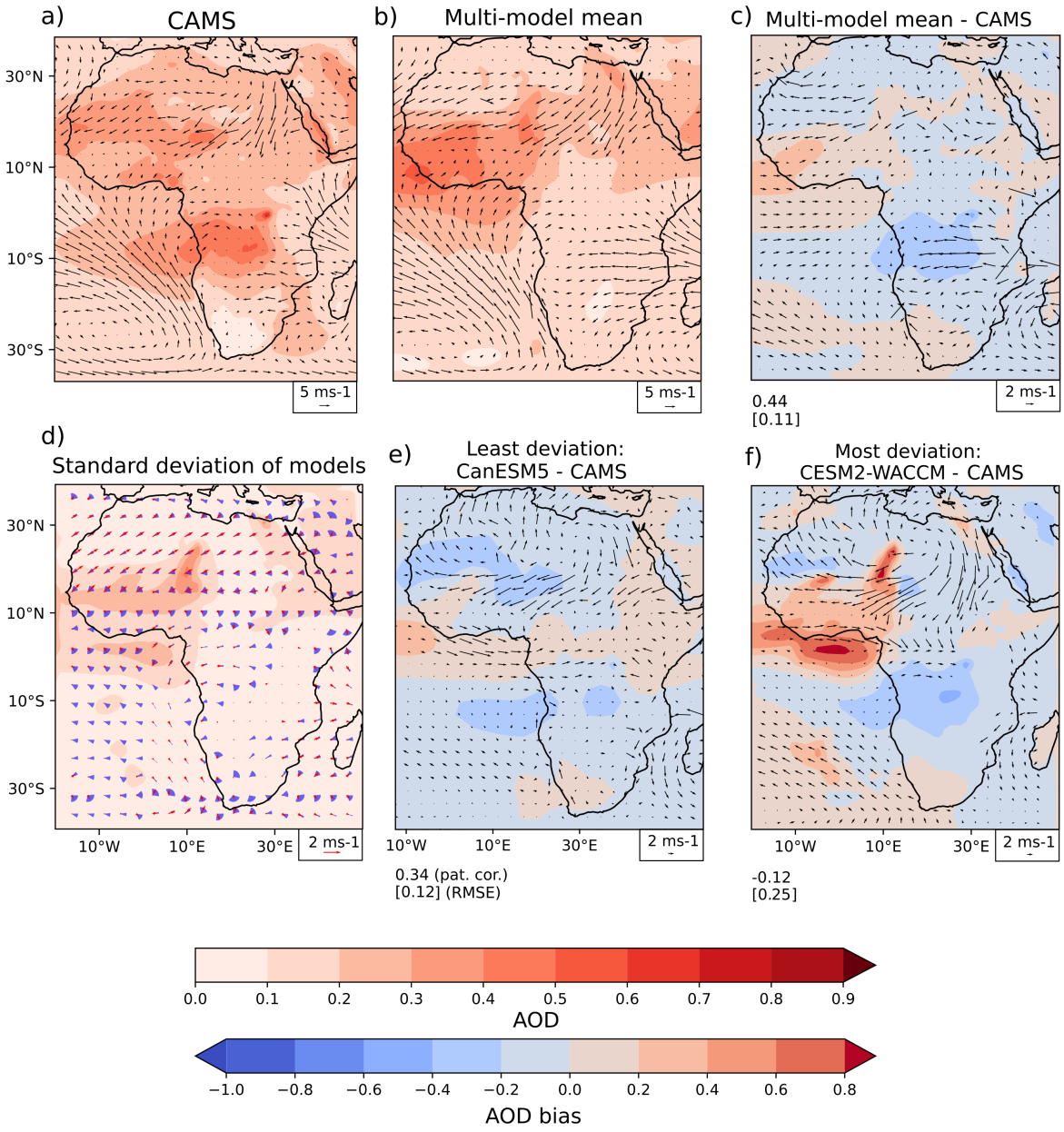

Figure S1. SON-mean total AOD at 550 nm and winds at 925 hPa for 2002–2023 in (a) observations (CAMS/ERA5) and (b) CMIP6 MMM. (c) CMIP6 MMM bias against observations and (d) intermodel standard deviation for precipitation. Bias in mean AOD at 550 nm in the models with the (e) least (CanESM5) and (f) most (CESM2-WACCM) deviation from CAMS as determined by pattern correlation. Pattern correlation with CAMS is shown below

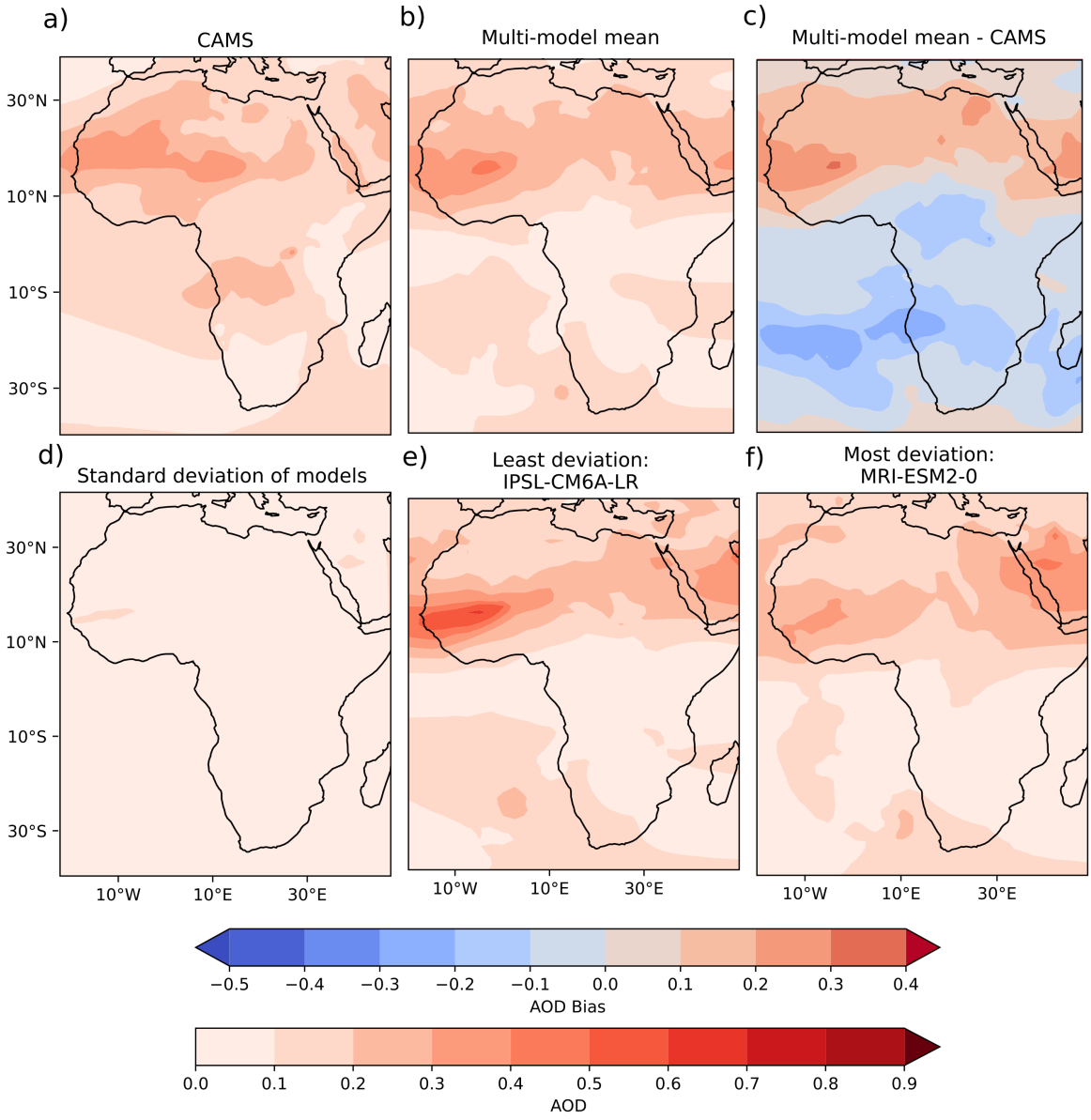

Figure S2. SON-mean total AOD at 870 nm for 2002–2023 in (a) observations (CAMS) and (b) CMIP6 MMM. (c) CMIP6 MMM bias against observations and (d) intermodel standard deviation for precipitation. Mean AOD at 870 nm in the models with the (e) least (IPSL-CM6A-LR) and (f) most (MRI-ESM2-0) deviation from CAMS as determined by pattern correlation.

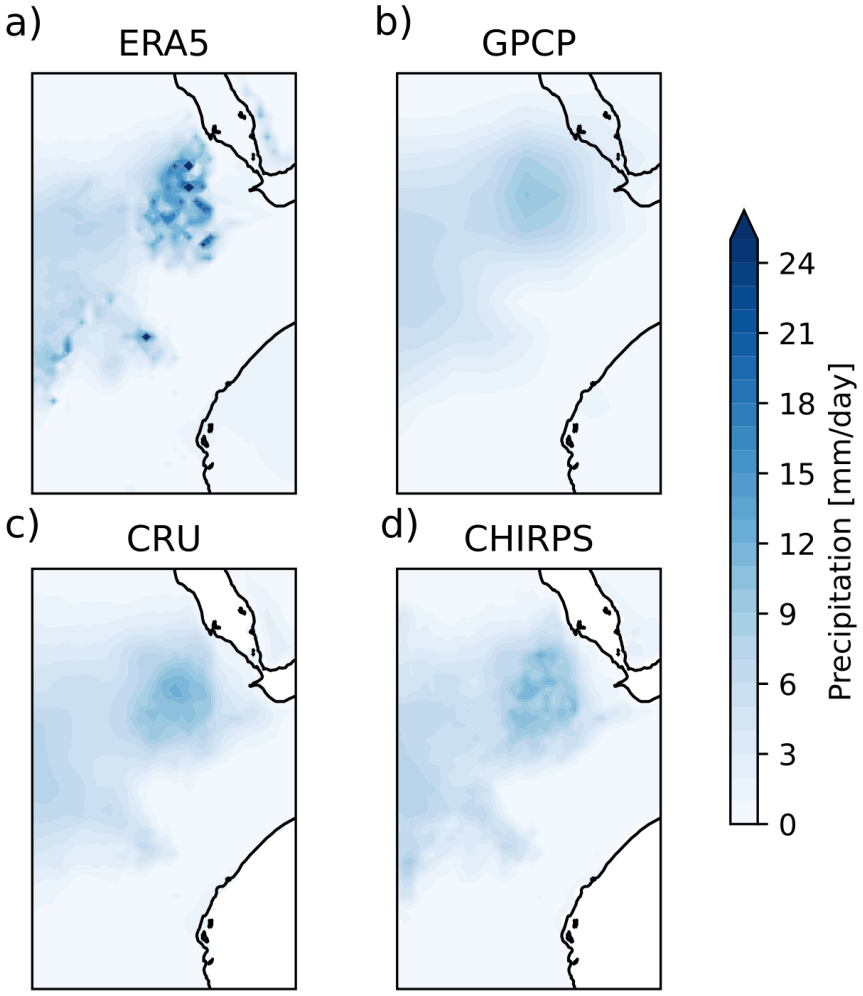

Figure S3. Average distribution of rainfall in August from 1981-2023 for a) ERA5 b) GPCP c) CRU and d) CHIRPS, demonstrating the high orographical rainfall in ERA5 not present in other observational datasets.

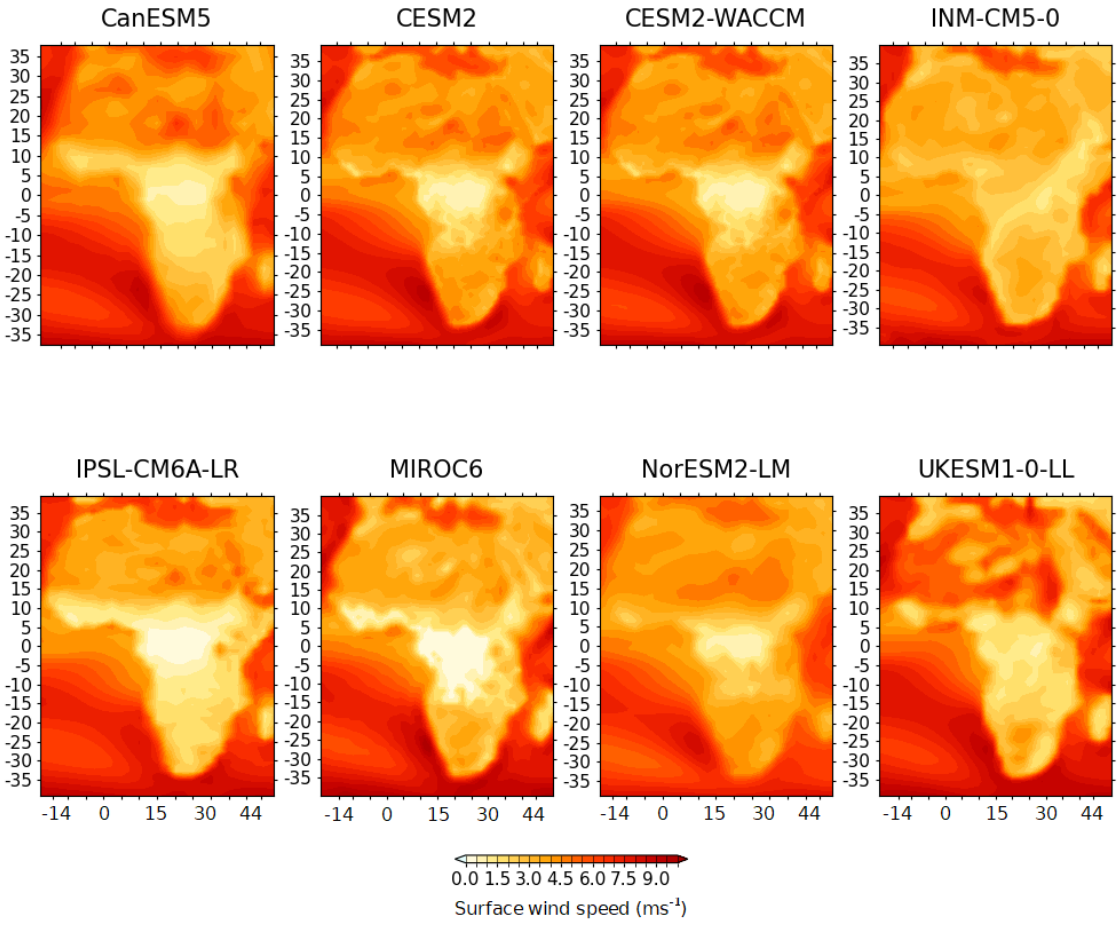

Figure S4. Surface wind speed during SON from 2002-2023 for selected models.

U.S. Embassy Location	Model	R^2	RMSE (μgm^{-3})	MAE (μgm^{-3})
Accra	GFDL-ESM4	0.50	12.24	7.00
	GISS-E2-1-G	0.55	11.69	6.76
	IPSL-CM5A2-INCA	0.36	13.91	8.34
	MIROC6	0.38	13.68	8.59
	NorESM1-LM	0.42	13.27	7.77
	CESM2	0.51	12.21	7.83
	EC-Earth3-AerChem	0.64	10.44	6.90
	UKESM1-0-LL	0.53	11.94	7.09
Ouagadougou	GFDL-ESM4	0.39	22.95	15.55
	GISS-E2-1-G	0.45	21.93	14.84
	IPSL-CM5A2-INCA	0.27	25.14	17.48
	MIROC6	0.13	27.46	19.93
	NorESM1-LM	0.50	20.85	15.67
	CESM2	0.38	23.13	17.40
	EC-Earth3-AerChem	0.32	24.31	16.90
	UKESM1-0-LL	0.27	25.14	17.27
Abidjan	GFDL-ESM4	0.56	8.09	6.21
	GISS-E2-1-G	0.59	7.83	6.35
	IPSL-CM5A2-INCA	0.39	9.52	7.31
	MIROC6	0.34	9.93	8.01
	NorESM1-LM	0.45	9.01	6.72
	CESM2	0.37	9.69	7.72
	EC-Earth3-AerChem	0.57	7.96	6.34
	UKESM1-0-LL	0.60	7.71	6.21
Abuja	GFDL-ESM4	0.62	21.97	14.68
	GISS-E2-1-G	0.50	25.36	15.68
	IPSL-CM5A2-INCA	0.34	29.10	19.02
	MIROC6	0.20	32.00	22.02
	NorESM1-LM	0.29	30.20	23.17
	CESM2	0.37	28.50	19.87
	EC-Earth3-AerChem	0.35	28.81	20.07
	UKESM1-0-LL	0.40	27.82	17.33
Addis Ababa	GFDL-ESM4	0.02	7.44	5.90
	GISS-E2-1-G	0.01	7.49	5.89
	IPSL-CM5A2-INCA	0.08	7.21	5.53
	MIROC6	0.003	7.50	5.89
	NorESM1-LM	0.07	7.25	5.26
	CESM2	0.06	7.27	5.27
	EC-Earth3-AerChem	0.11	7.07	5.38
	UKESM1-0-LL	0.05	7.32	5.59
Kampala	GFDL-ESM4	0.02	13.53	10.45
	GISS-E2-1-G	0.01	13.60	10.58
	IPSL-CM5A2-INCA	0.01	13.63	10.49
	MIROC6	0.0003	13.69	10.68
	NorESM1-LM	0.02	13.58	10.45
	CESM2	0.00006	13.69	10.69
	EC-Earth3-AerChem	0.002	13.68	10.68
	UKESM1-0-LL	0.01	13.60	10.60

Nairobi	GFDL-ESM4	0.001	8.35	6.36
	GISS-E2-1-G	0.003	8.34	6.31
	IPSL-CM5A2-INCA	0.02	8.28	6.05
	MIROC6	0.004	8.35	6.29
	NorESM1-LM	0.08	8.01	5.71
	CESM2	0.60	8.11	5.68
	EC-Earth3-AerChem	0.01	8.31	6.23
	UKESM1-0-LL	0.008	8.32	6.23
Kigali	GFDL-ESM4	0.001	13.81	11.21
	GISS-E2-1-G	0.02	13.05	11.25
	IPSL-CM5A2-INCA	0.02	13.08	11.17
	MIROC6	0.11	12.47	11.05
	NorESM1-LM	0.12	13.67	11.45
	CESM2	0.05	12.85	10.85
	EC-Earth3-AerChem	0.00004	13.19	11.23
	UKESM1-0-LL	0.001	13.18	11.25
Lome	GFDL-ESM4	0.95	2.96	2.42
	GISS-E2-1-G	0.91	4.06	3.70
	IPSL-CM5A2-INCA	0.96	2.57	1.86
	MIROC6	0.89	4.55	4.30
	NorESM1-LM	0.57	8.89	6.37
	CESM2	0.77	6.51	5.42
	EC-Earth3-AerChem	0.80	6.13	4.73
	UKESM1-0-LL	0.93	3.54	3.07
Dakar	GFDL-ESM4	0.25	12.89	10.03
	GISS-E2-1-G	0.23	13.03	10.63
	IPSL-CM5A2-INCA	0.15	13.76	10.88
	MIROC6	0.22	13.14	11.20
	NorESM1-LM	0.31	12.40	8.63
	CESM2	0.11	14.06	10.86
	EC-Earth3-AerChem	0.14	13.79	10.90
	UKESM1-0-LL	0.29	12.58	10.39
Cairo	GFDL-ESM4	0.005	13.82	10.48
	GISS-E2-1-G	0.009	13.79	10.87
	IPSL-CM5A2-INCA	0.15	12.75	10.70
	MIROC6	0.12	12.98	10.50
	NorESM1-LM	0.06	13.41	10.39
	CESM2	0.15	12.79	9.07
	EC-Earth3-AerChem	0.03	13.62	11.00
	UKESM1-0-LL	0.01	13.76	10.90
Bamako	GFDL-ESM4	0.03	31.06	25.07
	GISS-E2-1-G	0.05	30.69	24.52
	IPSL-CM5A2-INCA	0.01	31.28	24.97
	MIROC6	0.12	29.60	23.54
	NorESM1-LM	0.09	30.07	24.45
	CESM2	0.26	26.91	22.01
	EC-Earth3-AerChem	0.003	31.44	25.25
	UKESM1-0-LL	0.10	29.84	23.72

Table S1. Comparison of CMIP6 models and surface $PM_{2.5}$ observations with reference monitors at U.S. embassy locations in Africa.

	PR JJA	PR SON	PR DJF	PR MAM	JJA DAOD	SON DAOD	DJF DAOD	MAM DAOD	JJA non-DAOD	SON non-DAOD	DJF non-DAOD	MAM non-DAOD
ACCESS_CM2	0.77	0.86	0.90	0.87								
ACCESS_ESM1_5	0.87	0.83	0.90	0.88								
AWI_CM_1_1_MR	0.83	0.85	0.84	0.78								
AWI_ESM_1_1_LR	0.85	0.81	0.80	0.75								
BCC_CSM2_MR	0.83	0.88	0.92	0.88								
BCC_ESM1	0.84	0.89	0.94	0.88								
CAMS_CSM1_0	0.83	0.90	0.90	0.85								
CanESM5	0.82	0.88	0.94	0.88	0.78	0.80	0.75	0.90	0.69	0.39	0.35	0.46
CanESM5_1	0.82	0.89	0.93	0.89	0.78	0.80	0.75	0.90	0.06	-0.08	0.46	0.20
CanESM5_CanOE	0.83	0.88	0.93	0.89	0.73	0.64	0.58	0.89	0.21	0.07	0.47	0.18
CAS_ESM2_0	0.74	0.81	0.84	0.79								
CESM2	0.90	0.91	0.90	0.90	0.64	0.61	0.64	0.78	0.21	0.50	0.30	0.25
CESM2_FV2	0.85	0.91	0.81	0.88								
CESM2_WACCM	0.91	0.91	0.90	0.91	0.61	0.58	0.62	0.75	0.26	0.12	0.27	0.27
CIESM	0.87	0.91	0.90	0.90								
CMCC_CM2_HR4	0.86	0.90	0.91	0.86								
CMCC_CM2_SR5	0.87	0.89	0.87	0.87								
CMCC_ESM2	0.86	0.89	0.88	0.88								
CNRM_CM6_1	0.67	0.83	0.85	0.78								
CNRM-ESM2-1	0.86	0.91	0.90	0.79	0.86	0.89	0.90	0.88	0.30	0.16	0.40	0.27
CNRM_CM6_1_HR	0.69	0.81	0.85	0.79								
E3SM_1_0	0.89	0.91	0.92	0.87								
E3SM_1_1_ECA	0.89	0.91	0.92	0.87								
E3SM_2_0	0.88	0.91	0.91	0.89								
EC_Earth3	0.81	0.85	0.90	0.82								
EC_Earth3_AerChem	0.81	0.86	0.89	0.83								
EC_Earth3_CC	0.85	0.88	0.89	0.84								
EC_Earth3_Veg	0.84	0.89	0.90	0.84								
ESM_1_1	0.89	0.91	0.92	0.86								
FGOALS_F3_L	0.75	0.75	0.85	0.73								
FGOALS_g3	0.67	0.78	0.84	0.77								
FIO_ESM_2_0	0.86	0.88	0.89	0.87								
GFDL_CM4	0.89	0.93	0.90	0.89								
GFDL_ESM4	0.88	0.93	0.91	0.89	0.96	0.95	0.77	0.92	0.37	0.29	0.49	0.26
GISS_E2_1_G	0.83	0.86	0.84	0.82								
GISS_E2_1_G_CC	0.82	0.86	0.85	0.82								
GISS_E2_1_H	0.76	0.83	0.78	0.78								
GISS_E2_2_G	0.78	0.85	0.86	0.79								
GISS_E2_2_H	0.71	0.81	0.77	0.75								
HadGEM3_GC31_LL	0.84	0.87	0.90	0.87								
HadGEM3_GC31_MM	0.88	0.86	0.91	0.87								
IITM_ESM	0.81	0.83	0.76	0.81								
INM_CM4_8	0.81	0.78	0.88	0.86	0.86	0.75	0.77	0.91	0.12	-0.03	0.33	-0.12
INM_CM5_0	0.82	0.83	0.89	0.88	0.87	0.81	0.76	0.91	0.30	0.04	0.15	0.33
IPSL_CM5A2_INCA	0.81	0.88	0.88	0.85								
IPSL_CM6A_LR	0.89	0.91	0.89	0.89	0.92	0.77	0.87	0.93	0.23	0.04	-0.02	0.23
IPSL_CM6A_LR_INCA	0.90	0.92	0.91	0.89								
KACE_1_0_G	0.85	0.89	0.91	0.88								

KIOST_ESM	0.83	0.85	0.86	0.85								
MCM_UA_1_0	0.88	0.89	0.88	0.81								
MIROC_ES2H	0.87	0.89	0.89	0.88								
MIROC_ES2L,	0.84	0.88	0.86	0.87	0.75	0.72	0.76	0.84	0.04	0.06	0.62	0.13
MIROC6	0.88	0.90	0.90	0.88	0.95	0.84	0.88	0.92	0.47	0.31	0.62	0.49
MPI_ESM_1_2_HAM	0.86	0.88	0.84	0.80								
MPI_ESM1_2_HR	0.82	0.88	0.85	0.82								
MPI_ESM1_2_LR	0.84	0.87	0.86	0.82								
MRI_ESM2_0	0.90	0.88	0.92	0.86	0.93	0.94	0.91	0.96	0.28	0.14	0.36	0.15
NESM3	0.90	0.91	0.86	0.82								
NorCPM1	0.86	0.89	0.84	0.86								
NorESM2_LM	0.92	0.91	0.92	0.90	0.63	0.52	0.46	0.66	0.19	0.28	0.32	0.28
NorESM2_MM	0.92	0.89	0.91	0.90	0.65	0.55	0.60	0.76	0.19	0.02	0.19	0.15
SAM0_UNICON	0.83	0.86	0.84	0.83								
TaiESM1	0.86	0.88	0.89	0.88								
UKESM1_0_LL	0.84	0.87	0.90	0.86	0.73	0.78	0.71	0.83	0.10	0.16	0.49	0.15
UKESM1_1_LL	0.85	0.87	0.90	0.86								

Table S2. Pattern correlations for seasonal precipitation, dust AOD and non-dust AOD for the models as shown in Figure 6 and 11 of the main paper.