

1 **Table S1.** List of variables analyzed in this study and their corresponding model variable names under SSP245,
 2 SSP585, G6-1.5K-SAI, G6solar, G6sulfur, and Geo-SAI scenarios. (ET is QSOIL+QVEGE+ QVEGT).

Variable name	SSP245	SSP585	G6-1.5K-SAI	G6solar	G6sulfur	Geo-SAI
Temperature	TSA	tas	TSA	tas	tas	TSA
Precipitation	pr	pr	PRECT	pr	pr	PRECT
Evapotranspiration	ET	evspsbl	ET	evspsbl	evspsbl	ET
Available water	P – ET	P – ET	P – ET	P – ET	P – ET	P – ET
Snowfall flux	prsn	prsn	PRECSC+PRECSL	prsn	prsn	PRECSC+PRECSL
Snow melt flux	snm	snm	QSNOMELT	snm	snm	QSNOMELT
Runoff	QOVER	mrros	QOVER	mrros	mrros	QOVER
Soil moisture	SOILWATER_10CM	mrsos	SOILWATER_10CM	mrsos	mrsos	SOILWATER_10CM
Leaf area index	TLAI	lai	TLAI	lai	lai	TLAI

3 **Table S2.** Summary of stratospheric sulfur injection characteristics for CESM2 experiments used in this study.
 4 Injection rates represent approximate mean values over 2055–2084. Differences in injection amount, location,
 5 and strategy reflect distinct experimental objectives (temperature stabilization vs transient forcing), which are
 6 accounted for through normalization by sulfur injection. (Lee et al., 2025; Tilmes et al., 2020; Visioni et al.,
 7 2021; Visioni et al., 2024).

Experiment	Baseline Scenario	Injection Locations	Injection Strategy	Injection Locations	Injection Altitude (km)	Mean Injection Rate (Tg SO ₂ yr ⁻¹)	Notes
G6-1.5K-SAI	SSP2-4.5	Stabilized at 1.5°C	Feedback-controlled SAI	30°N, 30°S	~21–25	~11.7	Designed to maintain global temperature at 1.5°C; symmetric subtropical injection
G6sulfur	SSP5-8.5 vs SSP2-4.5	Transient offset	Feedback-controlled SAI	10°N–10°S	~25	~21	Injection increases over time to offset SSP5-8.5 warming toward SSP2-4.5
Geo-SAI (Geo SSP5-8.5 1.5)	SSP5-8.5	Stabilized at 1.5°C	Feedback-controlled SAI	15°N, 15°S, 30°N, 30°S	~20–25	~25–35	Higher injection due to strong baseline forcing; peaks up to ~48 Tg yr ⁻¹

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9 **Table S3.** Statistical performance (R² values) of multiple linear regression models for AW under SSP2-4.5 and
 10 G6-1.5K-SAI scenarios across WCA, ECA, TP, and SA. The table reports minimum, maximum, average, and
 11 final R² values representing model strength and predictive accuracy in each region.

Region	SSP2-4.5				G6-1.5K-SAI			
	WCA	ECA	TIB	SAS	WCA	ECA	TIB	SAS
Min R ²	0.976	0.615	0.963	0.975	0.999	0.550	0.977	0.998
Max R ²	0.978	0.999	0.969	0.977	0.999	0.999	0.999	0.999
Average R ²	0.977	0.807	0.966	0.976	0.999	0.775	0.988	0.998
Final R ²	0.978	0.999	0.968	0.977	0.999	0.999	0.997	0.999

12 **Table S4.** Same as Table S1, but for SSP5-8.5 and G6solar.

Region	SSP5-8.5				G6solar			
	WCA	ECA	TIB	SAS	WCA	ECA	TIB	SAS
Min R ²	0.999	0.573	0.993	0.999	0.999	0.605	0.985	0.999
Max R ²	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999

Average R ²	0.999	0.786	0.996	0.999	0.999	0.802	0.992	0.999
Final R ²	0.999	0.999	0.998	0.999	0.999	0.999	0.997	0.999

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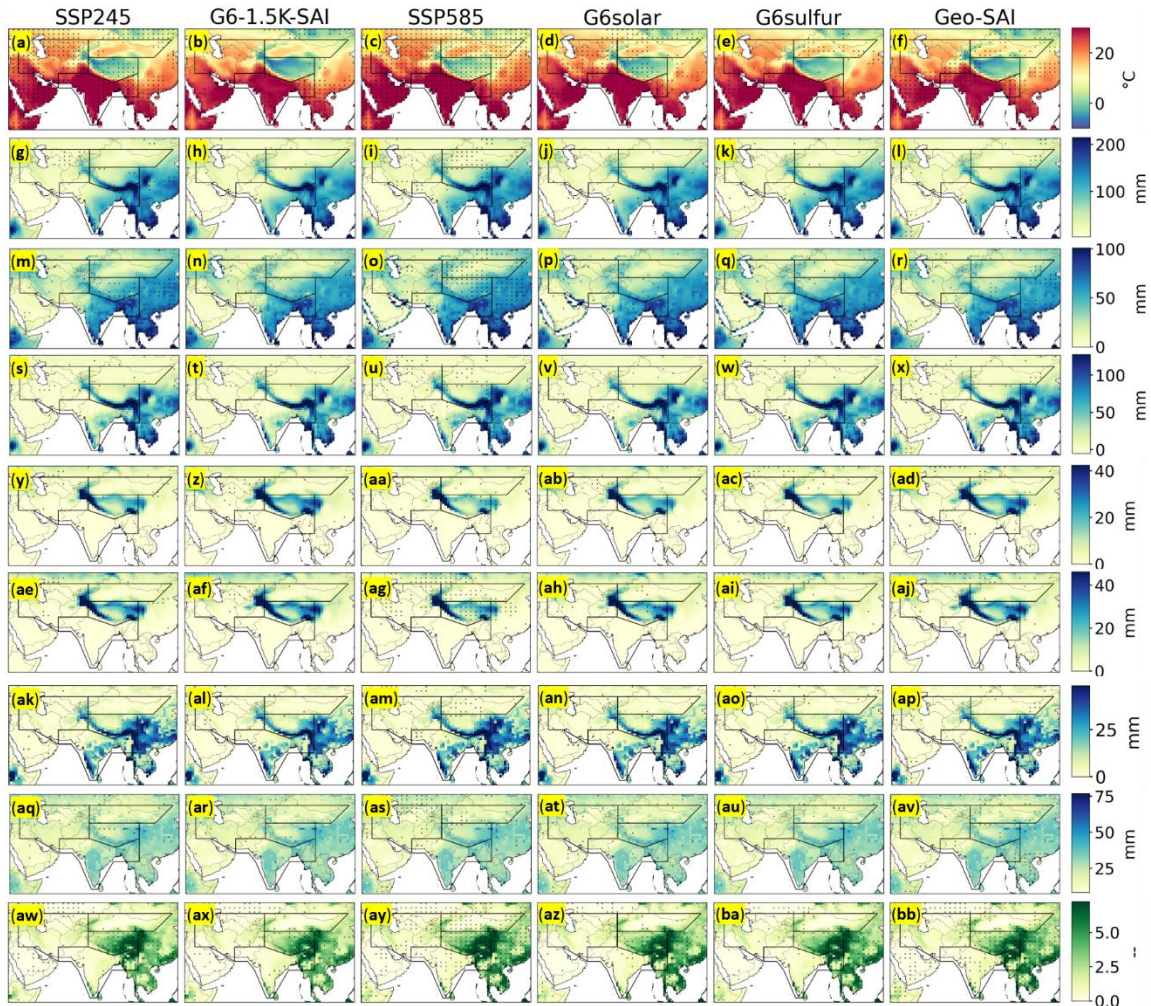
14 **Table S5.** Same as Table S1, but for G6sulfur and Geo-SAI.

Region	G6sulfur				Geo-SAI			
	WCA	ECA	TIB	SAS	WCA	ECA	TIB	SAS
Min R ²	0.999	0.615	0.988	0.999	0.999	0.505	0.982	0.998
Max R ²	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
Average R ²	0.999	0.807	0.993	0.999	0.999	0.752	0.990	0.998
Final R ²	0.999	0.999	0.998	0.999	0.999	0.999	0.997	0.999

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16 **Table S6.** Percent change (%) in peak hydroclimatic variables during the future period (2055–2084) relative to
17 the present-day baseline (2015–2034) across WCA, ECA, TIB, and SAS. Positive (negative) values indicate
18 increases (decreases) relative to the present-day climatology. Bold values denote statistically significant changes
19 at the 95% level.

region	scenario	TMP	PCP	ET	AW	Snowfall	Snowmelt	Runoff	SM	LAI
WCA	SSP245	6.68	-1.43	4.29	-0.21	-9.29	-19.29	0.74	-2.79	28.70
	SSP585	11.43	4.49	4.33	7.04	-24.94	-28.59	2.68	-2.10	42.53
	G6-1.5K-SAI	0.08	3.26	-2.49	-9.03	11.63	7.10	-0.53	-1.96	21.59
	Geo-SAI	-1.18	10.51	-3.81	35.42	3.68	3.89	5.42	2.09	38.30
	G6solar	4.20	6.21	-1.83	13.73	-6.50	-13.86	0.02	-0.58	33.81
	G6sulfur-SSP2-4.5	5.95	2.80	-0.83	-24.14	-11.60	-24.09	-2.36	-4.70	30.11
	G6sulfur-SSP5-8.5	4.83	6.17	-0.68	7.59	-17.96	-22.81	3.09	-1.35	35.95
ECA	SSP245	7.58	1.57	0.95	7.54	7.01	-2.89	3.43	-0.77	10.47
	SSP585	13.35	3.23	2.17	22.80	4.51	-11.81	6.54	2.52	21.49
	G6-1.5K-SAI	-1.47	-0.58	-2.11	-49.19	17.84	19.48	-2.84	0.51	7.15
	Geo-SAI	-1.12	8.91	0.39	30.45	1.65	19.99	9.61	5.43	33.66
	G6solar	4.14	1.67	-0.84	37.28	10.64	1.52	4.88	3.02	24.39
	G6sulfur-SSP2-4.5	6.29	8.21	0.10	-31.47	6.19	-4.68	2.69	-0.40	24.33
	G6sulfur-SSP5-8.5	5.62	8.37	0.34	65.39	0.67	-3.44	8.38	2.21	27.63
TIB	SSP245	13.26	3.29	5.88	6.69	-6.03	-14.63	6.15	-3.67	19.06
	SSP585	24.17	13.02	2.55	18.76	-9.83	-26.27	12.38	-1.82	26.31
	G6-1.5K-SAI	1.13	-5.43	0.51	-4.17	18.71	5.91	-2.44	-3.36	7.44
	Geo-SAI	3.91	-0.69	-2.74	2.38	9.60	3.96	1.23	1.68	12.70
	G6solar	10.71	1.04	-2.68	3.74	-2.18	-9.93	0.99	0.17	16.46
	G6sulfur-SSP2-4.5	13.44	10.51	-0.94	19.06	-0.08	-9.48	14.59	-1.25	19.99
	G6sulfur-SSP5-8.5	12.32	9.75	-0.10	15.26	-0.47	-10.68	11.22	1.09	20.03
SAS	SSP245	5.94	2.07	6.52	5.96	-29.71	-25.03	9.86	0.39	16.29
	SSP585	9.89	7.53	4.74	9.44	-49.01	-44.31	12.08	0.12	32.53
	G6-1.5K-SAI	1.88	-3.80	2.35	-12.20	-4.74	-2.03	-1.52	-1.09	21.09
	Geo-SAI	1.57	4.00	-12.41	8.91	-5.98	-7.99	8.44	-0.47	53.73
	G6solar	4.93	2.17	2.61	2.85	-24.14	-21.68	5.35	-0.40	40.09
	G6sulfur-SSP2-4.5	3.13	6.76	20.29	-3.25	-24.12	-21.25	15.22	1.82	41.45
	G6sulfur-SSP5-8.5	4.81	9.24	2.65	12.81	-24.99	-19.82	15.55	0.77	45.06



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21 **Figure S1.** Spatial distribution of the ensemble-mean of (a-f) temperature, (g-l) precipitation, (m-r) ET, (s-x)
 22 AW, (y-ad) snowfall flux, (ae-aj) snowmelt flux, (ak-ap) runoff, (aq-av) SM, (aw-bb) LAI, averaged over 2055–
 23 2084 for six scenarios: SSP2-4.5, G6-1.5K-SAI, SSP5-8.5, G6solar, G6sulfur, and Geo-SAI. Dotted regions
 24 indicate grid cells where the ensemble-mean linear trend over 2055–2084 is statistically significant at $p < 0.05$.