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Supporting Information for

Observational constraint on the contributions of greenhouse gas emission and anthropogenic aerosol removal to Tibetan Plateau future warming

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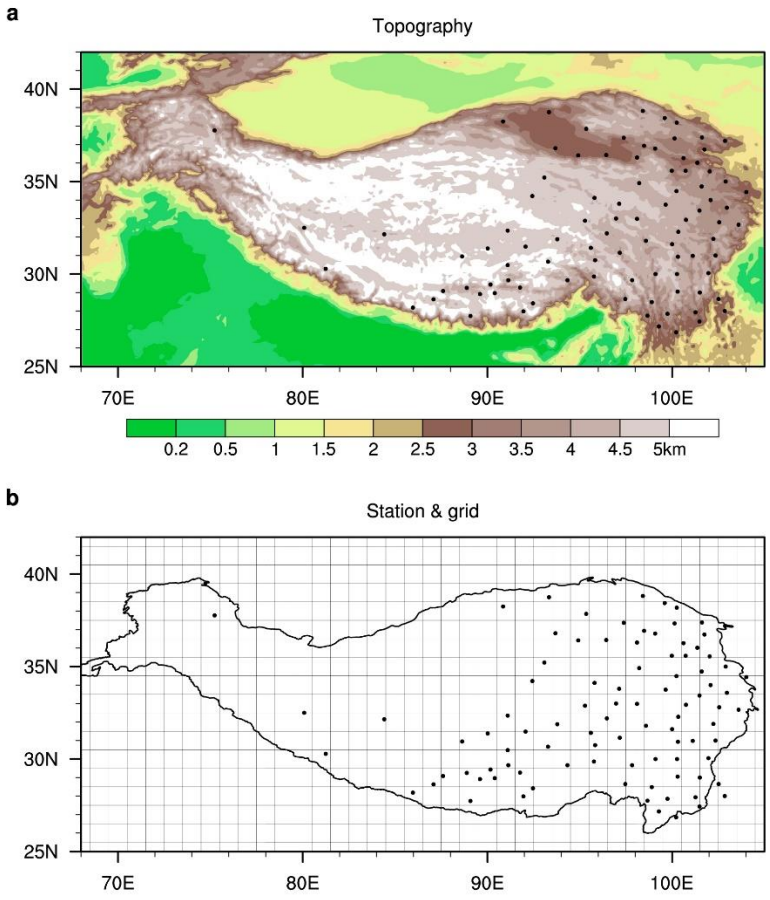

Figure S1. Station distribution over the TP. (a) The topography of the TP, and the distribution of 93 stations. (b) The station distribution and the grid boxes for 1°×1° resolution.

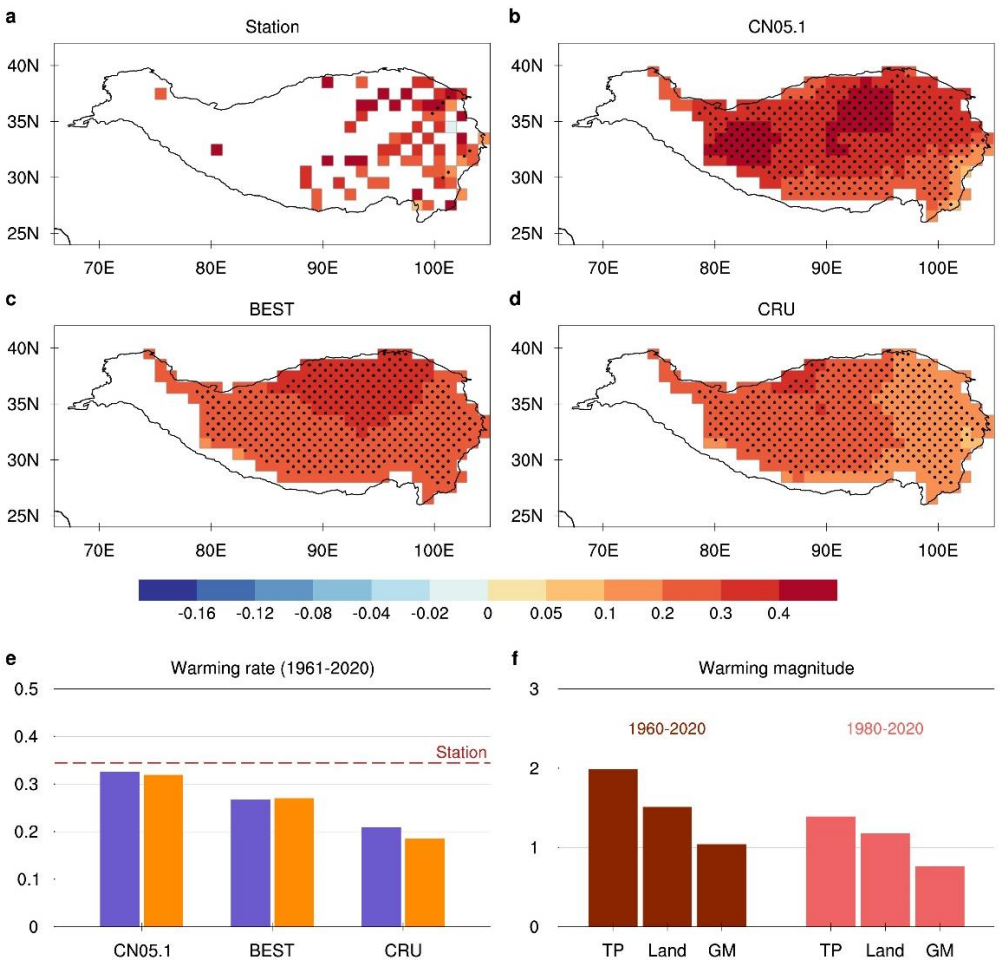

Figure S2. Observed trends of annual mean surface air temperature (SAT) over the TP during 1961-2020. (a-d) The spatial pattern of the linear trends (℃/decade) of SAT derived from (a) station observation, (b) CN05.1, (c) BEST, and (d) CRU. The stippling indicates that the linear trend is significant at the 10% level according to the Mann-Kendall test. (e) Linear trends of the area-averaged SAT over the TP derived from gridded observations. The blue bars denote the original results, and the orange bars denote the results for grids with station observation records. The dotted line denotes the result for station observation. (f) Observed increase in SAT (℃) over the TP and for the global land and global mean (GM) during 1960-2020 and 1980-2020 relative to 1995-2014. The results of global land and global mean are obtained from IPCC AR6 (2021).

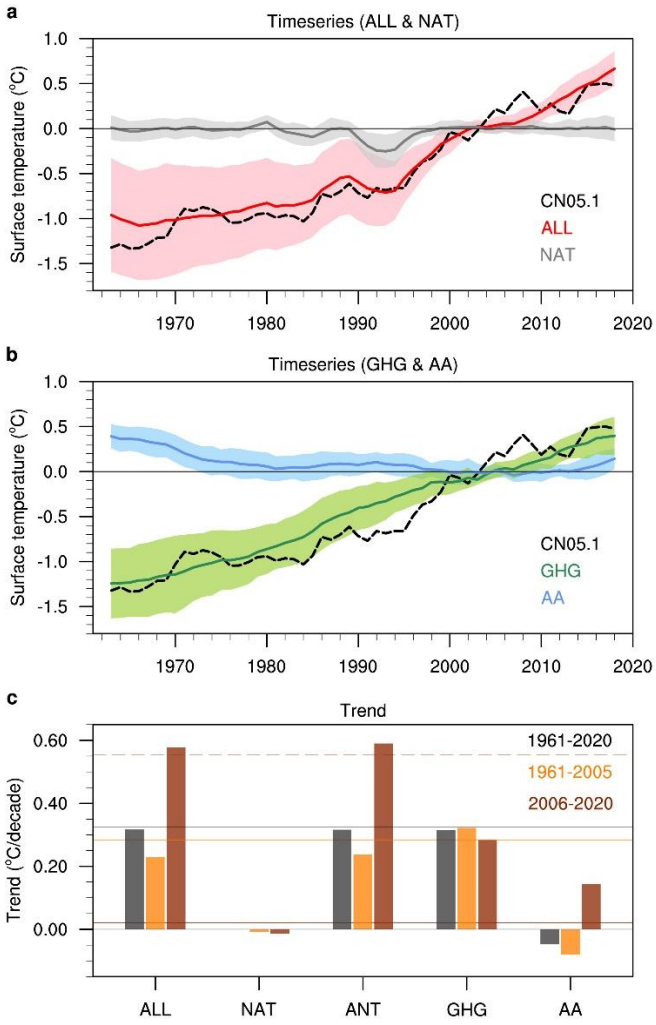

Figure S3. The evolution of annual mean surface air temperature (SAT) over the TP during 1961-2020. (a-b) Five year running mean annual mean SAT anomalies (℃) averaged over the TP relative to 1995-2014 derived from CN05.1 (black), and the multi-model average under all external forcings (ALL), natural forcing alone (NAT), greenhouse gases forcing alone (GHG), and anthropogenic aerosol forcing alone (AA). The shading denotes the one standard deviation among the models. (c) The linear trends in TP SAT (℃/decade) derived from the muti-model average under different forcings during 1961-2020 (black), 1961-2005 (orange) and 2006-2020 (red). The solid lines denote the results of CN05.1. The dotted line denotes the estimated trend due to external forcing in CN05.1 during 2006-2020.

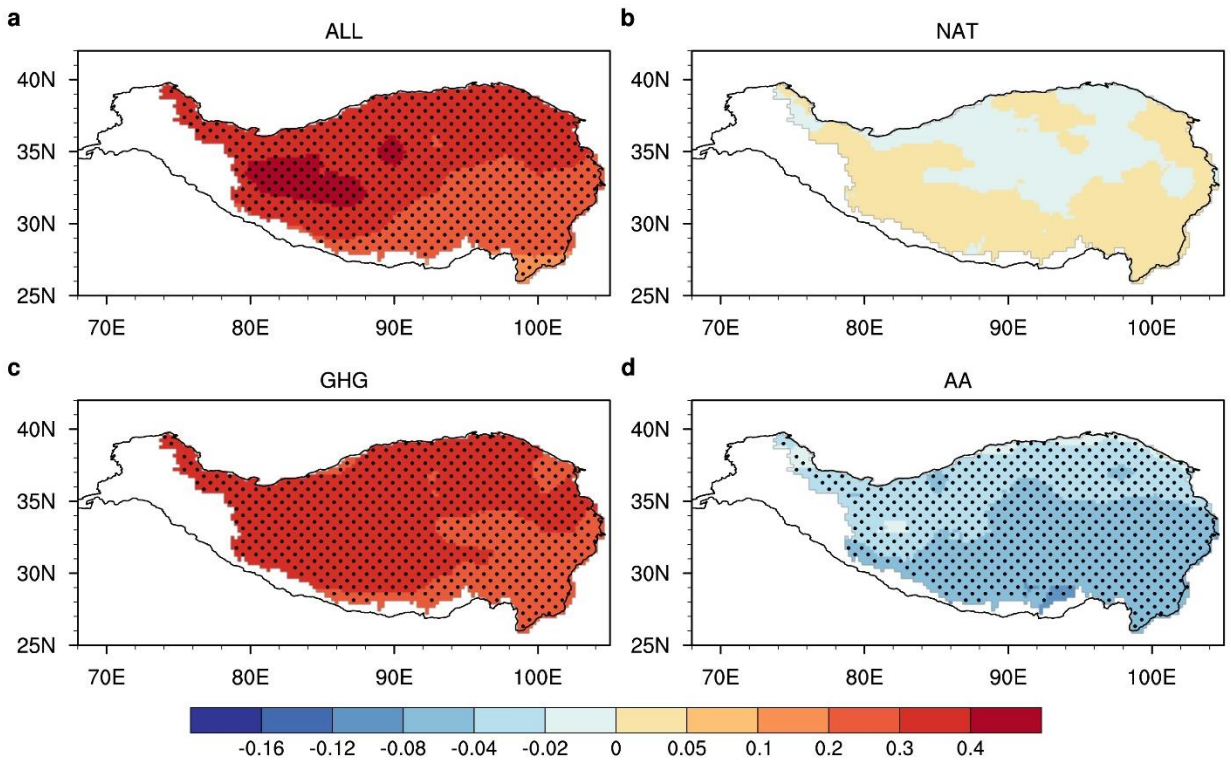

Figure S4. Simulated warming trend during 1961-2020. The linear trends of annual mean surface air temperature (°C/decade) over the TP during 1961-2020 derived from the multi-model average of all models under (a) ALL forcing, (b) NAT forcing, (c) GHG forcing, and (d) AA forcing. The stippling indicates that the linear trend is significant at the 10% level according to the Mann-Kendall test.

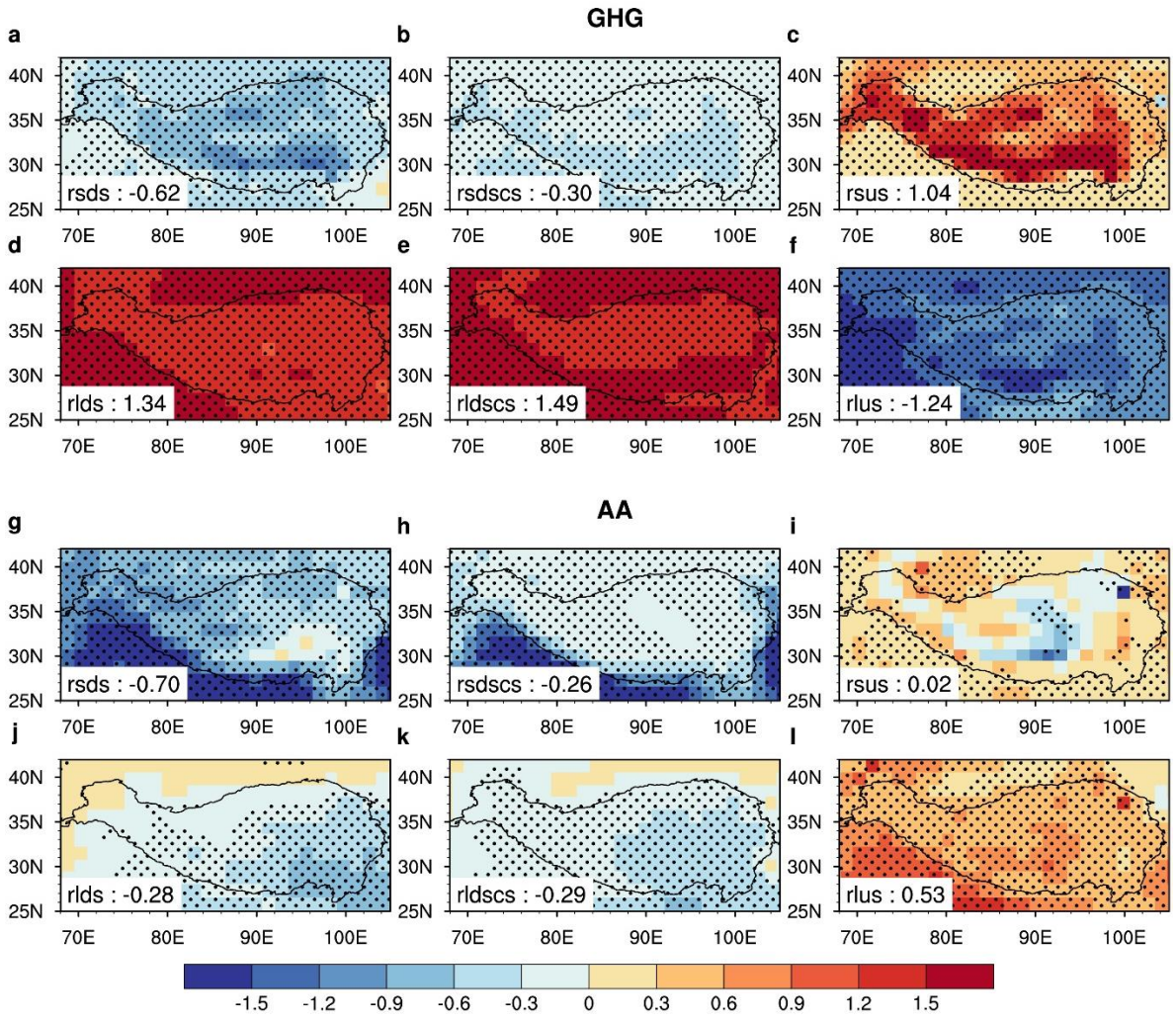

Figure S5. Simulated trends in surface radiation fluxes during 1961-2020. (a-f) The linear trends (W/m^2/decade) of annual mean surface (a) downwelling shortwave radiation, (b) downwelling clear-sky shortwave radiation, (c) upwelling shortwave radiation, (d) downwelling longwave radiation, (e) downwelling clear-sky longwave radiation, (f) upwelling longwave radiation over the TP during 1961-2020 derived from the ensemble mean of MIROC6 under GHG forcing. The downward fluxes are positive. The stippling indicates that the linear trend is significant at the 10% level according to the Mann-Kendall test. The numbers denote the linear trends for the area-averaged radiation fluxes over the TP. (g-l) As in (a-f), but for trends under AA forcing.

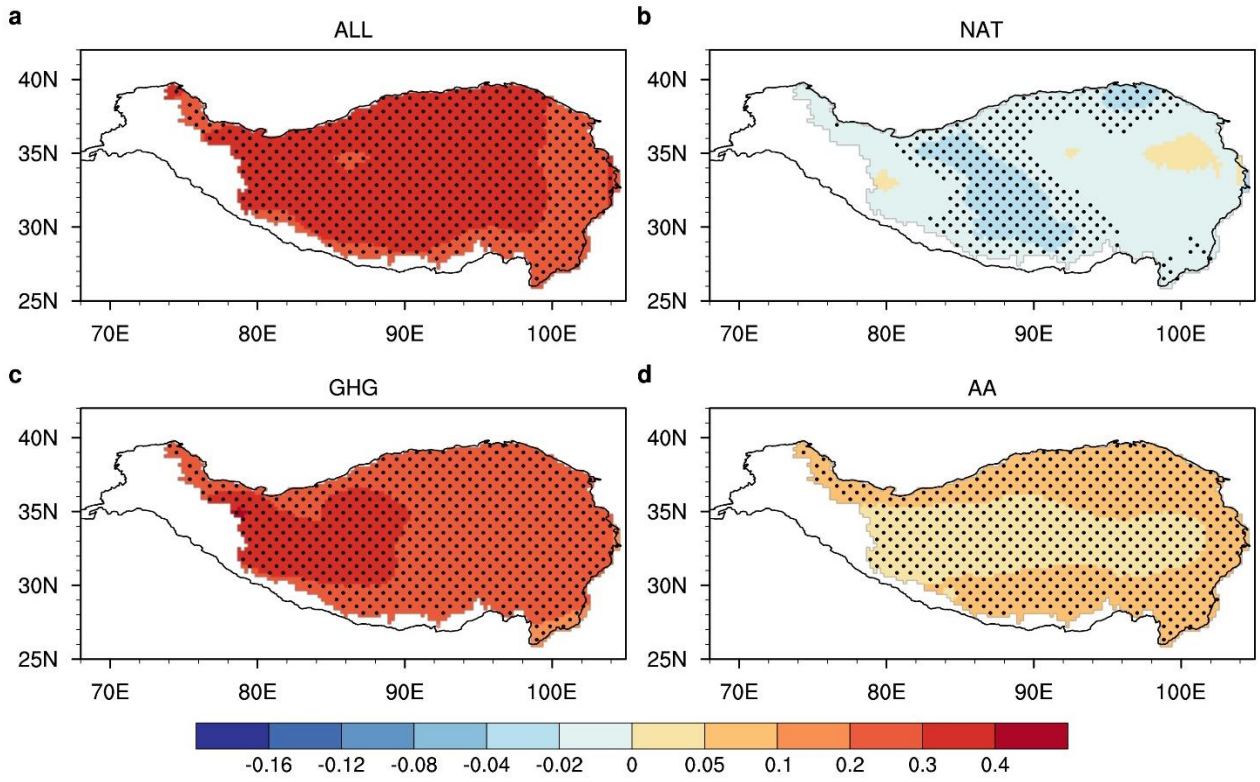

Figure S6. Projected warming trend during 2021-2020 under SSP2-4.5 scenario. The linear trends of annual mean surface air temperature (℃/decade) over the TP during 2021-2100 derived from MIROC6 under (a) ALL forcing, (b) NAT forcing, (c) GHG forcing, and (d) AA forcing. The stippling indicates that the linear trend is significant at the 10% level according to the Mann-Kendall test.

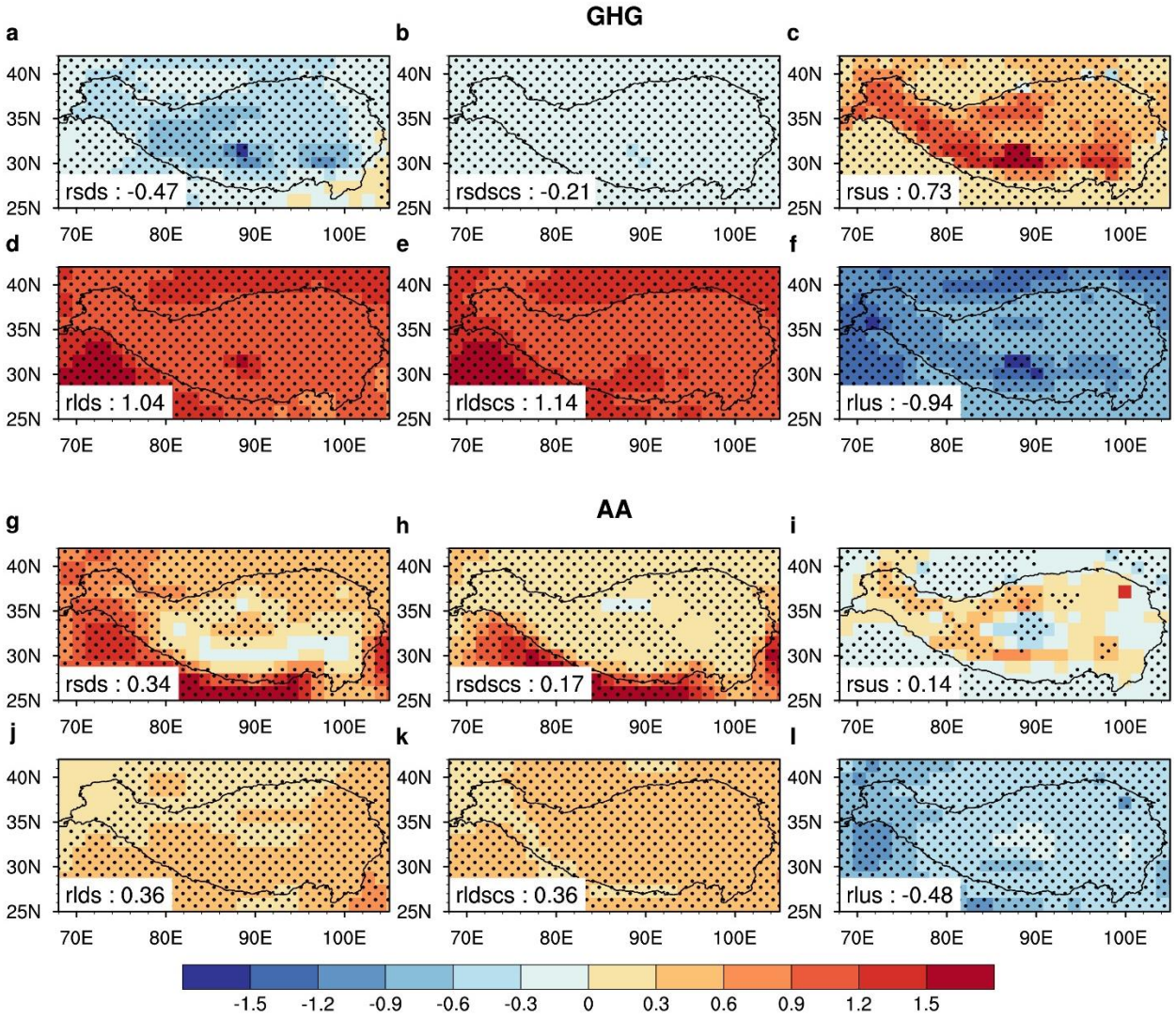

Figure S7. As in Figure S5, but for projected trends during 2021-2020 under SSP2-4.5 scenario.

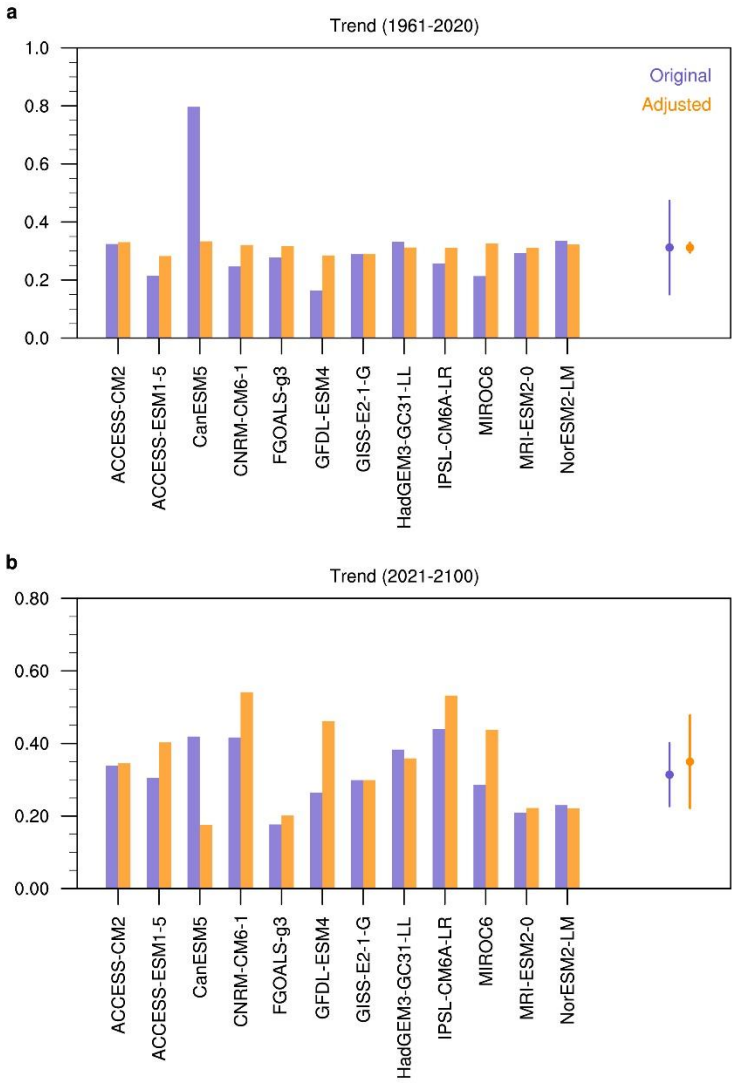

Figure S8. Simulated TP warming by individual models. (a) The simulated linear trends of annual mean surface air temperature (℃/decade) averaged over the TP during 1961-2020 derived from the original results (purple) and constrained by the scaling factor of ALL forcing from 1-signal analysis (orange). The dots denote the corresponding average, and the line denote the corresponding standard deviation (±SD). (b) As in (a), but for the projected trends in 2021-2100.

Table S1. Descriptions of the temperature datasets used in this chapter.

Dataset	Source	Time period	Horizontal resolution
CN05.1	CAS CCRC	1961-2021	0.25°×0.25°
BEST	Berkeley Earth	1700-2021	1°×1°
CRU	CRU	1901-2020	0.5°×0.5°

Table S2. CMIP6 models used in this study and corresponding information. The numbers denote the members for historical, hist-nat, hist-GHG and hist-aer simulations, and the lengths of the piControl simulations.

No	Model	Institute	lon×lat	historical	hist-nat	hist-GHG	hist-aer	piControl (yr)
1	ACCESS-CM2	CSIRO/Australia	192×144	5	3	3	3	500
2	ACCESS-ESM1-5	CSIRO/ Australia	192×145	10	3	3	3	1000
3	CanESM5	CCCma/Canada	128×64	10	10	10	10	1000
4	CNRM-CM6-1	CNRM-CERFACS/France	256×128	6	10	10	10	500
5	FGOALS-g3	CAS/China	180×80	4	3	3	3	700
6	GFDL-ESM4	NOAA-GFDL/USA	288×180	3	3	1	1	500
7	GISS-E2-1-G	NASA-GISS/USA	144×90	5	5	5	5	851
8	HadGEM3-GC31-LL	MOHC/UK	192×144	5	10	5	5	2000
9	IPSL-CM6A-LR	IPSL/France	144×143	7	10	10	10	800
10	MIROC6	MIROC/Japan	256×128	50	50	50	10	800
11	MRI-ESM2-0	MRI/Japan	320×160	5	5	5	5	700
12	NorESM2-LM	NCC/Norway	144×96	3	3	3	3	500
	Total			113	115	108	68	

Table S3. Attributable warming (℃/decade) due to ALL, NAT, ANT, GHG and AA forcings. For all contributions, the original results and the constrained results with the 90% confidence intervals are shown. The results of CMIP5 are provided by Zhou & Zhang (2021), the results of CMIP6 are derived from the multi-model ensemble mean of 12 models in Table S2.

		ALL	**NAT**	**ANT**	**GHG**	**AA**
CMIP5 (1961-2005)	Original	0.22	0.03	0.19	0.30	-0.11
	Constrained	0.21 [0.11, 0.30]	0.02 [-0.01, 0.06]	0.21 [0.08, 0.35]	0.30 [0.03, 0.62]	-0.06 [-0.37, 0.21]
CMIP6 (1961-2005)	Original	0.23	-0.01	0.24	0.32	-0.08
	Constrained	0.25 [0.16, 0.33]	-0.01 [-0.02,0.00]	0.25 [0.16, 0.33]	0.26 [0.07, 0.45]	0.03 [-0.11, 0.18]
CMIP6 (1961-2020)	Original	0.32	0.00	0.32	0.31	-0.05
	Constrained	0.32 [0.25, 0.40]	0.00 [-0.00, 0.00]	0.32 [0.25, 0.40]	0.33 [0.23, 0.43]	-0.00 [-0.06, 0.06]