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The warming Tibetan Plateau improves winter air quality in the Sichuan Basin, China

Shuyu Zhao et al.

Correspondence to: Xuexi Tie (tiexx@ieecas.cn)

Text S1 We use three statistical indices to evaluate O_3, CO and $PM_{2.5}$ mass concentrations simulated by the WRF-CHEM model against the measurements monitored by the Ministry of Environmental Protection, China. These three indices are the mean bias (MB), root mean square error (RMSE), and index of agreement (IOA), and the calculation formulas are as follows.

$$\mathrm{MB} = \frac{1}{\mathrm{N}}\sum_{\mathrm{i}=1}^{\mathrm{N}} (\mathrm{P_i}\text{-}\mathrm{O_i}) \tag{1}$$

$$\mathrm{RMSE} = \left[\frac{1}{\mathrm{N}}\sum_{\mathrm{i}=1}^{\mathrm{N}}(\mathrm{P_i}\text{-}\mathrm{O_i})^2\right]^{\frac{1}{2}} \tag{2}$$

$$\mathrm{IOA} = 1 - \frac{\sum_{\mathrm{i}=1}^{\mathrm{N}}(\mathrm{P_i}\text{-}\mathrm{O_i})^2}{\sum_{\mathrm{i}=1}^{\mathrm{N}}(|\mathrm{P_i}\text{-}\bar{\mathrm{O}}|+|\mathrm{O_i}\text{-}\bar{\mathrm{O}}|)^2} \tag{3}$$

where P_i and O_i are the simulated and observed variables, respectively. N is the total sample number of the simulations, and $\bar{O}$ denotes the average of the observations. The IOA varies from 0 to 1, and the closer to 1 the IOA is, the better the model simulation is.

Table S1 Observational winter mean temperature at 10 weather stations over the Tibetan Plateau from 2013 to 2017.

Sites / Year	T (°C)										
	Wudaoliang	Lhasa	Nagqu	Qamdo	Qumarleb	Shiquanhe	Litang	Tuotuohe	Xainza	Zadoi	**Avg.**
2013	-13.84	1.55	-8.85	-0.03	-10.18	-10.61	-2.46	-13.63	-7.78	-7.90	-7.37
2014	-12.97	0.82	-10.17	-0.37	-10.08	-9.18	-2.26	-13.70	-8.53	-9.36	-7.58
2015	-14.72	2.15	-9.48	-0.35	-11.29	-7.91	-3.22	-13.65	-8.11	-7.67	-7.43
2016	-12.48	2.48	-7.33	0.66	-9.54	-7.03	-1.21	-11.72	-6.22	-6.23	-5.86
2017	-12.49	2.85	-6.91	1.56	-9.02	-6.94	-0.40	-11.33	-5.68	-5.25	-5.36
	ΔT(°C)										
T(2017) – T(2013)	1.35	1.30	1.94	1.59	1.16	3.67	2.06	2.30	2.10	2.65	**2.01**

Table S2 Significance differences in concentrations of chemical composition in $PM_{2.5}$ between the baseline simulation and the sensitivity simulation in which the plateau warms by 2 °C. The *p*-value of every chemical composition is followed.

Chemical composition	SO_4^{2-}	NO_3^-	NH_4^+	Cl^-	SOA	POA	EC	Undef
p-value	2.78E-04	5.05E-06	6.84E-05	3.29E-04	6E-130	2.14E-06	0.0011	2.63E-15

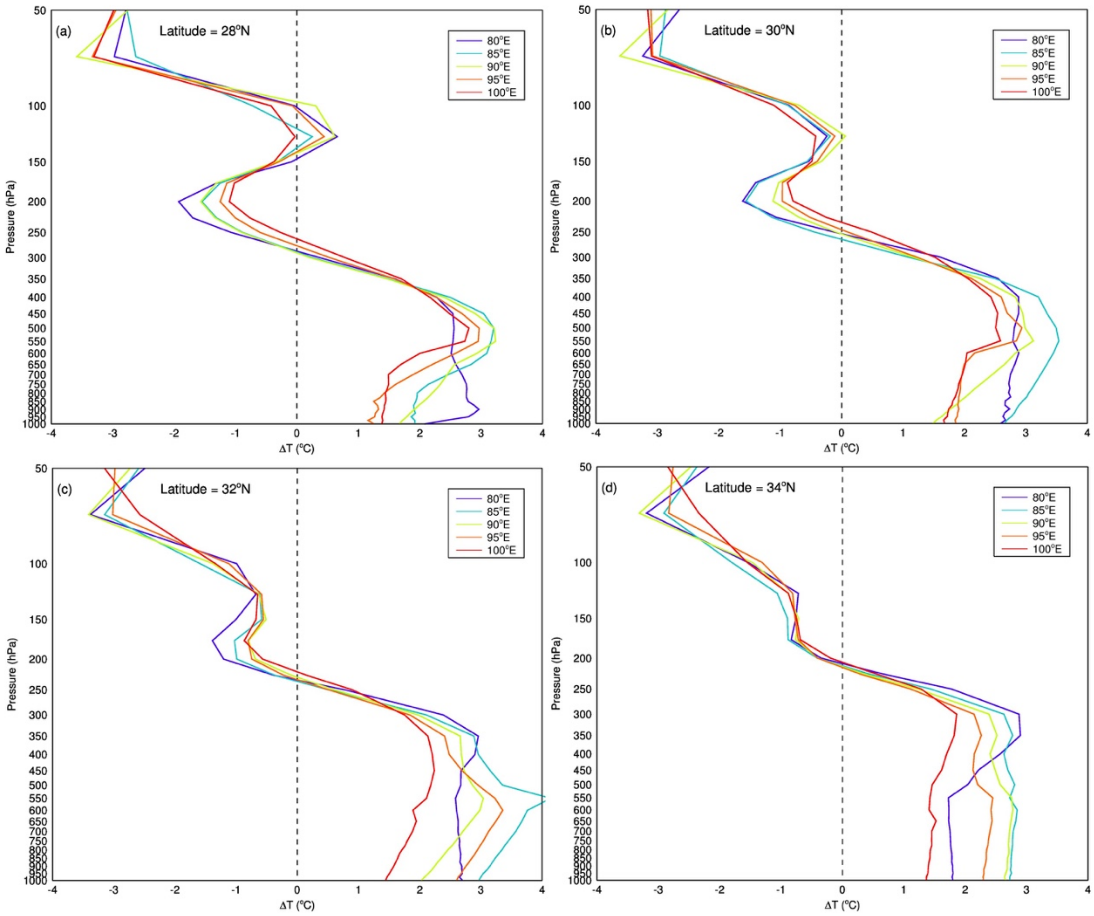

Figure S1 Vertical profile of temperature change along the longitude (80°E -100°E) covering the plateau at 28°N, 30°N, 32°N and 34°N, ΔT is calculated by the annual temperature increase rate from 2013 to 2017 multiplying by the number of years ($N = 5$). Noted that the temperature in the troposphere over the Tibetan Plateau (600 hPa - 250 hPa) is inhomogeneously warming by 0 - 4 °C from 2013 to 2017, and the average temperature increase is around 2 °C.

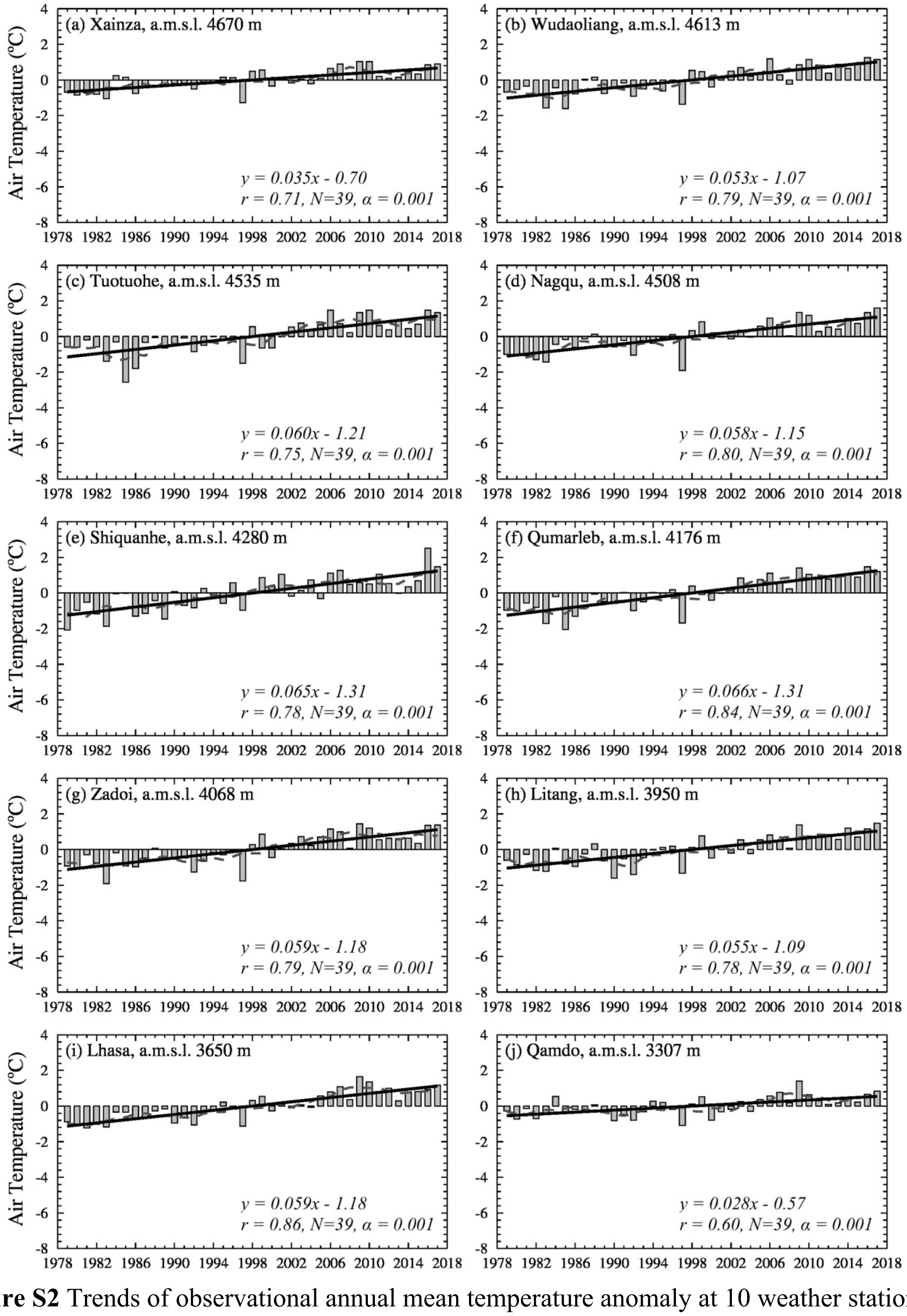

Figure S2 Trends of observational annual mean temperature anomaly at 10 weather stations over the Tibetan Plateau during the last four decades (1979-2017).

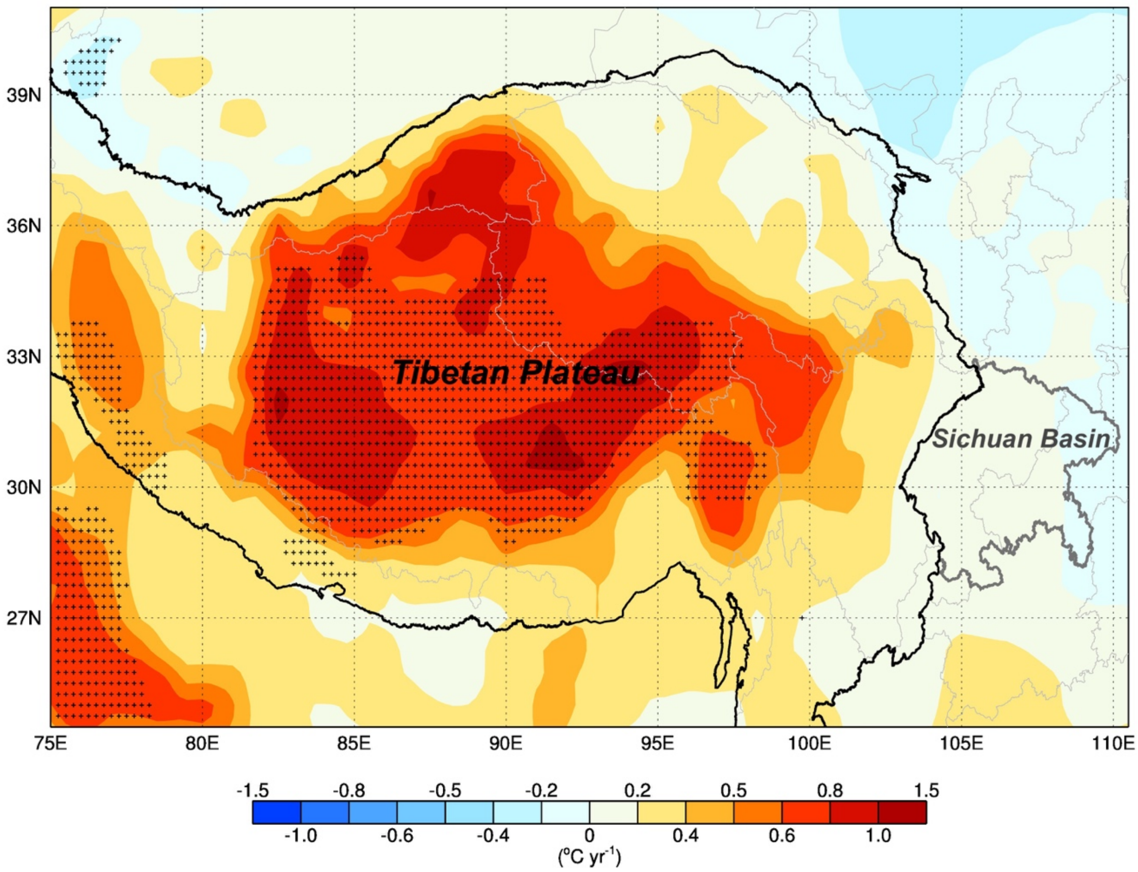

Figure S3 Trends of ERA-interim reanalysis winter mean temperature over the Tibetan Plateau from 2013 to 2017. The dotted regions show statistical significance with 95% confidence level (p-value < 0.05) from the Student's t test.

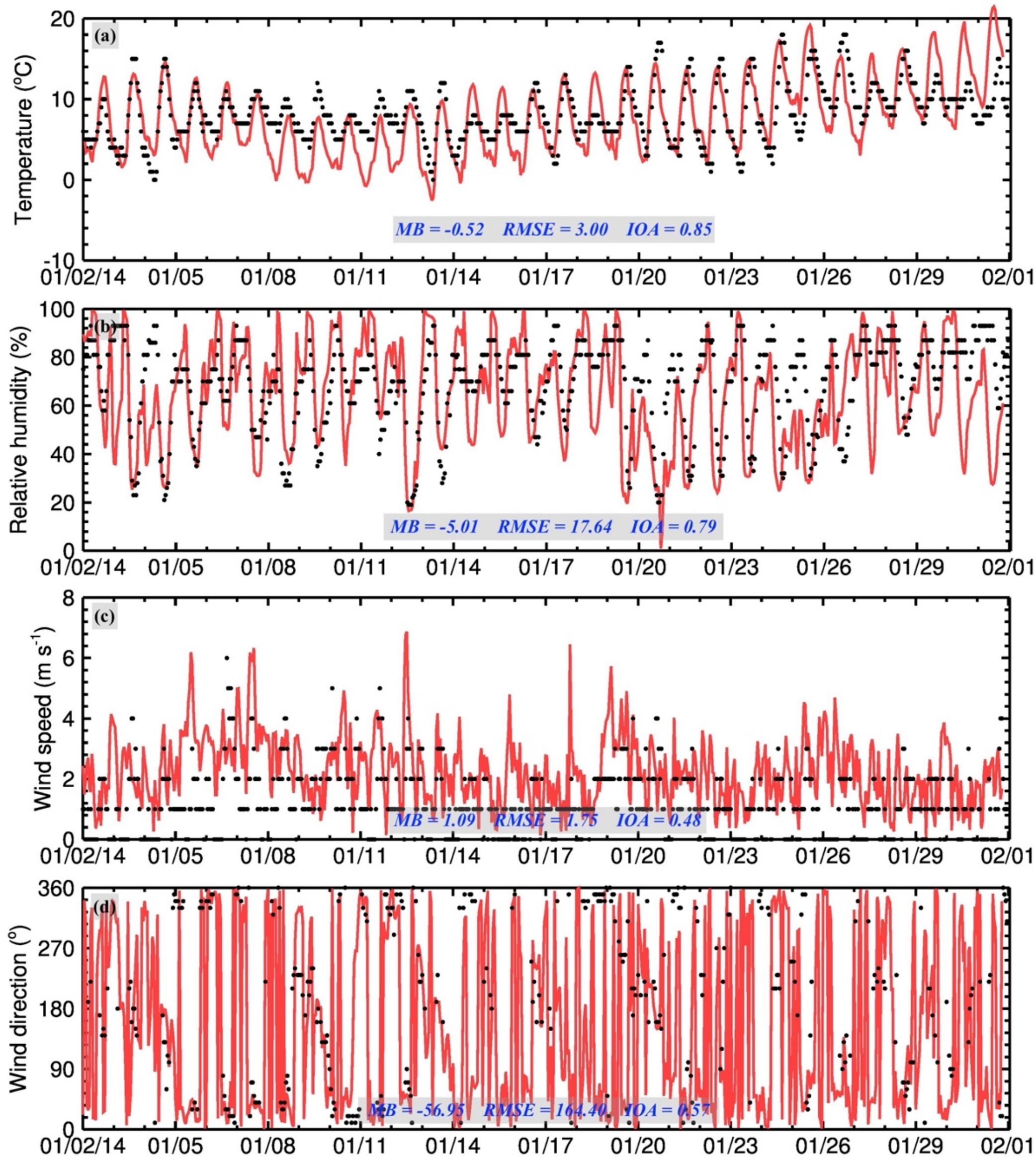

Figure S4 Simulated (red curves) and observed (black dots) hourly air temperature, relative humidity, and wind speed and direction at Chengdu in the Sichuan Basin in January 2014.

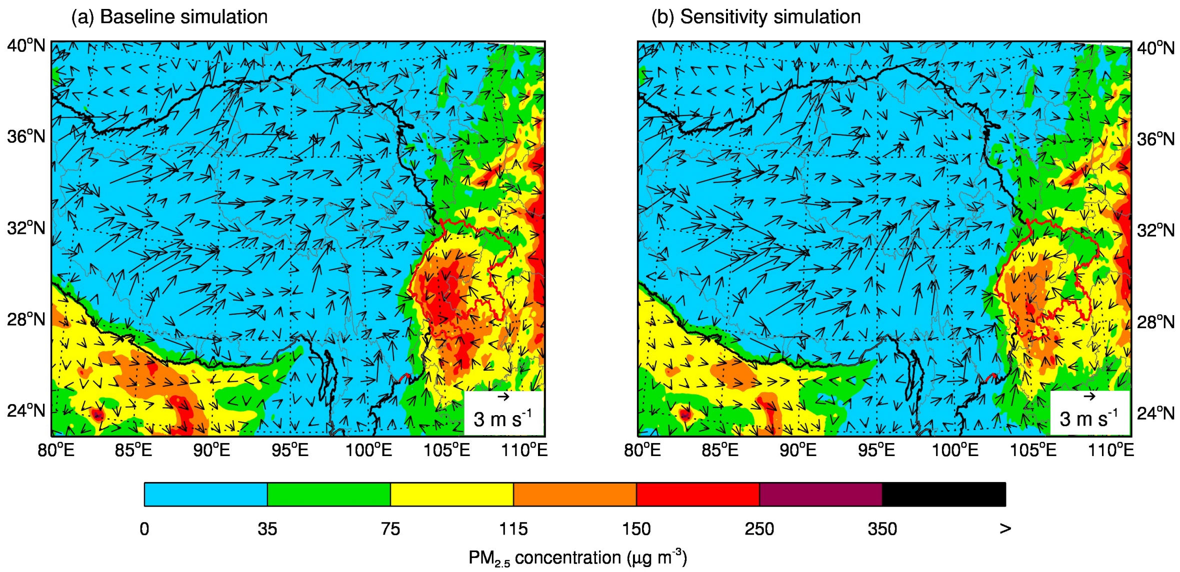

Figure S5 Comparison of spatial distributions of surface $PM_{2.5}$ concentration and winds between the (a) baseline simulation and (b) sensitivity simulation with 2°C warming over the plateau.

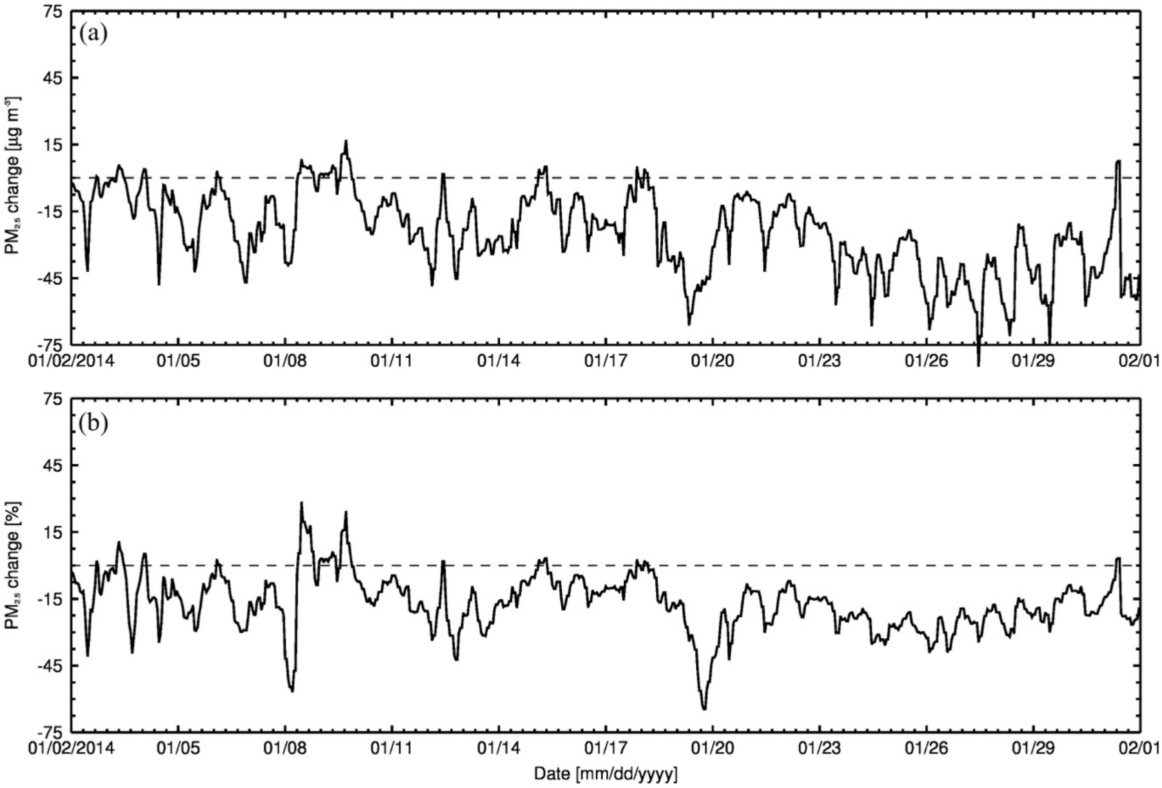

Figure S6 Changes in time series of $PM_{2.5}$ concentration (a) and the percentage (b) over the basin after the plateau is 2°C warmer. (Sensitivity simulation *minus* baseline simulation, the change in the following study is all calculated by the sensitivity simulation minus baseline simulation.

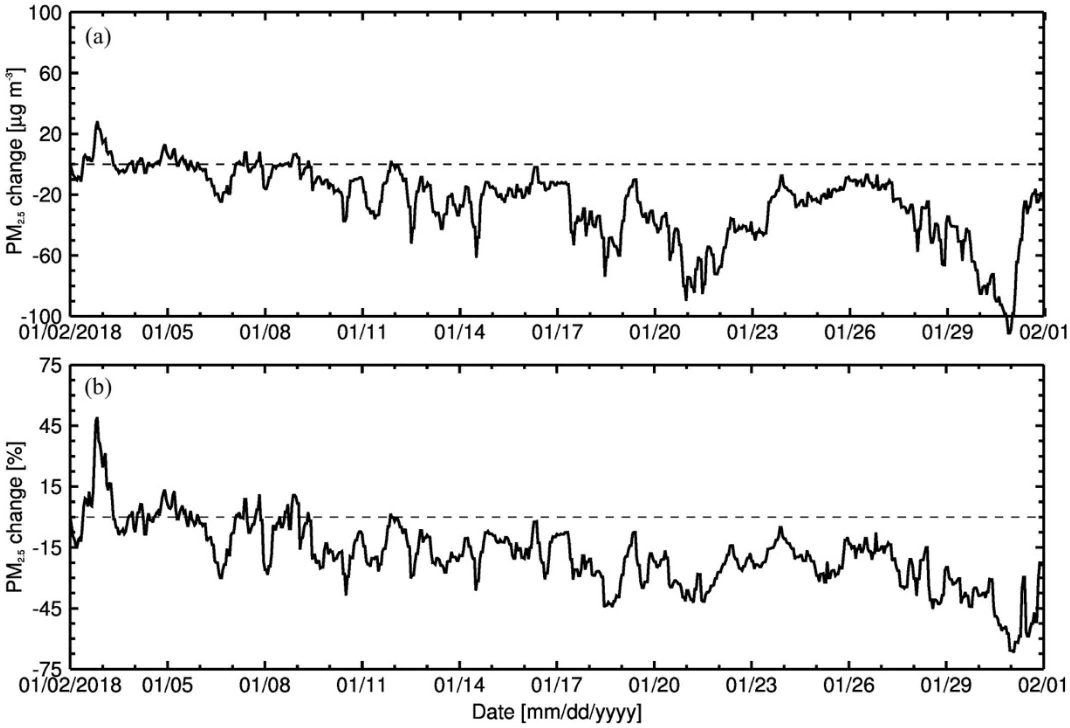

Figure S7 Same as Figure S6, but for time series of changes in $PM_{2.5}$ concentration (a) and the percentage (b) over the basin after the plateau warms by 2°C at 2018.

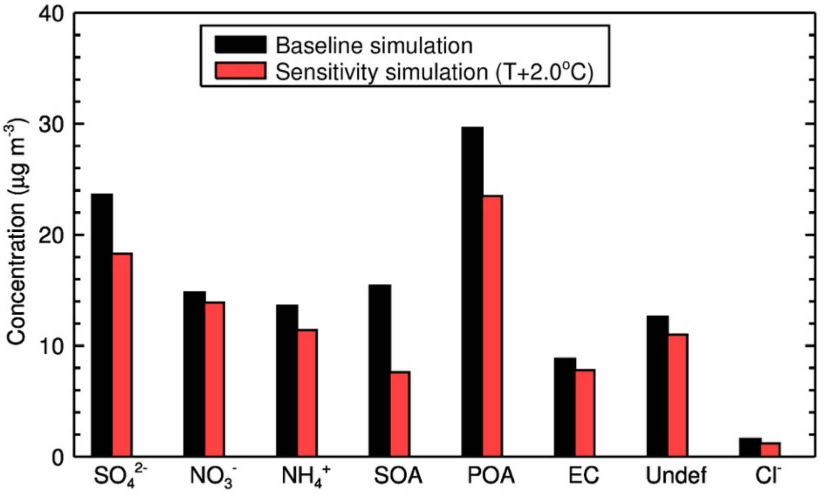

Figure S8 Same as Figure 6, but for comparison of $PM_{2.5}$ chemical composition between the baseline simulation (black bar) and sensitivity simulation (red bar) in the basin in January 2018.

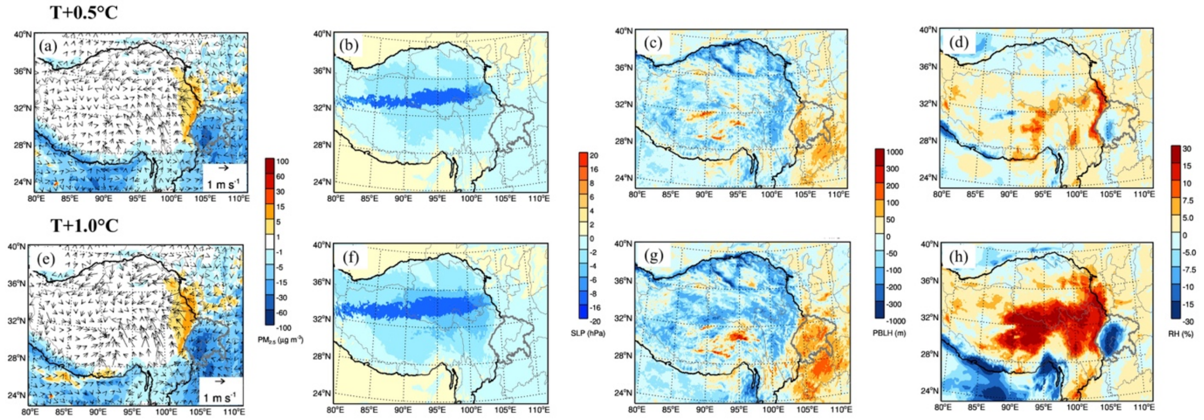

Figure S9 Differences in spatial distributions of surface $PM_{2.5}$ concentration and meteorological parameters between the baseline simulation and sensitivity simulations over the Tibetan Plateau and Sichuan Basin. (a) - (d) for $PM_{2.5}$ concentration and winds, SLP, PBLH and RH when the plateau warms by 0.5°C. (e) - (h) for the same as (a) - (d), but for the situation in which the plateau warms by 1.0°C.

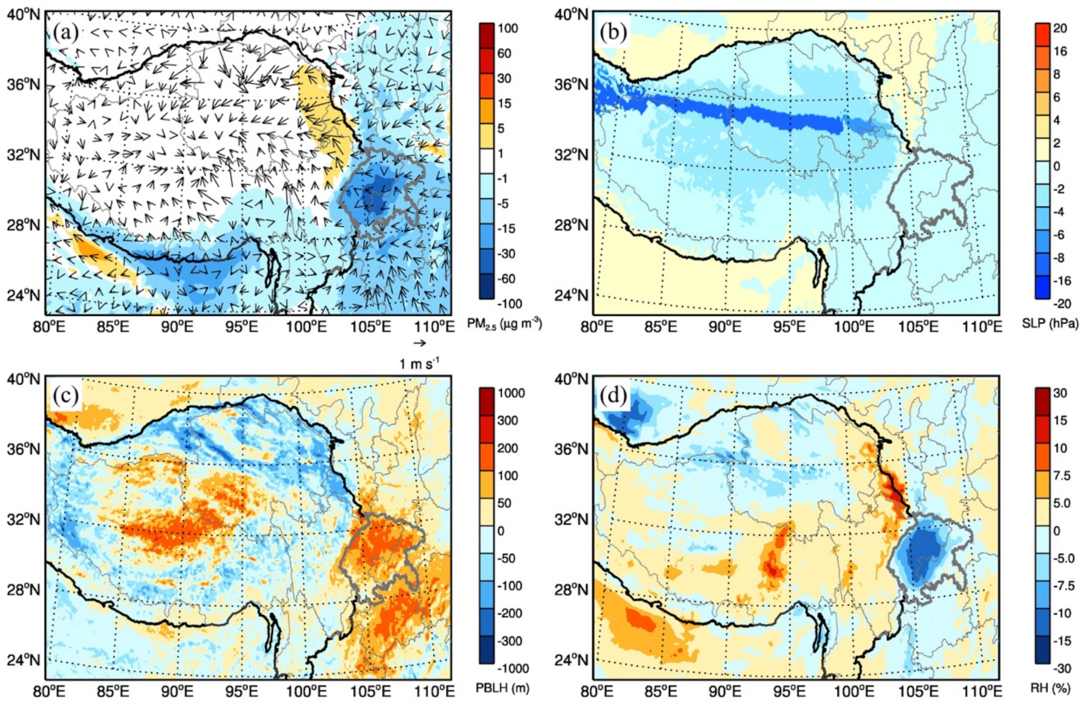

Figure S10 Same as Figure S9, but for differences in spatial distributions of surface $PM_{2.5}$ concentration and meteorological parameters between the baseline simulation and sensitivity simulation at 2018 when the plateau warms by 2.0°C. (a) $PM_{2.5}$ concentration and winds, (b) SLP, (c) PBLH and (d) RH.

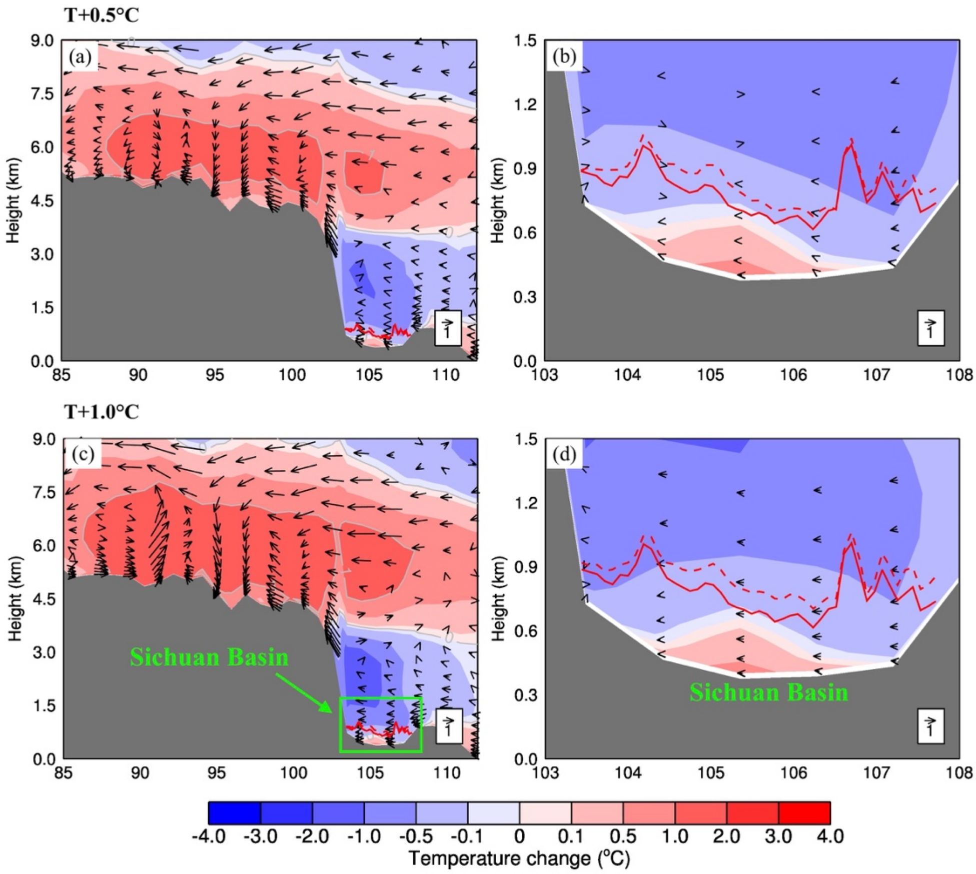

Figure S11 Vertical profiles of changes in temperature (shading and gray contour) and winds (arrows) along 30°N in January 2014. The gray shaded area presents topography. The green box for the Sichuan Basin, and the red solid (baseline simulation) and dash (sensitivity simulation) lines for the PBL height. (a) - (b) for the plateau warming by 0.5°C, and (c) - (d) for the plateau warming by 1.0°C.

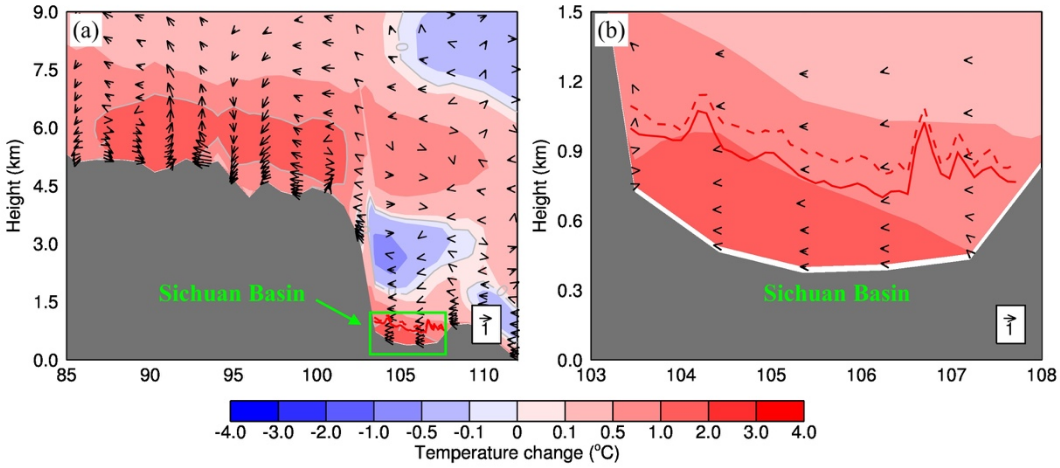

Figure S12 Same as Figure 10, but for vertical profiles of changes in temperature (shading and gray contour) and winds (arrows) along 30°N in January 2018. The gray shaded area presents topography. The green box for the Sichuan Basin, and the red solid (baseline simulation) and dash (sensitivity simulation) lines for the PBLH. (a) The Tibetan Plateau and Sichuan Basin, and (b) The Sichuan Basin.