AGU PUBLICATIONS

Geophysical Research Letters

Supporting Information for

Impact of Dust on climate and AMOC during the Last Glacial Maximum Simulated by CESM1.2

Ming Zhang[1], Yonggang Liu[1*], Jiang Zhu[2], Zhuoqun Wang[1], Zhengyu Liu[3]

[1] Laboratory for Climate and Ocean-Atmosphere Studies, Department of Atmospheric and Oceanic Sciences, School of Physics, Peking University, Beijing, 100871, China

[2] Climate and Global Dynamics Laboratory, National Center for Atmospheric Research, Boulder, CO, 80305, USA

[3] Atmospheric Science Program, Department of Geography, Ohio State University, Columbus, Ohio, 43210, USA.

Contents of this file

Text S1. Supporting information for the experimental setup.

To understand the mechanisms of climate change more clearly, we carried out a pair of atmosphere-only experiments, one with dust (called LGM_fixedSST) and the other without (called LGMND_fixedSST), in which the sea surface temperature (SST) and sea-ice concentration from the fully coupled experiment LGMCtl are prescribed. The climate forcings (e.g., orbital parameters, GHGs, LISs, vegetation and dust) in both experiments are the same as those in the coupled experiments (i.e., LGMCtl and LGMND). Both experiments were run for 20 years and the final 5 years of data are used for analysis. The simulated GMST and global dust loading in the control experiment are 7.56 °C and 41.79 Tg, respectively, close to the numbers in the fully coupled experiment (LGMCtl) (Table S1).

In order to quantify the contribution of ocean dynamics to surface temperature change, we performed a pair of slab-ocean experiments without ocean dynamics (called LGM_SOM and LGMND_SOM). The slab ocean model (SOM) uses prescribed heat transport convergence (q flux) and mixed layer depth derived from LGMCtl. Settings for the orbital parameters, GHGs, LISs, vegetation and dust in both experiments are the same as those in LGMCtl and LGMND. Both of the with-dust and without-dust experiments were run for 40 years and the final 10 years of data are used for analysis. The GMST in the slab-ocean experiment with dust is 8.82 °C, ~1 °C higher than that in LGMCtl. The most significant warming occurs over the high latitudes of Southern Hemisphere (Figure S6). This difference in surface temperature may have some influence on the estimated impact of sea-ice expansion on temperature, but is likely small (related discussion can be found in section 5.1 of the main text). The simulated global dust loading is 42.62 Tg, similar to that in the fully coupled experiment (LGMCtl).

To test the influence of the uncertainty in dust emission, we carried out a pair of prescribed-SST experiments with a different dust source distribution. One of them is the same as the prescribed-SST experiment with dust described above. In the other (called LGM_fixedSST_gladst), the glaciogenic emission of 1090 Tg/year in total from Albani et al. (2014) is considered in addition (Figure S8a, b). The glaciogenic dust flux is prescribed in the model, mainly located in Europe, Siberia, South America and North America (Figure S8a). The experiments were run for 20 years and the final 5 years of data are used for analysis.

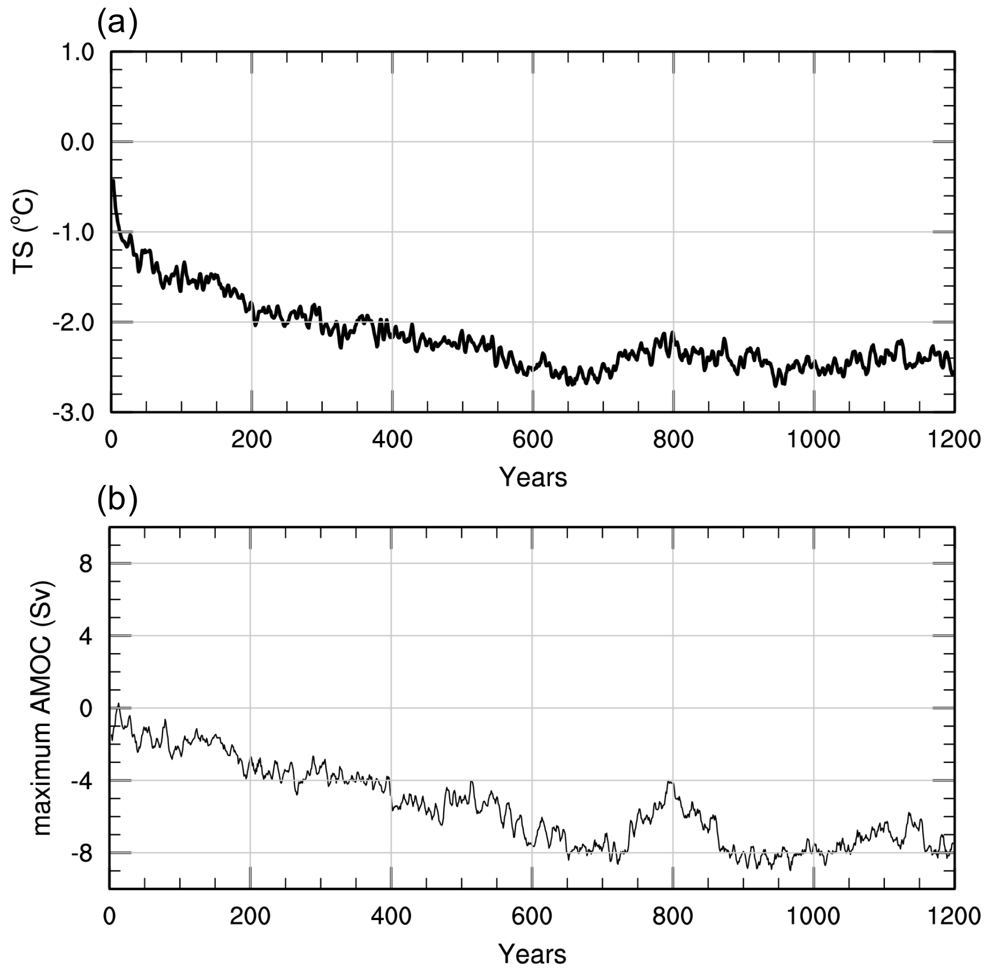

Figure S1. Evolution of anomalies of (a) global annual-mean surface temperature (unit: °C) and (b) maximum AMOC below 500 m depth (unit: Sv) in the LGMND experiment relative to the control simulation LGMCtl. A 5-yr running mean filter has been applied to both curves.

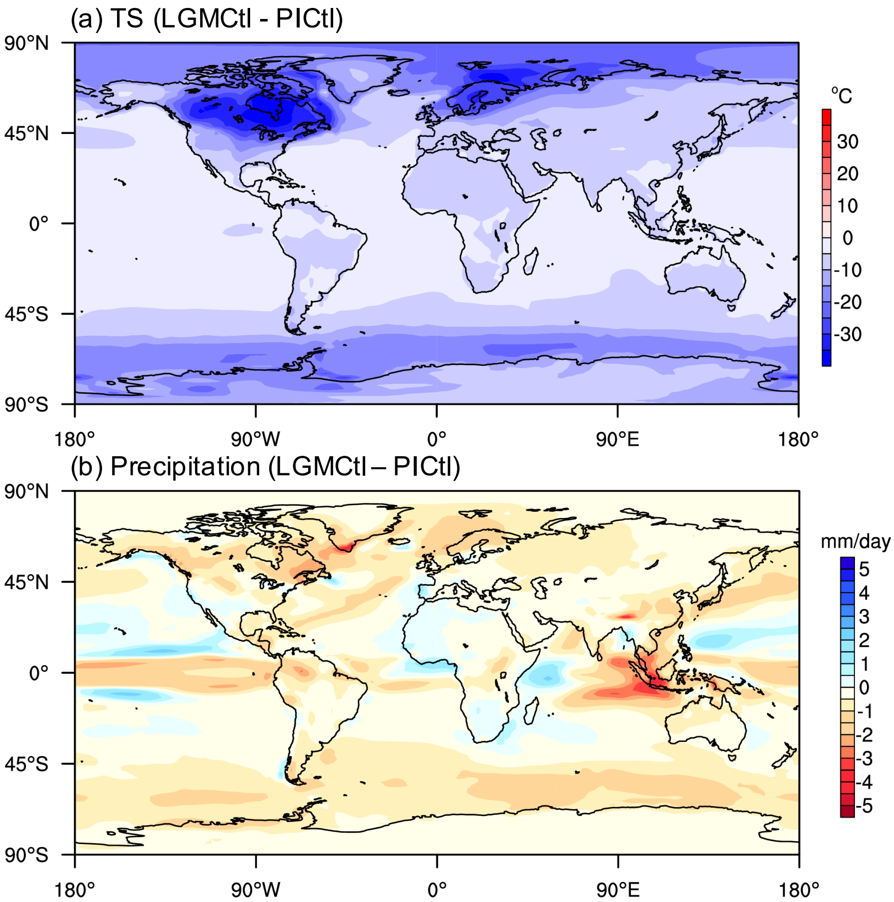

Figure S2. Simulated annual mean (a) surface temperature anomaly (unit: °C) and (b) precipitation (unit: mm/day) in the LGMCtl experiment compared to PI.

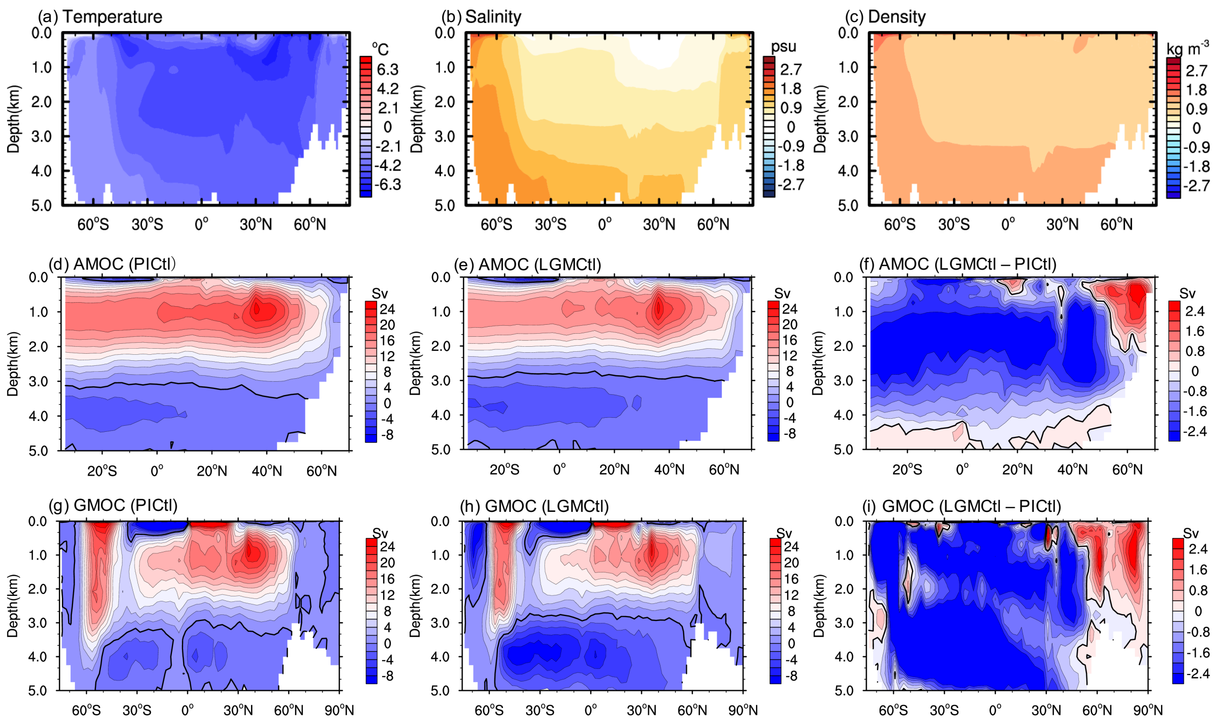

Figure S3. Anomalies of zonal mean (a) potential temperature (unit: °C), (b) salinity (unit: psu) and (c) potential density (unit: kg m^{-3}) in the Atlantic Ocean for experiment LGMCtl relative to PI. Annual mean Atlantic meridional streamfunction (AMSF, unit: Sv) for PI and LGM is shown in (d) and (e), respectively. The AMSF difference between LGM and PI is shown in (f). Figures g-i are similar to d-f but for the global meridional streamfunction (GMSF, unit: Sv). The zero contour lines are shown in black.

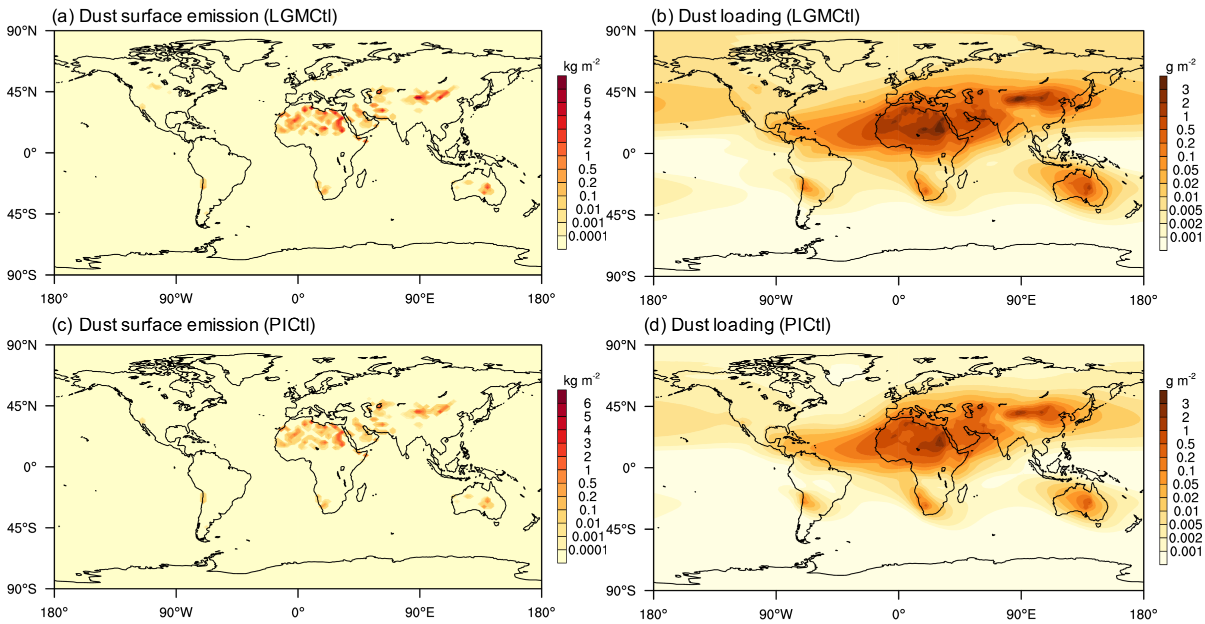

Figure S4. Annual mean dust emission (unit: kg m^{-2}) and dust loading (unit: g m^{-2}) for LGM (a-b) and PI (c-d).

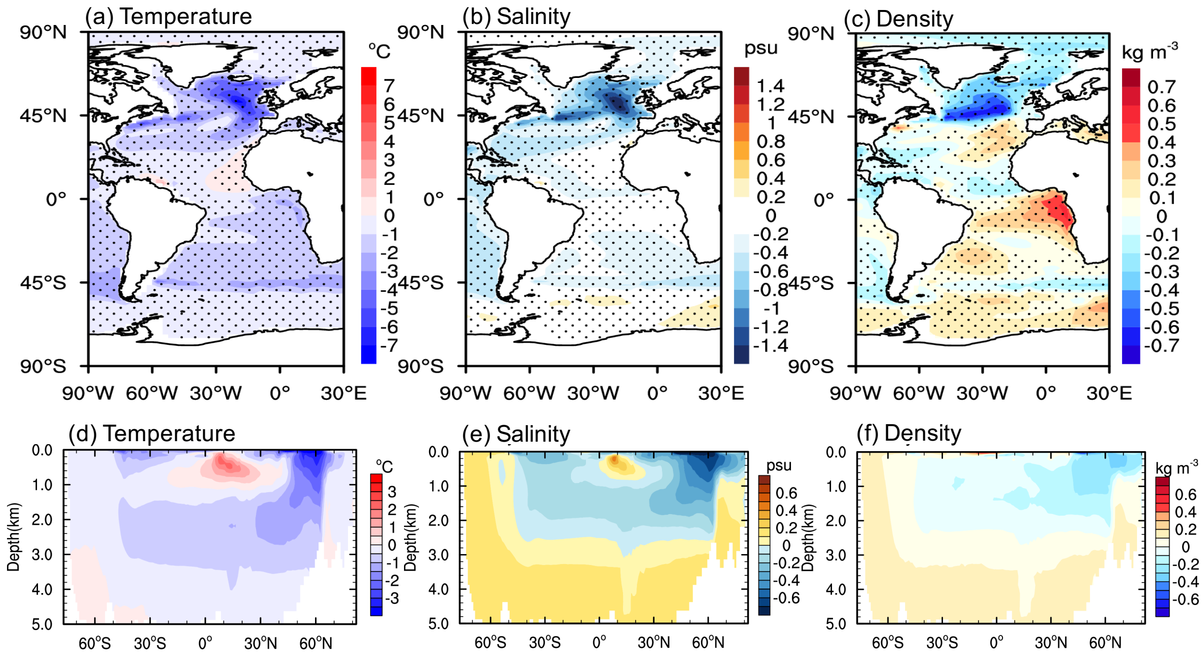

Figure S5. Anomalies of annual mean surface (top 100 m) (a) potential temperature (unit: °C), (b) salinity (unit: psu) and (c) potential density (unit: kg m^{-3}) over the Atlantic Ocean for the LGMND experiment compared to LGMCtl and anomalies of zonal mean (d) potential temperature, (e) salinity and (f) potential density in the Atlantic Ocean for LGMND compared to LGMCtl.

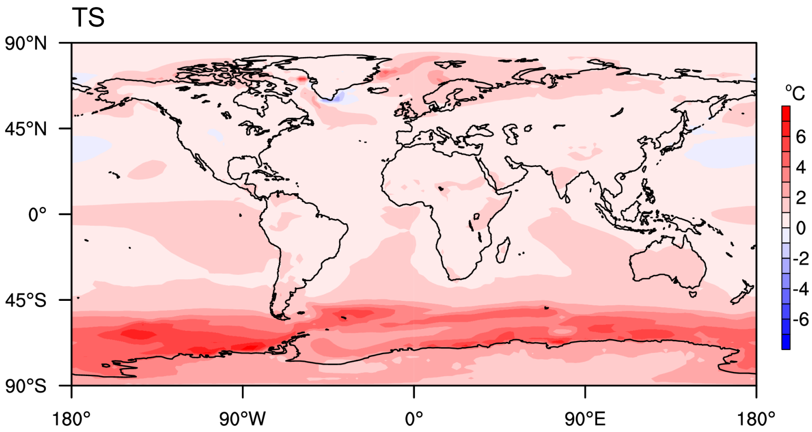

Figure S6. Difference of annual mean surface temperature (unit: °C) between the LGM control experiments with slab ocean model and fully coupled model.

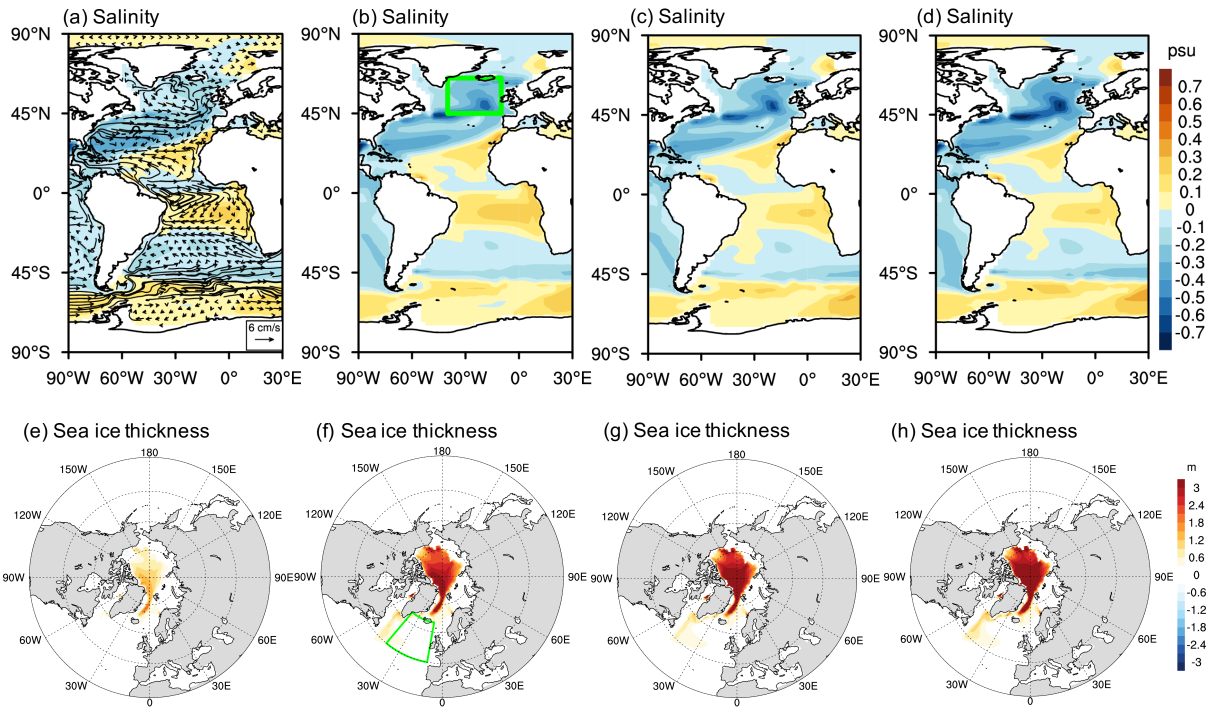

Figure S7. Changes of annual mean sea surface (top 100 m) salinity (unit: psu) in Atlantic (upper row) and annual mean sea-ice thickness (unit: m) in Arctic (bottom row) averaged over (a), (b) year 1-50; (c), (d) year 51-100; (e), (f) year 101-150; (g), (h) year 151-200 after dust removal.Vectors in (a) show the annual-mean surface (top 100 m) ocean current in LGMCtl (unit: cm/s). The green boxes (45° N-65° N, 40° W-10° W) in (b) and (f) show where salinity budget is calculated.

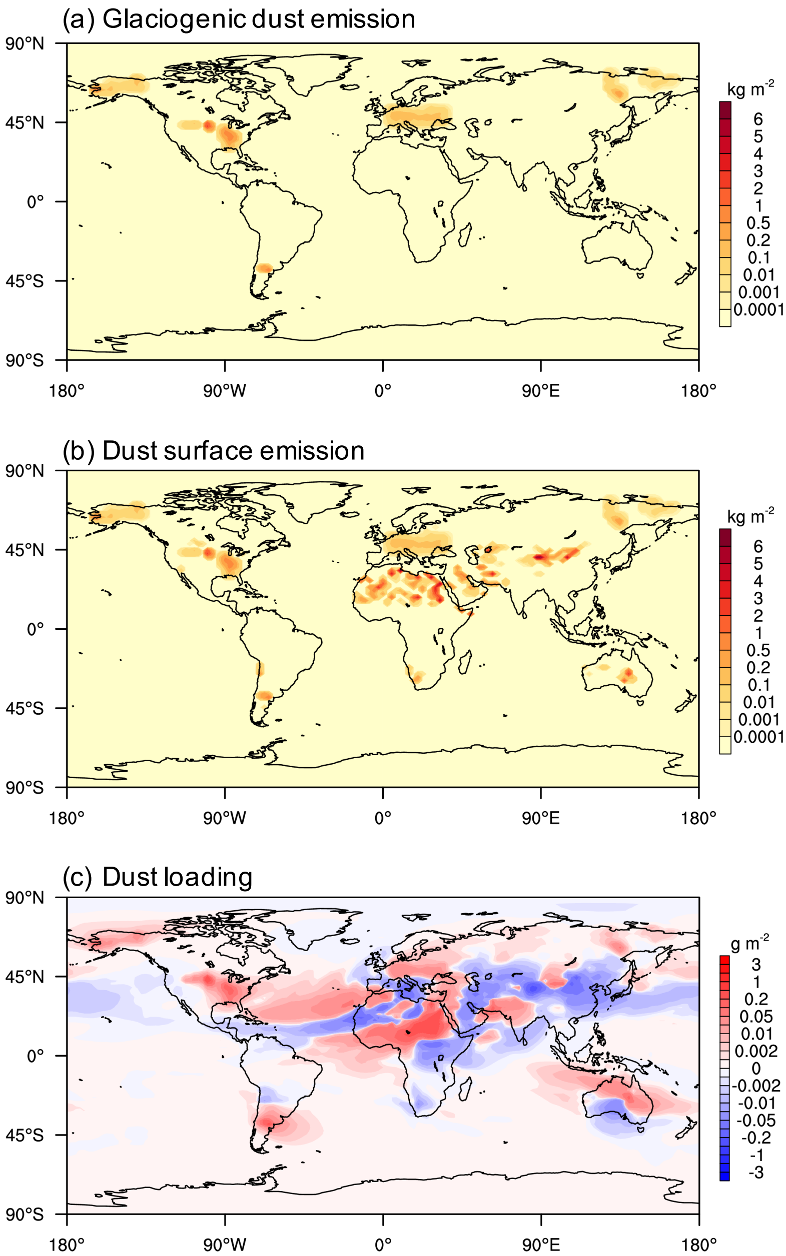

Figure S8. (a) Glaciogenic dust flux (unit: kg m^{-2}) from Albani et al. (2014), (b) total dust emissions (including glaciogenic and non-glaciogenic dust emissions) (unit: kg m^{-2}) in our simulation, (c) difference of annual-mean dust loading (unit: g m^{-2}) between the experiments with additional glaciogenic dust and without glaciogenic dust.

Table S1. Summary of the experiment parameters and results. TS and Prec. are the global annual-mean surface temperature and precipitation, respectively. Max. AMOC is defined as the maximum Atlantic meridional streamfunction below 500 m depth.

Experiment	LGM control (LGMCtl)	No dust (LGMND)	LGM_fixedSST	LGMND_fixedSST	LGM_SOM	LGMND_SOM	LGM_fixedSST_gladst
Orbit	21 ka	21 ka	21 ka	21 ka	21 ka	21 ka	21 ka
CO_2 (ppm)	185	185	185	185	185	185	185
CH_4 (ppb)	350	350	350	350	350	350	350
N_2O (ppb)	200	200	200	200	200	200	200
Ice sheets	ICE-6G	ICE-6G	ICE-6G	ICE-6G	ICE-6G	ICE-6G	ICE-6G
Topography Coastlines	ICE-6G	ICE-6G	ICE-6G	ICE-6G	ICE-6G	ICE-6G	ICE-6G
Duration (year)	4000	1200	20	20	40	40	20
TS (℃)	7.66	5.24	7.57	7.26	8.82	7.61	7.60
Prec. (mm/day)	2.57	2.52	2.55	2.66	2.64	2.67	2.56
Max. AMOC (Sv)	24.79	17.08	-	-	-	-	-
TS trend (℃/kyr)	0.056	-0.15	-	-	-	-	-
AMOC trend (Sv/kyr)	-0.18	-2.16	-	-	-	-	-
Dust emissions (Tg)	6369.17	0	6329.89	0	6314.89	0	7472.02
Dust loading (Tg)	41.96	0	41.79	0	42.62	0	42.74