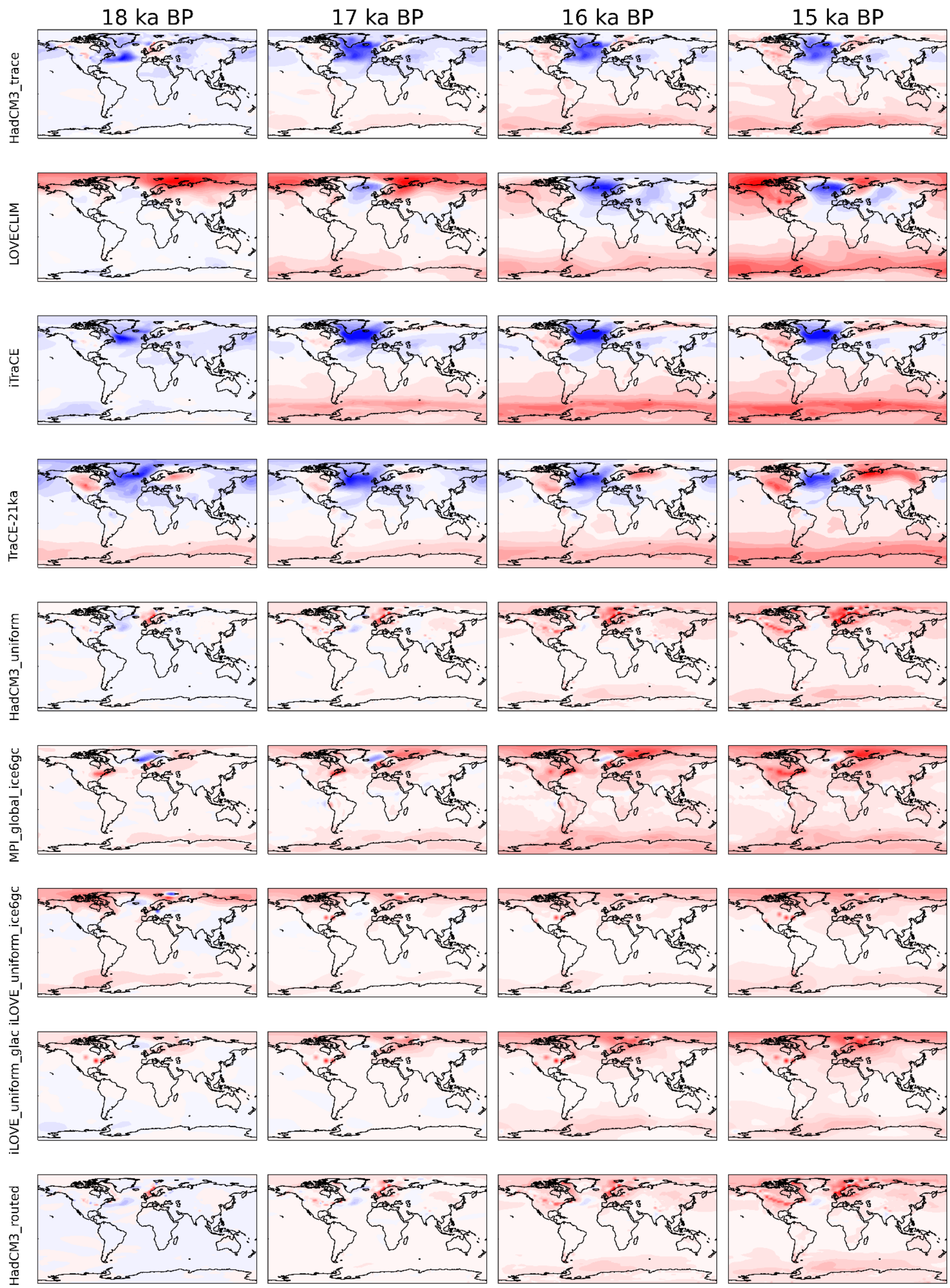
Supplementary Information



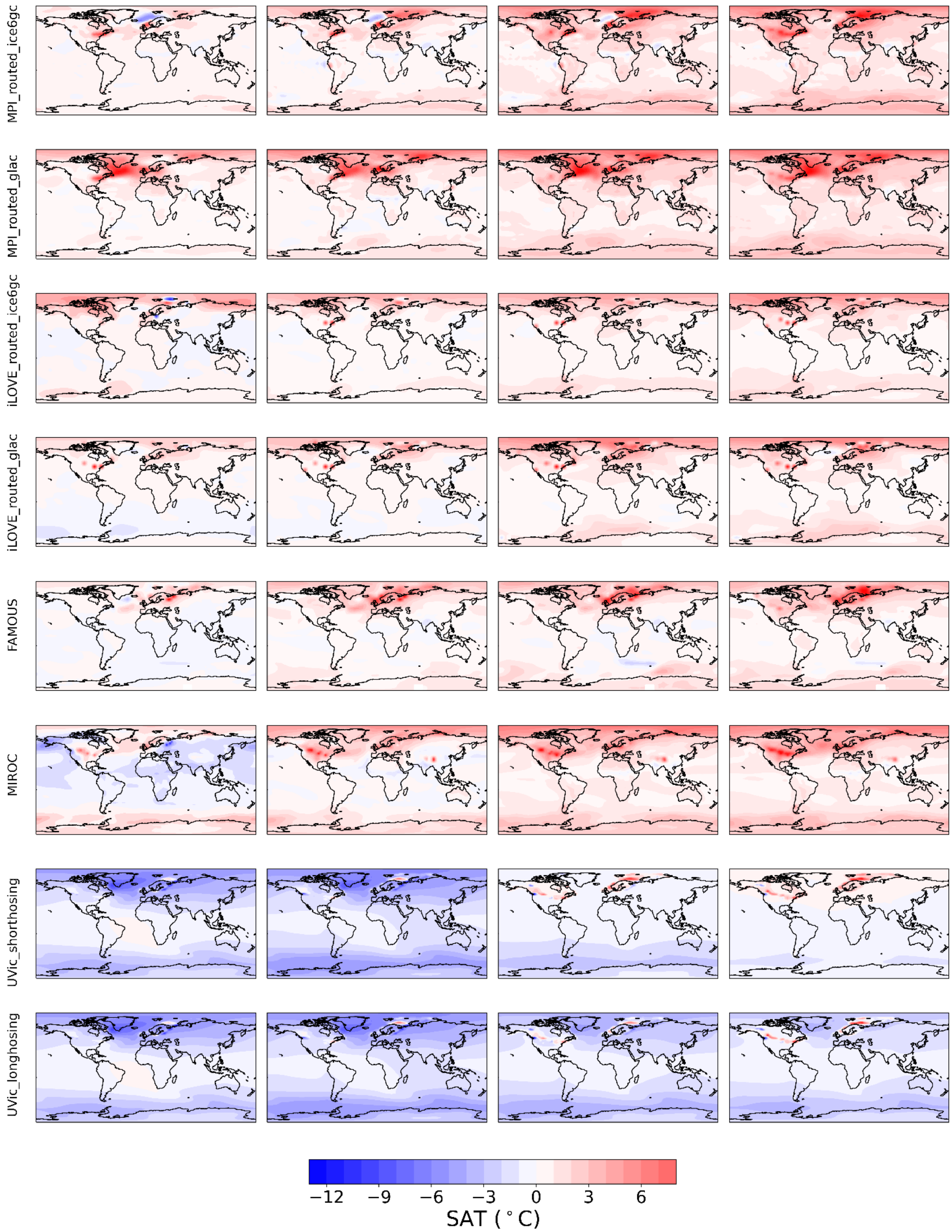


Fig. S1: Global decadal surface air temperature as anomalies from the LGM (average between 20 and 19.5 ka BP). 18, 17, 16, and 15 ka BP are calculated as 60-year decadal means centred around the respective time period (e.g., from 17.97 to 18.03 ka BP for 18 ka BP).

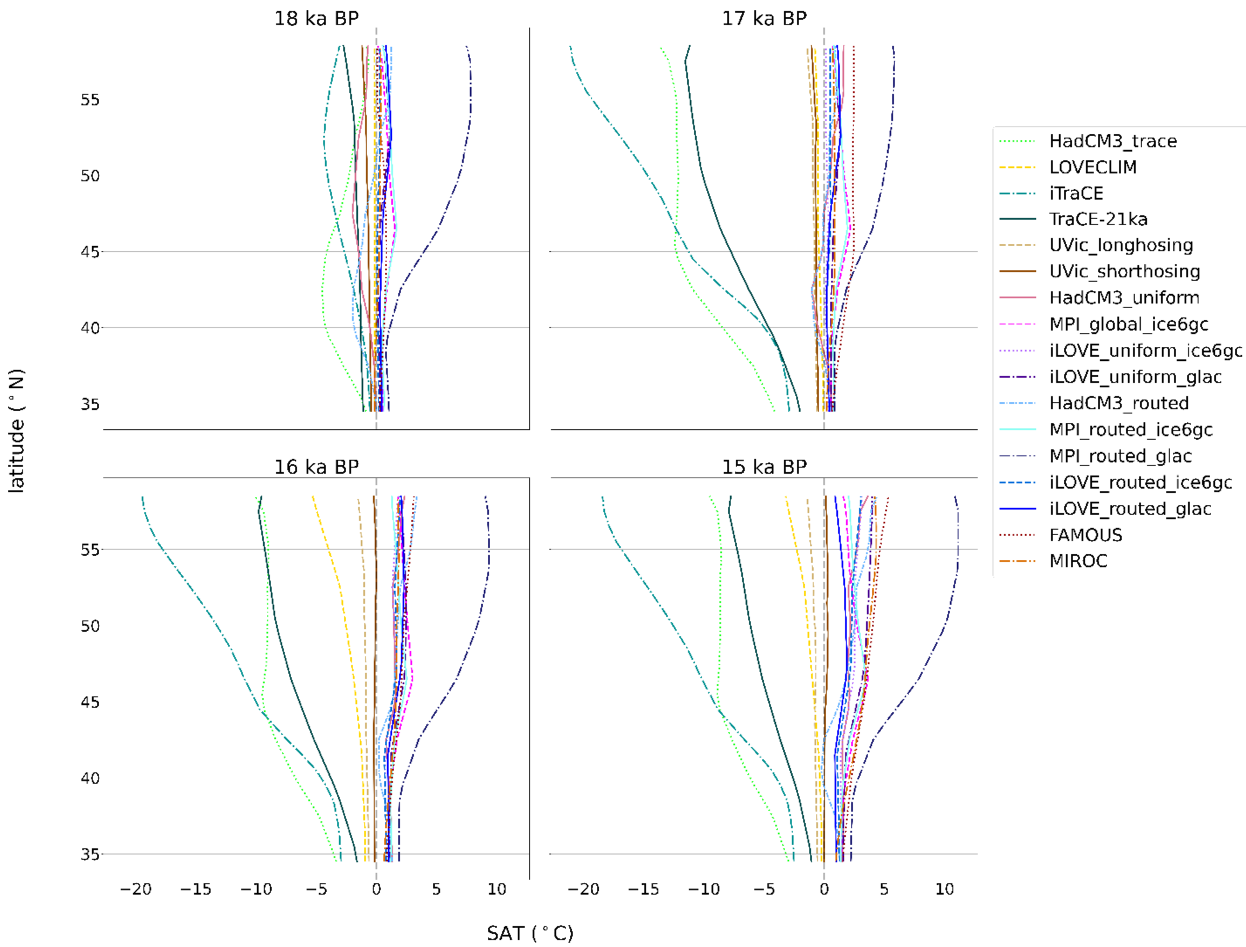


Fig. S2: Zonal average of decadal surface air temperature across the ensemble for the North Atlantic (between 35 and 60° N and -60 and 0° E) as anomalies from the LGM (20 – 19.5 ka BP) for each simulation. 18, 17, 16, and 15 ka BP are calculated as 60-year decadal means centred around the respective time period (e.g., from 17.97 to 18.03 ka BP for 18 ka BP).

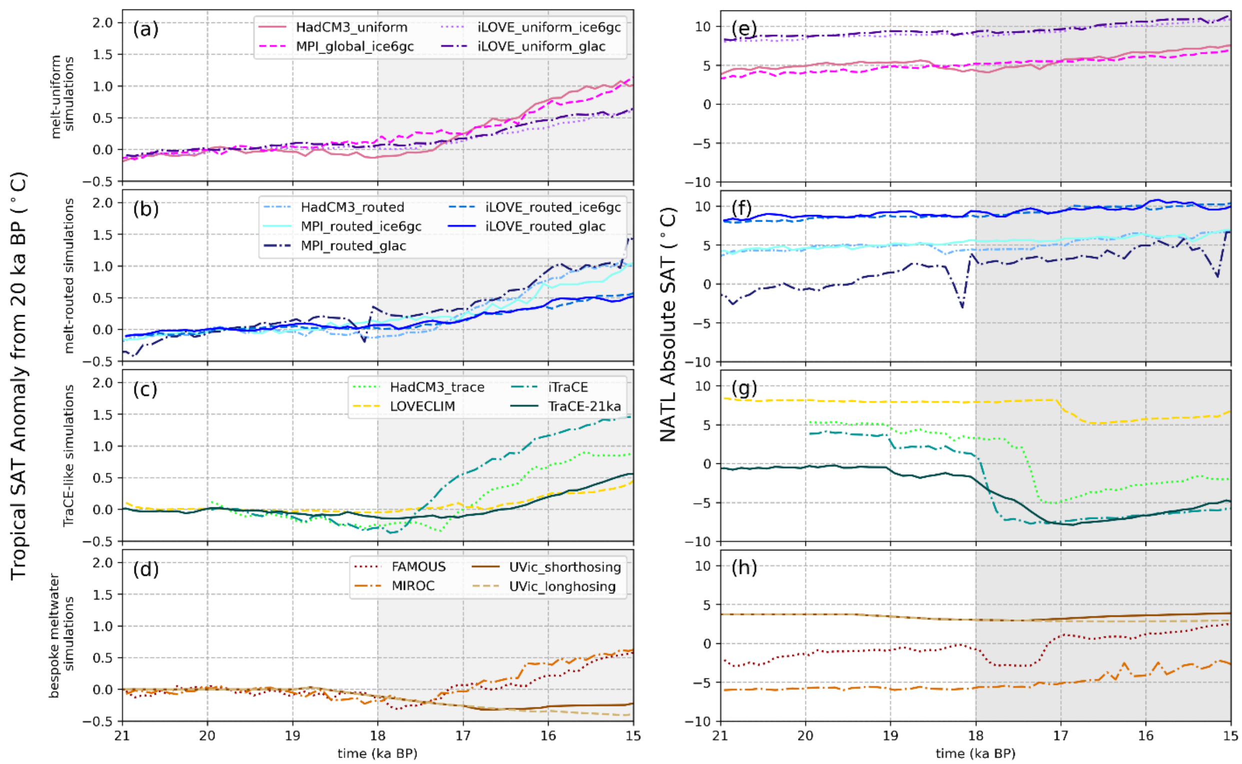


Fig. S3: (a) – (d) Surface air temperature of the tropics (30° N to 30° S) anomaly from the LGM (20 to 19 ka BP) (e) – (h) Absolute surface air temperature of the North Atlantic region (between 35 and 60° N and -60 and 0° E) for each simulation grouped by meltwater scenario.

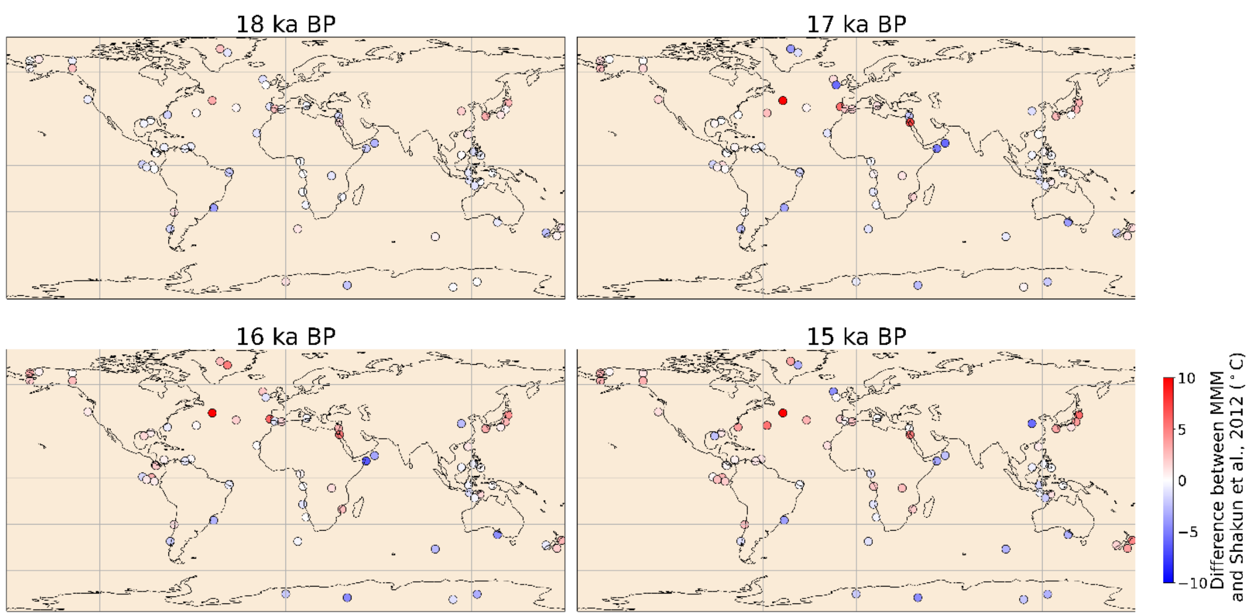


Fig. S4: Point-by-point difference between multi-model ensemble mean surface temperature (Figure 4) and the surface temperature stack by Shakun et al., (2012).

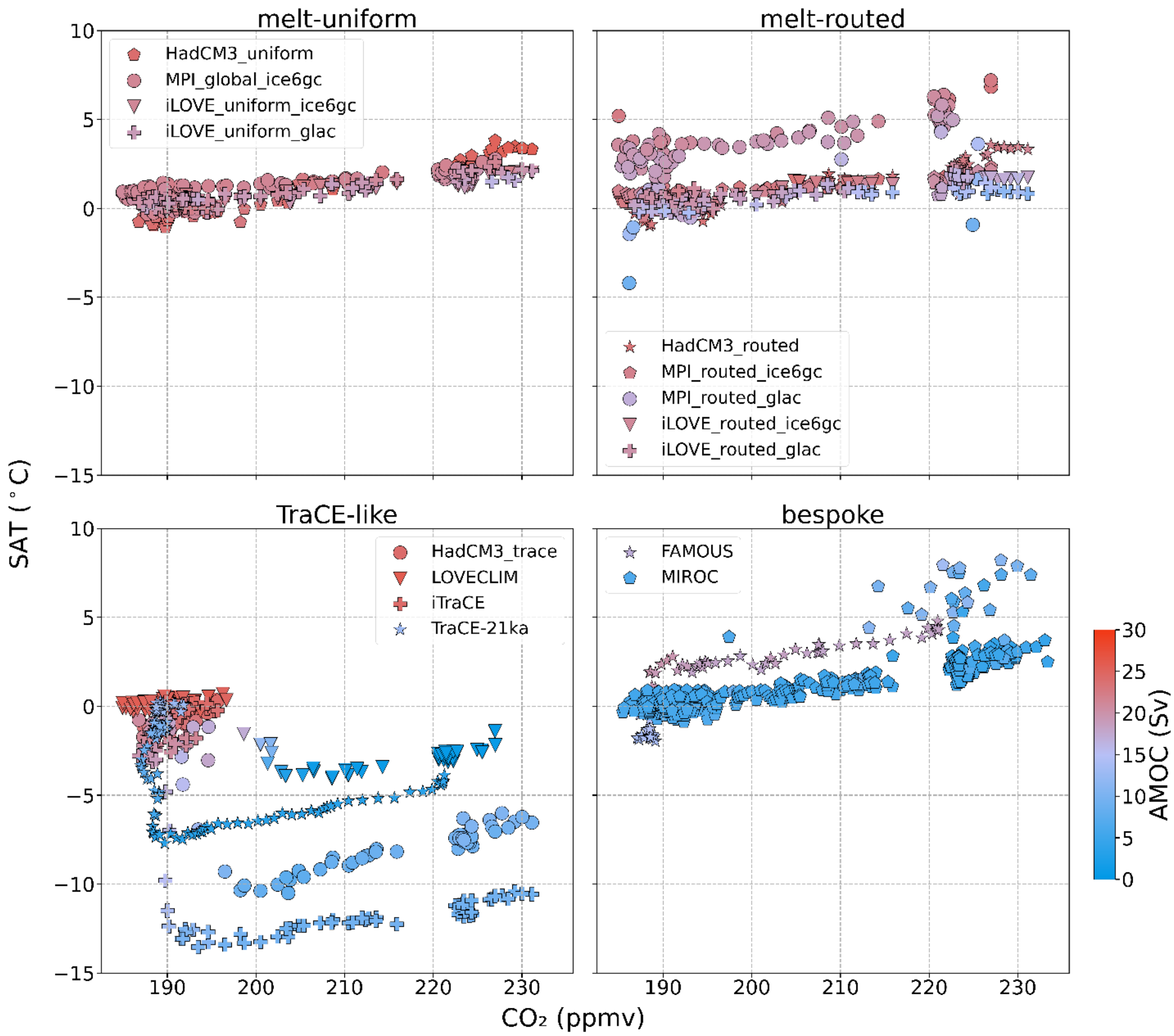


Fig. S5: Anomalous surface air temperature from the LGM (20 – 19.5 ka BP) over the North Atlantic (between 35 and 60° N and -60 and 0° E) as a function of CO_2 concentration with symbols' shading representing the strength of the AMOC (Sv) split into groups defined by meltwater scenario. Each simulation is represented as 50 year means except for MIROC which is shown as decadal means to capture the smaller-scale variability.

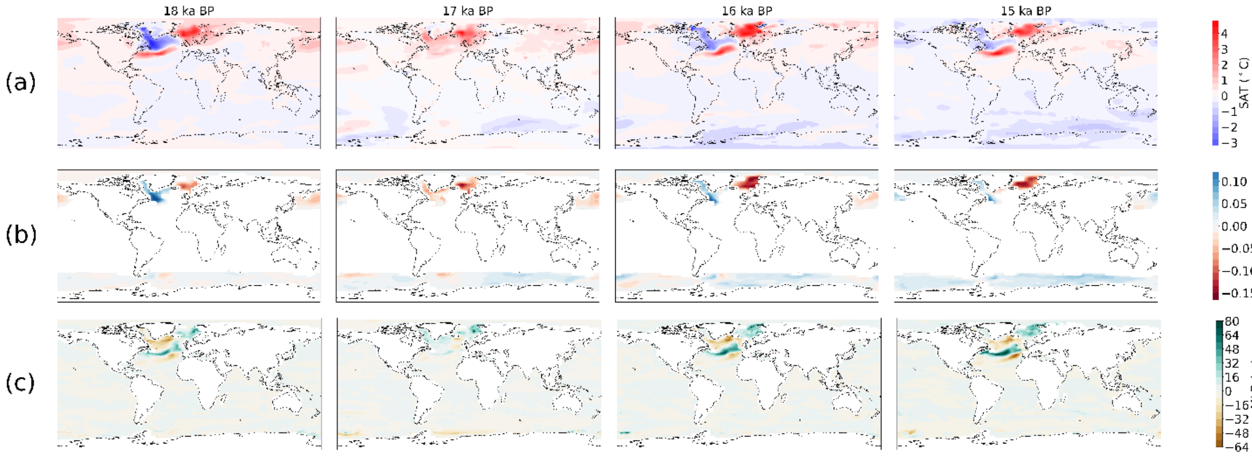


Fig. S6: Anomaly of HadCM3_uniform and HadCM3_routed for (a) surface air temperature, (b) sea ice concentration, and (c) Mixed-layer depth (MLD). 18, 17, 16, and 15 ka BP are calculated as 60-year decadal means centred around the respective time period (e.g., from 17.97 to 18.03 ka BP for 18 ka BP).

Table S1: Corresponding AMOC changes from before the abrupt decrease in Greenland surface air temperature (19 ka BP) and after the abrupt increase in meltwater (16 ka BP) for the TraCE-like simulations. Average depth is calculated as the average vertical reach of the upper cell of the AMOC in the water column between 25° S and 25° N (as Muglia and Schmittner 2021). The level of max AMOC is the depth of the maximum stream function at ~26.6 °N (as Sigmond et al. 2020). Max strength of the Northern Hemisphere (NH) is calculated as the maximum stream function between ~500 and 3500 meters depth above 0 °N. Maximum strength at 26.6° N is calculated at the same depth range, but only at 26.6° N.

[1]Convection site appears to be in Arctic Ocean (Fig. S7) where sea ice is located, however, this is not affecting the global climate or the AMOC (Fig. S8).
[2]Upper cell reaches the seabed (Fig. S8).
[3]At 16.8 ka BP, depth has raised to average of 2650.0 meters before AMOC collapses (see Fig. S8).

Simulation Reference Name	Average depth at 19 ka BP (m)	Average depth at 16 ka BP (m)	Level of max AMOC at 19ka BP at 26.6° N (m)	Level of max AMOC at 16 ka BP at 26.6° N (m)	Max strength in NH 19 ka BP (Sv)	Max strength in NH 16 ka BP (Sv)	Max strength at 26.6° N at 19 ka BP (Sv)	Max strength at 26.6° N at 16 ka BP (Sv)	NADW formation sites at 19 ka BP	NADW formation sites at 16 ka BP
HadCM3_TraCE	2586.5	1995.7	800.0	800.0	24.6	9.8	18.4	7.9	Southeast of Iceland/Norwegian Sea	Weak convection in Irminger Sea
TraCE-21ka	2017.9	1606.6	600.0	600.0	12.6	3.4	12.6	3.4	Irminger Sea/Labrador Sea	Weak convection in Greenland Sea
iTraCE	2500.0	2691.2	800.0	600.0	23.9	9.3	16.8	5.0	Irminger Sea	Weak convection[1]
LOVECLIM	5000.0[2]	AMOC shutdown[3]	1750.0	600.0	26.8	1.0	22.5	0.0	Norwegian Sea	NADW shut down

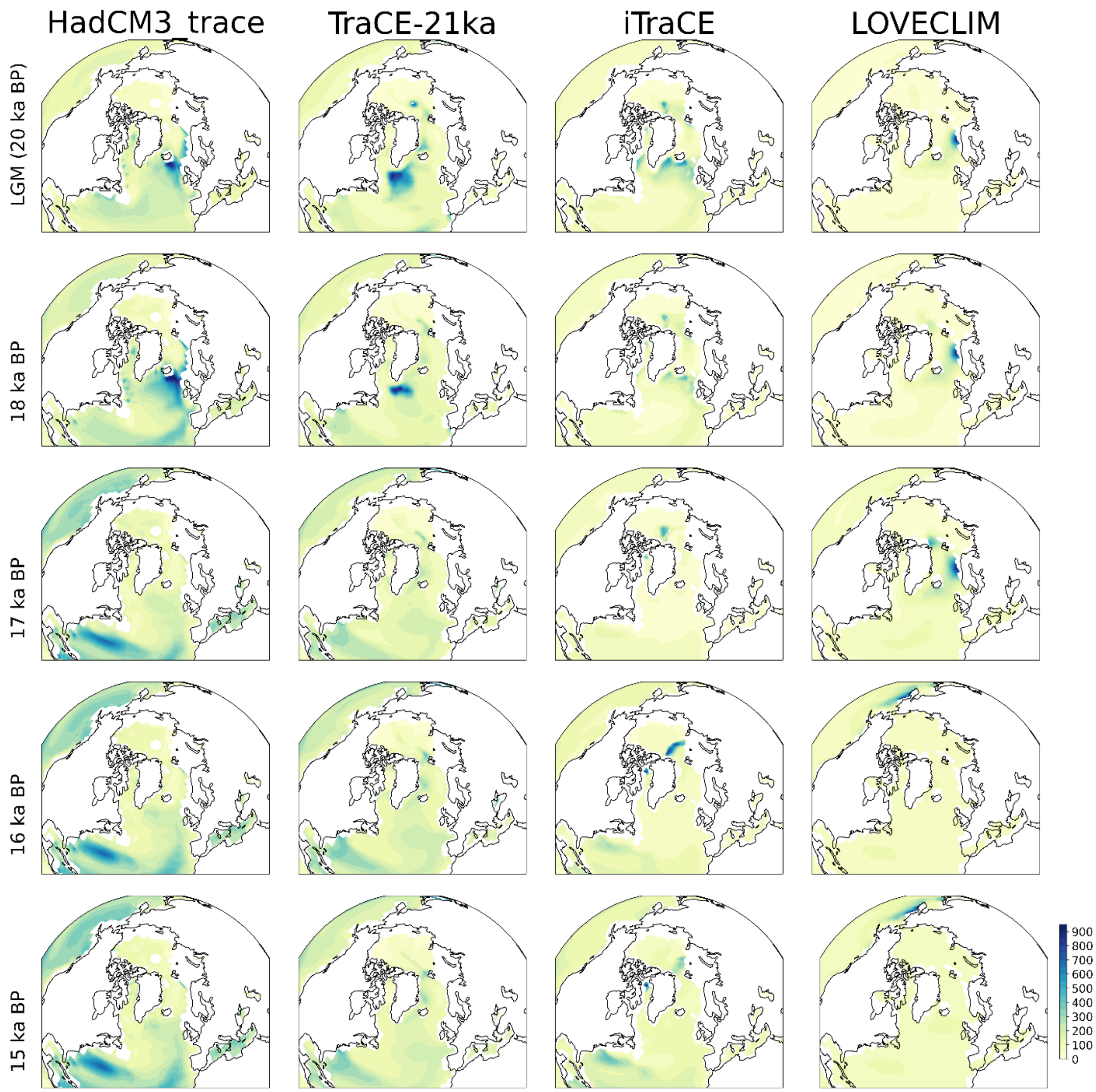


Fig. S7: Evolution of mixed-layer depth for the TraCE-like simulations. 18, 17, 16, and 15 ka BP are calculated as 100-year decadal means centred around the respective time period (e.g., from 17.95 to 18.05 ka BP for 18 ka BP). The LGM is calculated as a 500-year mean between 20 and 19.5 ka BP.

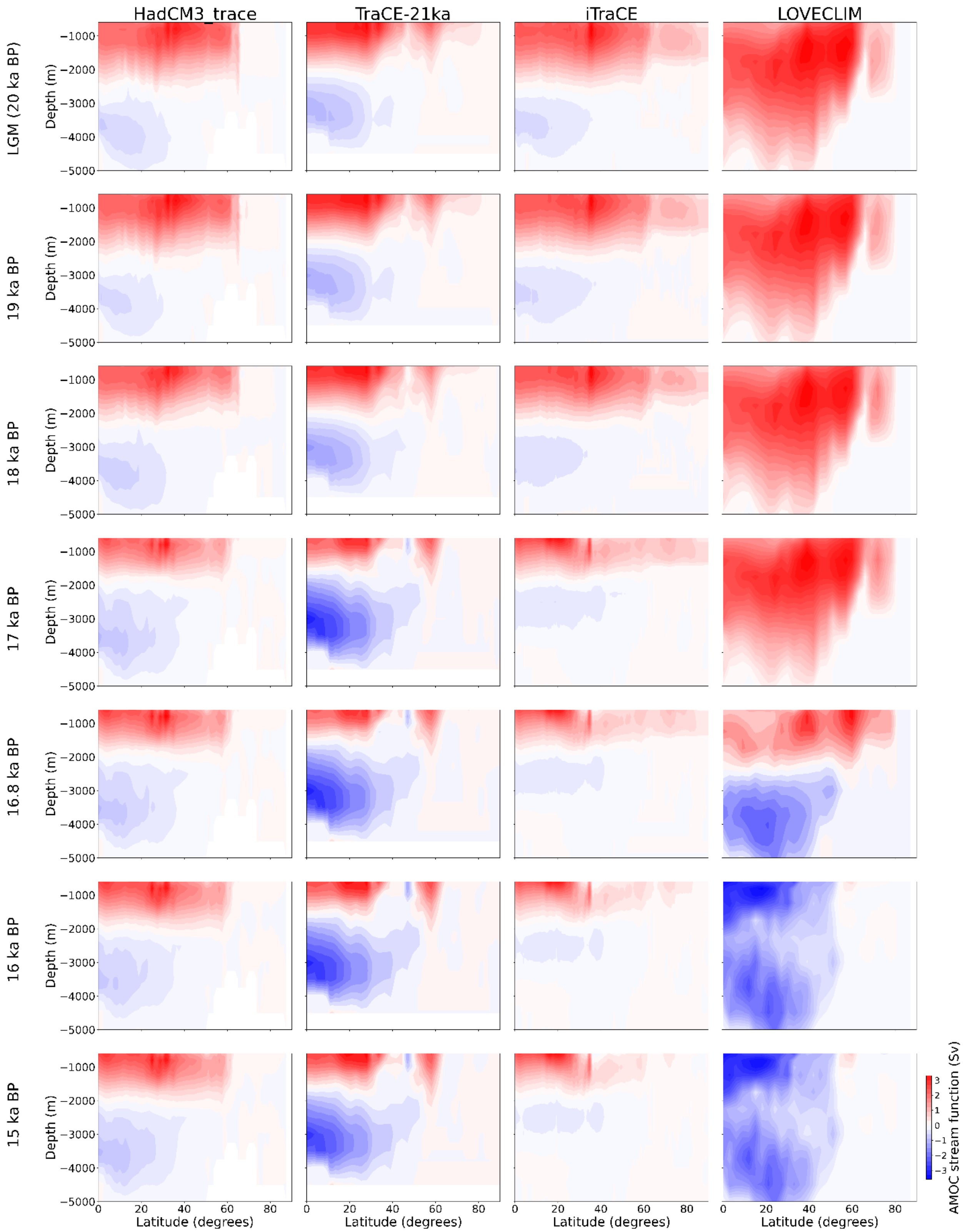


Fig. S8: AMOC stream function evolution for the TraCE-like simulations in the Northern Hemisphere. 19, 18, 17, 16, 16.8, and 15 ka BP are calculated as 100-year decadal means centred around the respective time period (e.g., from 17.95 to 18.05 ka BP for 18 ka BP). The LGM is calculated as a 500-year mean between 20 and 19.5 ka BP.