

Supplementary data

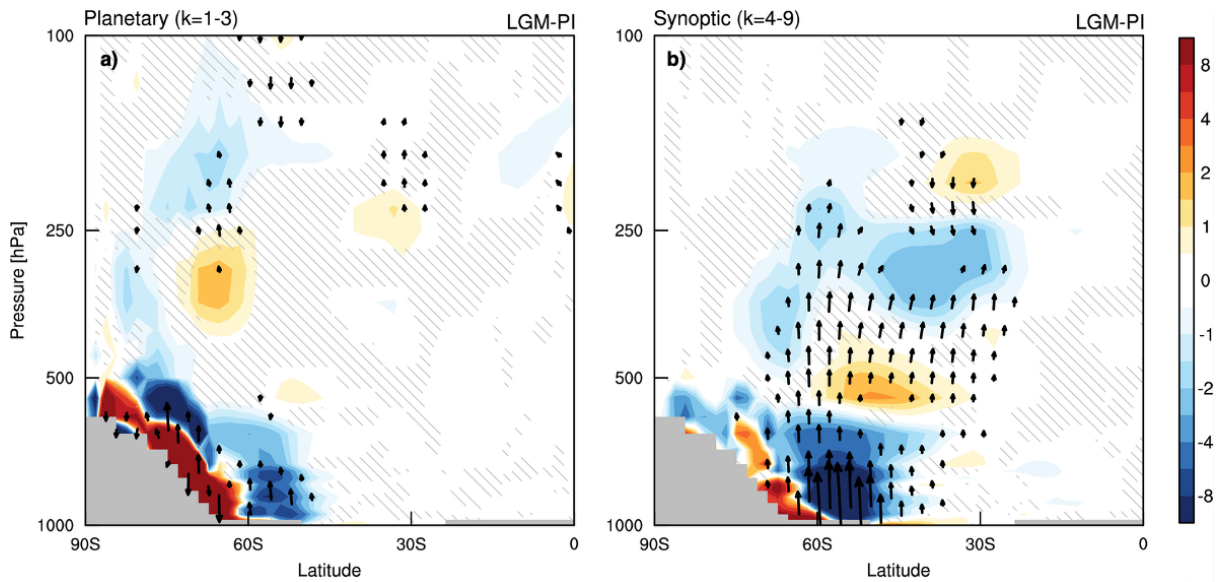


Figure S1. Same as in Figure 7c, but decomposed into zonal wavenumber (k) components to distinguish the contributions of different spatial scales. Panels show the difference between the LGM and PI simulations (LGM minus PI) for **(a)** planetary scale ($k = 1-3$) and **(b)** synoptic scale ($k = 4-9$). Hatching indicates regions where the differences are not statistically significant at the 99% confidence level based on a Student's t -test.

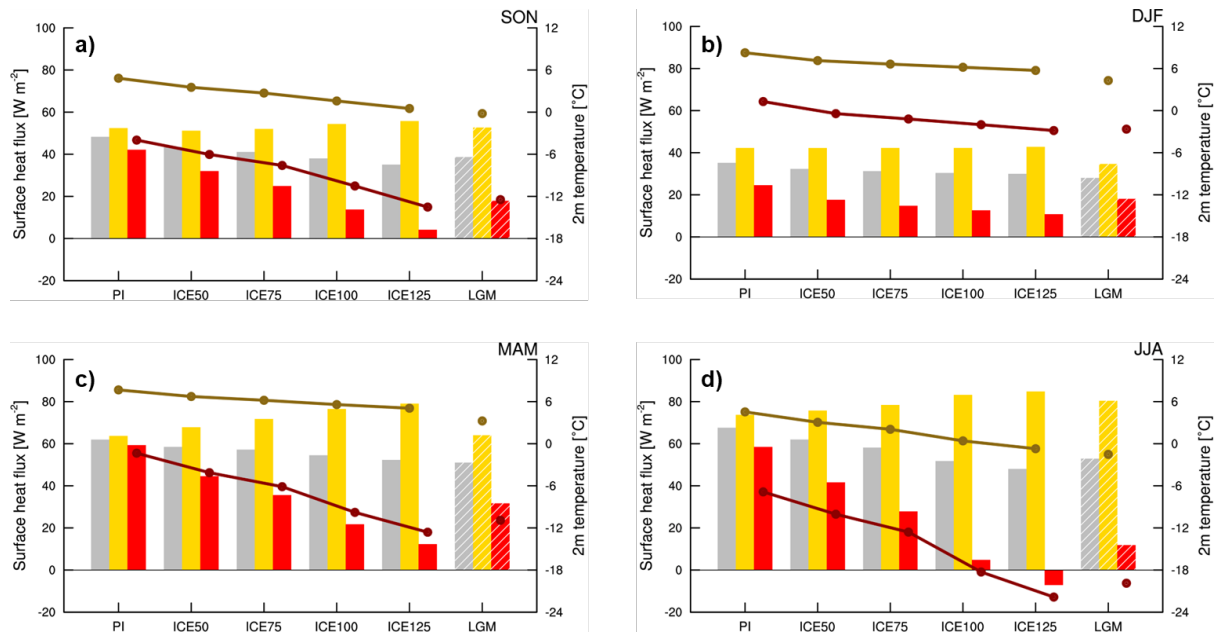


Figure S2. Seasonal variations of surface boundary conditions for the four austral seasons: **(a)** spring (SON), **(b)** summer (DJF), **(c)** autumn (MAM), and **(d)** winter (JJA). The plots show surface upward heat flux (bars; W m^{-2}) and 2-meter temperature (lines; $^{\circ}\text{C}$) averaged

over two key analysis regions: Area 1 (45°S–55°S, open ocean zone) and Area 2 (55°S–65°S, sea ice zone). Yellow and red colors correspond to Area 1 and Area 2, respectively, while gray bars show the average over the combined region. Hatched bars indicate the LGM experiment