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Impact of mid-glacial ice sheets on deep ocean circulation and global climate

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This study explores the effect of southward expansion of Northern Hemisphere (American) mid-glacial ice sheets on the global climate and the Atlantic Meridional Overturning Circulation (AMOC), as well as the processes by which the ice sheets modify the AMOC. For this purpose, simulations of Marine Isotope Stage (MIS) 3 (36ka) and 5a (80ka) are performed with an atmosphere-ocean general circulation model. In the MIS3 and MIS5a simulations, the global average temperature decreases by 5.0 °C and 2.2 °C, respectively, compared with the preindustrial climate simulation. The AMOC weakens by 3% in MIS3, whereas it strengthens by 16% in MIS5a, both of which are consistent with an estimate based on $^{231}Pa/^{230}Th$. Sensitivity experiments extracting the effect of the southward expansion of glacial ice sheets from MIS5a to MIS3 show a global cooling of 1.1 °C, contributing to about 40% of the total surface cooling from MIS5a to MIS3. These experiments also demonstrate that the ice sheet expansion leads to a surface cooling of 2 °C over the Southern Ocean as a result of colder North Atlantic deep water. We find that the southward expansion of the mid-glacial ice sheet exerts a small impact on the AMOC. Partially coupled experiments reveal that the global surface cooling by the glacial ice sheet tends to reduce the AMOC by increasing the sea ice at both poles, and hence compensates for the strengthening effect of the enhanced surface wind over the North Atlantic. Our results show that the total effect of glacial ice sheets on the AMOC is determined by the two competing effects, surface wind and surface cooling. The relative strength of surface wind and surface cooling effects depends on the ice sheet configuration, and the strength of the surface cooling can be comparable to that of surface wind when changes in the extent of ice sheet are prominent.