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Role of size and height of ice sheet on millennial-scale climate variability

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Unlike the interglacial stable climate, glacial climate was dominated by millennial-scale variability, which is strongly associated with changes in the Atlantic meridional overturning circulation (AMOC). The development of the North American ice sheet has been shown to have a significant impact on the strength of the AMOC through surface cooling and enhanced surface winds. However, the impact of mid-glacial ice sheet involved in millennial-scale variability of the AMOC are still elusive. Here, using a coupled atmosphere-ocean model MIROC4m, we perform several climate simulations under mid-glacial ice sheet configurations. We use Marine Isotope Stage (MIS)-5a and MIS-3 ice sheet configurations as boundary conditions, which are derived from the simulation of an ice sheet model, IcIES-MIROC. These volumes are the 40 m sea level equivalent for MIS5a (approximately 33% of the LGM) and the 96 m sea level equivalent for MIS3 (approximately 80% of the LGM). To account for uncertainty in the altitude of the ice sheet, we also conduct experiments under topographic conditions in which only the altitude was changed, but not the extent, for each ice sheet configuration. As a result, self-sustained oscillations of millennial-scale periodicity in the climate and AMOC are simulated for both ice sheet cases. The result suggests that the millennial-scale climate variability could occur as long as the North American ice sheet exists, even if the ice sheet is small. The expansion of the North American ice sheet from MIS5a to MIS3 have an influence of shortening the weak AMOC period (stadial) and lengthening of the strong AMOC period (interstadial), because the stronger surface winds over North Atlantic enhance retreat of sea-ice during the stadial and increase salt transport via wind-driven ocean circulation during the interstadial. Meanwhile, one of the other simulations under the ice sheet condition with MIS3-equivalent extent but altitudes as low as 50% results in a persistent stadial state, which is due to the large cooling effect. Our results show that the relative strength of surface wind and surface cooling effects depends on the ice sheet configuration, which could modify the length of stadial and interstadial.