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Why climate models often fail to reproduce the Atlantic Meridional Overturning Circulation at the Last Glacial Maximum

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The reproduction of the change of Atlantic Meridional Overturning Circulation (AMOC) by Coupled Atmosphere Ocean General Circulation Models (AOGCMs) is crucial for the future climate projection since it is important for both the global heat transport and the carbon cycle. Information from the paleo-proxy data shows a distinct change of the glacial ocean, i.e. a shoaling of the AMOC originated from the North Atlantic and the mild weakening of the AMOC at LGM. AOGCMs have been applied to the period of Last Glacial Maximum (LGM), and it was shown that the glacial AMOC in AOGCMs is often not well reproduced. Here we show that the improvement of simulating the sea surface temperature (SST) and seaice in the Southern ocean are required for reproducing the paleodata by both multi-model analysis of PMIP/CMIP3 and a series of sensitivity experiment. The sensitivity experiments using MIROC AOGCM show that the AMOC at modern and LGM depend upon the key factors such as the oceanic mixing and the surface heat flux input from the atmosphere due to cloud effect. If there is a warming bias in the modern ocean, the seaice at LGM around Antarctica is not forming enough to reject brine. This leads to an insufficient strengthening of the AABW and a stronger AMOC at LGM in turn, which is the opposite from the observation. A series of additional experiments show that the LGM Northern Hemisphere ice sheets are responsible for strengthening the AMOC. This implies that the result of glacial AMOC depends critically on the subtle balance between the strengthening of the AABW formation caused by the CO_2-induced cooling and the strengthening of AMOC by the growth of the northern hemisphere ice sheets. To reproduce the AMOC through this appropriate balance throughout the climate change, it is crucial to reproduce both the oceanic and atmospheric process near Antarctica in the Southern ocean region.