Bi-stable regime and mode transitions of the Atlantic Meridional Overturning Circulation in the glacial climate

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The Atlantic Meridional Overturning Circulation (AMOC) has an important role in the glacial climate changes. Dansgaard-Oeschger (D-O) oscillations found in the last glacial period are believed to be associated with the mode shifts of the AMOC, but the mechanism behind D-O oscillations is not well understood yet. Thus, studies which focus on the glacial modes of the AMOC are important for understanding glacial climate changes. Here, we conducted numerical experiments to investigate the structure of the modes of the glacial AMOC in comparison with that of the present-day AMOC.
In this study, we first simulated the AMOCs in the present-day and glacial climate with a climate model of intermediate complexity (MIROC-lite) in which model parameters are tuned with the results of a full-coupled general circulation model (MIROC4m). Then we conducted hysteresis experiments in which quasi-steady states of the AMOC under various amount of freshwater flux were obtained by gradually changing amount of freshwater flux at high latitudes in the North Atlantic as external forcing.
The present-day AMOC showed the transition from current “on” mode to “off” mode in which the circulation completely disappears by the freshwater forcing as a result of salinity feedback. As reported in many previous studies, in a certain range of forcing, the AMOC showed multiple equilibrium where both modes are stable. On the other hand, the glacial AMOC showed multiple equilibrium in a very limited range of freshwater forcing. More importantly, “off” mode was not observed in the glacial climate and “weak” mode with the shallow AMOC appeared instead. We found that this “weak” mode become stable in glacial climate due to southward shift of the deep convection region as a result of surface cooling. We also showed that basin-scale salt-advection feedback, which has been regarded as a key process in the transition of the present-day AMOC in previous studies, does not contribute to the AMOC transition in the glacial climate. Instead of salt-advection feedback, it is suggested that mode transition of the glacial AMOC is controlled by interactions with sea ice.

Keywords: glacial climate, AMOC, climate model