氷期の大西洋子午面循環の再現における風応力と熱境界条件の役割
Role of wind stress and surface thermal condition in simulating the glacial Atlantic meridional overturning circulation

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The Atlantic meridional overturning circulation (AMOC), which redistributes heat on a global scale, is deeply associated to the glacial abrupt climate changes. At the Last Glacial Maximum (LGM) about 20,000 years ago, the paleo proxy data suggests that the AMOC was a 'shallower and weaker' circulation than present day. However, as reported in the Paleoclimate Model Inter-comparison Project (PMIP), many numerical simulations using the coupled Atmosphere-Ocean General Circulation Model (AOGCM) reproduced the 'deeper and stronger' AMOC at the LGM, contrary to the proxy data. Prior researches pointed out three factors controling the strength of AMOC in LGM climate: the cooling of the oceans in the Southern hemisphere, cooling in the North Atlantic, and the surface wind stresses in the North Atlantic. However, in the above-mentioned prior researches, the influences of these three factors on AMOC were independently evaluated, thus limiting to the quantitative evaluation of each factor and the combined influences are still largely unknown. Our research emphasizes the quantitative evaluation of combined influences of above- mentioned three factors on the AMOC. For this purpose, various ocean model experiments were conducted; wind stress and thermal boundary conditions taken from PMIP experiments are applied to our ocean general circulation model. In our Anomaly experiments, we succeeded to reproduce strengthening and weakening AMOC for half PMIP model results. Then, we focus the differences of the boundary conditions between the anomaly experiments and several additional experiments were conducted in order to separately investigate the role of the individual boundary conditions for explaining the glacial AMOC response. As a result, it was found that the difference of thermal boundary condition in the southern hemisphere most affects the strength of AMOC. In addition, we found that this cooling in the southern hemisphere is a necessary condition for reproducing the ‘shallower and weaker’ AMOC, but not a sufficient condition. It was also shown that wind stress has some influences on the strength of AMOC, but we could not obtain the information about systematic feature of the wind stress which is important for controlling the strength of AMOC. We show that the results obtained from our anomaly experiments are also helpful for interpreting the original PMIP model results. From these results, it is implied that the stronger glacial AMOC reported in the PMIP models was possibly caused by the insufficient cooling in the southern hemisphere in LGM experiment, and this insufficient cooling possibly comes from warm bias there in the present state experiment and the associated underestimation of ice albedo feedback of sea ice. In this study, through the experiments using boundary condition of PMIP, we can demonstrate the quantitative evaluation of the effect of wind stress and thermal boundary conditions on AMOC and suggest the possible reason why many PMIP models exhibited the strong AMOC in their LGM experiment.

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