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The influence of glacial ice sheet on Atlantic meridional overturning circulation through atmospheric circulation change

SHERRIFF-TADANO, Sam[1*] ; ABE-OUCHI, Ayako[1] ; YOSHIMORI, Masakazu[3] ; OKA, Akira[1] ; CHAN, Wing-le[1]

[1]Atmosphere and Ocean Research Institute, University of Tokyo, [2]Japan Agency for Marine-Earth Science and Technology, [3]Faculty of Environmental Earth Science, Hokkaido University

Several atmosphere-ocean coupled general circulation model (AOGCM) studies suggest that glacial ice sheets exert a large impact on the Atlantic meridional overturning circulation (AMOC). However, the process by which the ice sheets impact on the AMOC is not yet fully understood because of the complicated nature of the AOGCMs. On the other hand, recent oceanographic studies showed that surface wind changes play a crucial role on changes to the AMOC under glacial climate. Therefore, in this study, we investigate in detail, the process by which the ice sheet modifies the AMOC through surface wind change. Moreover, recent modeling study using MIROC AOGCM showed that the effect of the glacial ice sheet on the AMOC depends on the background climate. In their study, they suggested that a strong relation between sea ice coverage and the wind field might play an important role. However, it is still unclear to what extent the sea ice coverage affects the surface wind change induced by the glacial ice sheet. Therefore, we will also explore the effect of the sea ice distribution on the ice sheet induced wind change. Here we conduct numerical experiments using an atmospheric general circulation model (AGCM) and an ocean general circulation model (OGCM) separately. Our method consists of 2 steps. First, from AGCM experiments, we evaluate the effect of glacial ice sheets on the surface wind. Second, from OGCM experiments, we evaluate the influence of the wind stress change on the AMOC by applying the surface wind change as a boundary condition, while leaving other boundary conditions (surface heat and water fluxes) unchanged. In this way, we can evaluate the wind effect of glacial ice sheet on the AMOC. In addition, we conduct several sensitivity experiments. Using the AGCM, we changed the sea ice distribution. Moreover, using the OGCM, we change the surface wind gradually or apply the surface wind change only at a specific region in order to explore the wind change effect in detail.

We find that glacial ice sheets largely intensify the AMOC by surface wind change under glacial climate. Compare to other regions, it reveals that the wind change at the North Atlantic mid-high latitude (NAMH) is a key region. There, the positive wind stress curl enhances, which intensifies the salt and heat transport at NAMH surface through strengthening the gyre circulation and the Ekman upwelling. As a result, the AMOC intensifies. On the other hand, we find that this wind effect of glacial ice sheet strongly depends on the NAMH sea ice cover, as the expansion of sea ice reduces the positive wind stress curl anomaly induced by the glacial ice sheet. This supports the important role of the sea ice coverage on glacial ice sheet effect suggested by the study using MIROC AOGCM.

Keywords: AMOC, surface wind, sea ice, glacial ice sheet