氷期に氷床が大気下層循環変化を通して大西洋子午面循環に与える影響

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Influence of ice sheet on AMOC through lower atmospheric circulation change during glacial climate

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Recently, some studies have revealed that, in glacial period, Atlantic meridional overturning circulation (AMOC) was strongly controlled by the ice sheet and greenhouse gases (Abe-Ouchi et al. in prep; Brady et al. 2013). By comparing the results from a coupled atmosphere and ocean general circulation model (AOGCM) with and without glacial ice sheets, they showed that the ice sheets had large influence on the glacial AMOC. This process is not fully understood, but it may be related to atmospheric circulation change due to the presence of huge ice sheets (Oka et al. 2012; Montoya and Levermann 2008). Some studies have shown that in the Last Glacial Maximum (LGM), the atmospheric circulation differed from that of today mainly due to the presence of the huge ice sheet, especially in the North Atlantic where the AMOC sinks. These atmospheric circulation differences would cause changes in wind stress and therefore may affect AMOC. Thus in this study, we investigate the influence of the ice sheets on glacial AMOC through wind stress. Here we use an atmosphere general circulation model, which is the atmospheric part of MIROC climate model for sensitivity experiments. As ice sheet has two effects (topography effect and albedo effect) on atmospheric circulation, we evaluate each effect separately as well. We conducted 3 experiments. The first experiment, named as NOICE, uses only the modern ice sheet distribution thus does not contain the effect of the glacial ice sheet. Second experiment, which is refferd as FLATICE experiment, contains the flat glacial ice sheet thus includeds the albedo effect of the glacial ice sheet but not the topography effect. For the third experiment, LGM, we added the whole glacial ice sheets. Therefore, from these experiments, we can determine the total effect of glacial ice sheets as LGM-NOICE, the albedo-only effect as FLATICE-NOICE, the topography-only effect as LGM-FLATICE. Hereafter we will focus in the North Atlantic where the AMOC sinks.

In the North Atlantic, consistent with previous studies, the LGM ice sheets, i.e., Laurentide and Fenno-Scandian ice sheets had large impact on the wind stress. Anomalies induced by the ice sheets were a southward wind stress anomaly in Greenland Sea and Baffin Bay, cyclonic anomaly at high latitude, and anti-cyclonic wind stress anomaly at mid and low latitudes. It was found that the topography effect was dominant, though for the eastward wind stress at mid-latitude, albedo effect also played an important role.

Using these wind stress as a boundary condition, we conducted several experiments using an ocean general circulation model to investigate the effect of the wind stress altered by the icesheet on the AMOC. All experiments were conducted under glacial cold condition, which we used surface heat flux of the LGM from the model simulation as Oka et al. (2012). As a result, wind stress without glacial ice sheet showed weaker and shallower AMOC compared to the modern AMOC. For the albedo-only effect, the AMOC intensified, though the interface between the North Atlantic Deep Water and the Atlantic Antarctica Bottom Water had only minor change. On the other hand, for the total glacial ice sheet effect and topography-only effect, this interface significantly deepenedin in addition that the circulation itself is intensified, though the strength of the topography-only effect was weaker than the total glacial ice sheet. These results suggest that the wind stress change due to the ice sheet is crucial to determine the state of the glacial AMOC.