Hydrological change in millennial-scale glacial climate variability and its impact on the Atlantic meridional overturning circulation

*Yuta Kuniyoshi[1], Ayako Abe-Ouchi[1], Wing-Le Chan[1,2], Sam Sherriff-Tadano[1,3]

1. The University of Tokyo, 2. JAMSTEC, 3. University of Leeds

Paleoclimate reconstructions indicate the existence of millennial-scale climate fluctuations, known as Dansgaard-Oeschger (DO) events, with global-scale impacts during the last glacial period. Evidence suggests that DO events are closely related to abrupt changes in the Atlantic meridional overturning circulation (AMOC) and its heat transport. It was originally suggested that the abrupt changes in the AMOC are induced by external freshwater forcing. However, centennial to millennial-scale oscillations driven by internal feedbacks have recently been simulated in several coupled atmosphere-ocean models. In such a self-sustained oscillatory framework, several mechanisms have been proposed such as a salt oscillator in the North Atlantic surface layer and a thermohaline oscillator which involves sea ice change and subsurface temperature change in the North Atlantic. On the former oscillator, it has been pointed out that the hydrological change in the tropical North Atlantic play an important role by changing surface salinity, but it is not clear whether changes in the hydrological change are response to the oscillations of the AMOC or act as a cause of the oscillations. Here, using the climate model, MIROC4m, we investigate the effects of changes in the hydrological cycle on the millennial-scale oscillations. For this purpose, we conducted a full-coupled atmosphere-ocean experiment under glacial condition (control experiment) and sensitivity experiments in which precipitation and evaporation flux passed to the ocean surface are replaced with a time-invariant freshwater flux over several specific regions. The control experiment shows self-sustained oscillation with a period of about 1,500 years. One cycle of oscillations consists of a weak AMOC phase (stadial; cold and dry period in the Northern Hemisphere(NH)), a rapid AMOC recovery (abrupt warming and wetting in the NH), a strong AMOC phase (interstadial; warm and wet period in the NH), and a rapid weakening of the AMOC (abrupt cooling and drying in the NH). At the same time, the Southern Hemisphere experiences gradual cooling and drying during the interstadial and gradual warming and wetting during the stadial. Sensitivity experiments also result in the oscillations of the AMOC as in the control experiment, although the periodicity was modulated. This result indicates that the millennial-scale oscillations of the AMOC can be driven without the involvement of the hydrological changes. In addition, all experiments show changes in the North Atlantic sea ice extent and subsurface water temperature, which suggest the importance of the thermal component in driving the oscillation of the AMOC.

Keywords: Glacial-Interglacial cycle, Dansgaard-Oeschger events, Climate model

