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Dynamical Ice Sheet-Climate System Response to Astronomical Forcing

Ayako Abe-Ouchi
Atmosphere and Ocean Research Institute (AORI), The University of Tokyo, Japan (abeouchi@aori.u-tokyo.ac.jp)

Paleoclimate modelling using simple models, EMICs (Earth System Models of Intermediate Complexity) and GCMs (General Circulation Models) combined with ice sheet models has become a powerful tool for understanding how the long-term climate system with ice sheets responds to external forcings such as Milankovitch forcing. With the aid of supercomputers and advances in climate model development, it is now possible to perform a much larger number of snapshot experiments with fixed forcings as well as transient experiments with evolving forcings. This talk will review the models that simulate the Northern Hemisphere ice sheet change and climate during the ice age cycles and discuss upcoming challenges. The talk will also present recent works on simulating millennial scale climate changes and the link with the ice age cycle. The last termination of the ice age cycles as well as glacial periods were punctuated by abrupt millennial scale climate changes, such as the Bølling-Allerød interstadial, the Younger Dryas and Dansgaard-Oeschger events. Abrupt climate changes have been shown to be strongly linked to changes in the Atlantic Meridional Overturning Circulation (AMOC) and the shift between the (quasi) multiple equilibria of AMOC, but the mechanism behind these abrupt changes and the link to climate change in the orbital scale are not clear. Modelling the stability of AMOC under different climate conditions together with deglacial climate change using fully coupled ocean-atmosphere GCMs has been challenging. Here we present a series of long transient experiments of at least 10,000 years with forcings under different ice sheet sizes, greenhouse gas levels and orbital parameters, as well as deglacial experiments following PMIP4 protocols, using a coupled ocean-atmosphere model, MIROC4m AOGCM. When forcing under glacial condition is applied, even without freshwater perturbation, the climate-ocean system shows self-sustained oscillations within a “sweet spot.” We also see a bipolar seesaw pattern and switching between interstadials and stadials, whose return time ranges from 1,000 years to nearly 10,000 years depending on the background forcing during the ice age cycle. Our transient deglaciation experiment with a gradually changing insolation, greenhouse gas forcing and ice sheet with meltwater from the glacial period to the Holocene is analysed and compared with proxy data as well as with the series of experiments with self-sustained oscillations for a better interpretation. Implications on the role of abrupt climate changes in shaping the longer-term global ice age cycle are further discussed.