Toward understanding the climate change in the Pleistocene: Reproduction of the dominant 40-kyr periodicity in the early Pleistocene using an ice-sheet model

*Yasuto Watanabe[1], Ayako Abe-Ouchi[1], Fuyuki SAITO[2]

1. The University of Tokyo, 2. JAMSTEC

The climate change in the Pleistocene is characterized by glacial-interglacial cycles that have a dominant periodicity at tens of thousands of years. Milankovitch theory suggests that variation of Earth’s orbital parameters changes the way the sunlight enters the Earth and the northern hemisphere high-latitude summer insolation that have a dominant periodicity at 20-kyr causes the glacial-interglacial cycles. In contrast to this periodicity, however, the dominant periodicity of the climate change in the early Pleistocene was 40-kyr. Various hypotheses are proposed but it has not yet been fully understood. One reason is that the 40-kyr cycles have not been reproduced using a realistic 3-D model with realistic input. Our aim is to reproduce the 40-kyr cycles using a 3-D ice-sheet model with realistic input and to reveal the role of each orbital paramerer by comparing the result with records of proxy. We used an ice-sheet model for Integrated Earth system Studies (IcIES; Abe-Ouchi et al., 2013), coupled with climate parameterization according to the results of a global climate model MIROC. The input is variability of insolation and atmospheric CO_2 concentration and the output is time evolution of ice-sheet distribution over the northern hemisphere.
We conducted experiments for two 40-kyr cycles. One is from MIS-49 to 47 and the other is MIS-45 to 43. These cycles are chosen as a representative of 40-kyr cycles that has a long and stable interglacial and that has a relatively short interglacial and long glacial respectively.
As a result, 40-kyr cycles are reproduced and the shape of the variation is similar to the proxy record. This is because the surface temperature exceeds a threshold that the North American ice-sheet starts deglaciating once in a 40-kyr cycle. Phase analysis of this result suggests that the difference in the shape of these cycles is explained by lead-lag relationship between obliquity and precession. For a long interglacial period, the peak of climatic precession precedes that of obliquity, and vice versa for a short interglacial period.
In summary, climatic precession decides a timing of a deglaciation because of the large influence on insolation and obliquity has a role as a pacemaker of 40-kyr cycles because of an existence of a threshold of an ice-sheet deglaciation. These are the role of the orbital parameters in the early Pleistocene.
We would also analyse several sensitivity experiments under different basal conditions, and those coupled with the temperature anomaly calculated by using atmosphere-ocean-vegetation GCM MIROC-LPJ (O’ishi and Abe-Ouchi, 2011).

Keywords: Pleistocene, glacial-interglacial cycles

