A Coupled Climate Model Simulation of the Last Glacial Maximum, Transient Multi-decadal Response

Seong-Joong Kim, Bang Yong Lee
Korea Polar Research Institute, KORDI

1. Introduction

Considerable effort has been devoted to the reconstruction of LGM climatic conditions based on geological proxy data (e.g., CLIMAP, 1976, 1981). However, each has limitations in revealing the features and factors involved in such a severe event. As an adjunct to the study of proxy data, researchers have employed numerical models to study the LGM climate. The objective of this study is to investigate the transient climate response to LGM conditions using the coupled atmosphere-ocean-sea ice model developed at Canadian Centre for Climate Modelling and Analysis (CCCma).

2. Model description and experiments

The model used in the current study is the second generation CCCma coupled general circulation model (CGCM2). The atmospheric component of CGCM2 has T32 horizontal resolution, which is 3.75° x 3.75° in gaussian grids, and 10 vertical levels. The oceanic component is based on the GFDL MOM version 1.1 with a horizontal resolution of 1.875° x 1.875° and 29 vertical layers. The sea ice model includes a representation of ice dynamics and thermodynamics. Monthly heat and freshwater flux adjustment fields are applied in all experiments. A detailed description of the atmosphere, ocean, sea ice, and land surface components of CGCM2 is given in other papers (Kim et al., 2003 and references therein).

Two experiments are analyzed. The control experiment (CTR) has a specified CO_2 concentration of 330 ppm, and a contemporary land mask and topography. The second experiment involves conditions representative of the LGM but, because we analyze only the initial transient evolution toward an LGM climate, we refer to this experiment as TRN. The imposed LGM conditions are the land mask, which is modified to account for the lower sea level (approximately 120 m), and LGM ice sheet topography. The CO_2 concentration of the atmosphere is reduced to 235 ppm from the 330 ppm which is used in our control integration. Orbital parameters and vegetation are unchanged.

3. Simulated climate

Upon imposition of LGM conditions, the initial response is a rapid decrease in global mean surface air and ocean temperatures of roughly 5°C and 3°C. However, air temperatures over much of the

Southern Ocean and portions of the northern North Atlantic actually increase by up to 10°C. This transient warming is driven by more vigorous oceanic convection that brings heat from the deep ocean to the surface. In the Southern Ocean, this warming leads to an almost complete disappearance of sea ice which further enhances warming via the ice-albedo feedback. Over these regions of anomalous warming the latent and sensible heat flux to the atmosphere increases markedly, resulting in the deep ocean heat loss to the atmosphere and cooling with time.

Precipitation and evaporation decrease on average, although evaporation increases over the Southern Ocean associated with the anomalous transient warming. The changes in precipitation and evaporation are not uniform, leading to substantial increases of river runoff draining into the Atlantic, but decreases into the Arctic. This ultimately affects the sea-surface salinity, with a decrease in the Atlantic of 1-2 psu, and increase in the Arctic Ocean of more than 3 psu.

In response to the LGM perturbation, the ocean circulation initially becomes more vigorous with the increase in the modelled Gulf Stream and the Kuroshio Current. The Antarctic Circumpolar Current transport increases by about 75% in the Drake Passage. The North Atlantic subpolar gyre increases from 10 to 30 Sv, and the Indonesian throughflow increases by 80%. The North Atlantic and Southern Ocean overturning stream function markedly increases from 12 to 36 Sv and from 2 to 26 Sv, respectively, as a consequence of the enhanced oceanic convection.

4. Conclusion

In conclusion, the climate response to LGM boundary conditions notably different from that of the associated mixed layer ocean version of the model (Joussaume and Taylor, 2000). The most notable oceanic feedbacks to LGM forcing captured in the coupled model are the features associated with the vigorous ocean convection including the anomalously warm surface temperature in the Southern Ocean and the northern North Atlantic.

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References

CLIMAP, 1976: The surface of the Ice-Age Earth. *Science*, **191**, 1131-1136

CLIMAP, 1981: Seasonal reconstructions of the Earth's surface at the last glacial maximum. Geol Soc Amer Map Chart Ser, MC-36

Joussaume, S., K. E. Taylor, 2000: The paleoclimate modeling intercomparison project (PIMIP). Proceedings of the third PIMIP Workshop, Braconnot P (ed), Canada, pp 9-24

Kim, S.-J., G. M. Flato,, G. J. Boer, 2003: A coupled climate model simulation of the Last Glacial Maximum, Part 2: approach to equilibrium. *Climate Dynamics*, **20**, 635-661