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THE GLOBAL HYDROLOGICAL AND ENERGY CYCLES AT LAST GLACIAL MAXIMUM IN CCSM3

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1. INTRODUCTION

Last Glacial Maximum (LGM), defined as the climate at 21ka (21000 years BP), was the peak of the last glacial period, when large inland ice sheets reached their maximum extent. Two of the largest ice sheets during LGM were in the Northern Hemisphere, the Laurentide Ice Sheet (located over North America) and the Fennoscandian Ice Sheet (over Northern Europe). This work focuses on a comparison between Last Glacial Maximum and Pre-industrial (PI), which is the climate before industrialization at 1800 A.D. (Otto-Bliesner et al. 2006).

Clouds are important within the climate system in part because they reflect solar radiation and contribute to the greenhouse effect. A cloud feedback occurs due to changes in these cloud effects. Cloud feedbacks can arise from changes in the cloud amount, top height, and cloud optical properties. Further discussion of cloud and other radiative feedbacks can be found in Bony et al. (2006).

Changes to climate during an ice age or global warming affect the distribution of clouds. The resulting cloud feedbacks can either amplify or damp changes in the globally averaged surface temperature.

In this study, we examine the cloud feedbacks that affect the differences between the LGM and PI climates as simulated by a climate model.

2. DATA AND METHODS

The Community Climate System Model Version 3 (CCSM3), developed at the National Center for Atmospheric Research (NCAR), is a coupled global climate model that simulates the atmosphere, ocean, sea ice, and land surface interactions. The component models of CCSM3 are linked through a coupler in which fluxes and state information are exchanged. A full model description of CCSM3 can be found in Collins et al. (2006).

Two paleoclimate simulations were used in this study to analyze the Last Glacial Maximum and Pre-industrial. The Pre-industrial and Last Glacial Maximum simulations both ran for 400 years. We show results based on the last 100 years of each simulation.

3. RESULTS

There is a well-known relationship between the globally averaged rate of atmospheric radiative cooling and the global-mean precipitation rate. Figure 1 shows that there is greater cooling at Last Glacial Maximum than Pre-industrial. This is expected in part because in a cooler climate there is less water vapor in the air. The reduced global-mean radiative cooling results in a decrease of global-mean precipitation, which can be seen in figure 1. A question that arises is how much of the change in the total atmospheric radiative cooling is due to changes in the radiative effects of clouds.

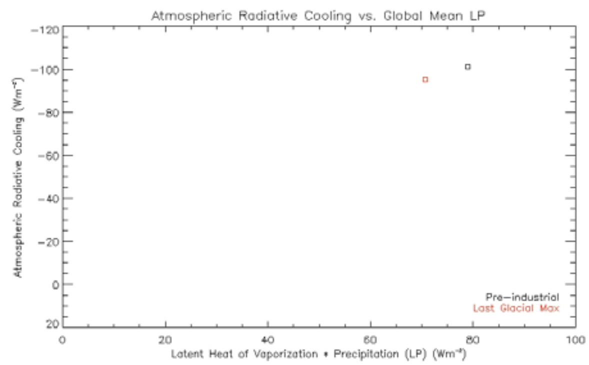

Figure 1. The atmospheric radiative cooling relationship with precipitation as computed from CCSM3 for Pre-industrial (black) and Last Glacial Maximum (red).

Figure 2 shows the cloud radiative effects (left) at the top of the model (TOM), surface (SFC) and of the atmosphere (Atmos) for LGM minus PI. The cloud radiative effects at the TOM were computed by subtracting the all-sky minus clear-sky SW at the TOM from the all-sky minus clear-sky LW at the TOM. Similar computations were done for the surface and the atmosphere.

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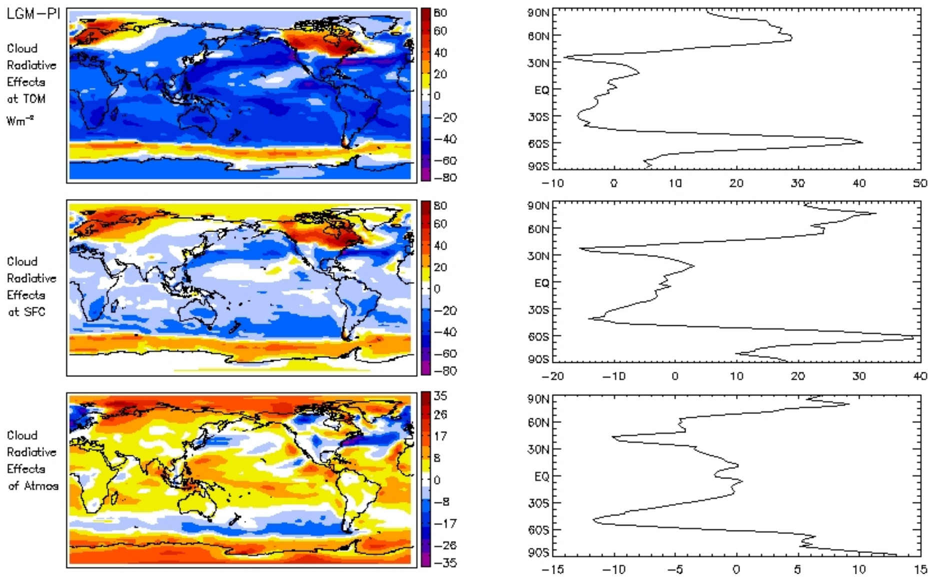

Figure 2. Cloud radiative effects for Last Glacial Maximum minus Pre-Industrial in Wm^{-2} for the top of the model, surface, and atmosphere.

The cloud radiative effects at the top of the model and surface indicate the location of the Laurentide and Fennoscandian Ice Sheets, which are seen through their effects on the shortwave radiation. A bright cloud over a dark surface produces a greater cooling at the surface than would occur due to a bright cloud over a light surface. Because of this, the cloud feedback is interconnected with the positive surface albedo feedback.

For the atmosphere, cloud feedbacks produce 2.85 Wm^{-2} more atmospheric radiative cooling at LGM relative to PI. The strongest additional cooling is found in the Atlantic and Pacific storm tracks, where there is less precipitation at LGM.

From Figs. 1 and 2 together, we conclude that cloud feedbacks tend to reduce the changes in the speed of the hydrologic cycle between PI and LGM.

4. FUTURE WORK

Additional goals of this study are to compare the global hydrological and energy cycles for PI and LGM, and to further analyze the radiative feedbacks that are related to the hydrological and energy cycles (i.e. cloud, surface albedo, water vapor, and lapse rate feedbacks). This will be discussed elsewhere.

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REFERENCES

Bony, S., R. Colman, V.M. Kattsov, R.P. Allan, C.S. Bretherton, J.-L. Dufresne, A. Hall, S. Hallegatte, M.M. Holland, W. Ingram, D.A. Randall, D.J. Soden, G. Tselioudis, and M.J. Webb, 2006: How well do we understand and evaluate climate change feedback processes? *J. Climate*, **19**, 3445-3482.

Collins, W.D., C.M. Bitz, M.L. Blackmon, G.B. Bonan, C.S. Bretherton, J.A. Carton, P. Chang, S.C. Doney, J.J. Hack, T.B. Henderson, J.T. Kiehl, W.G. Large, D.S. McKenna, B.D. Santer, and R.D. Smith, 2006: The community climate system model version 3 (CCSM3*). J. Climate*, **19**, 2122–2143.

Otto-Bliesner, B.L., E. Brady, G. Clauzet, R. Tomas, S. Levis, and Z. Kothavala, 2006: Last glacial maximum and holocene climate in CCSM3. *J. Climate*, **19**, 2526-2544.