Glacial Ocean Circulation and Property Changes in the North Pacific

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Abstract: The glacial property and circulation changes in the North Pacific Ocean are investigated using a coupled ocean-atmosphere-sea ice climate model. With glacial boundary conditions, an increase in potential density in upper layers of the northern North Pacific makes the water column highly unstable and eventually results in the enhancement of the North Pacific Intermediate Water (NPIW) production, in consistent with proxy evidence. The NPIW outflow reaches deeper layers than in present, but largely confined to the North Pacific. The increase in potential density is predominantly due to the increase in salinity and secondarily decreases in temperature. The increase in surface salinity is especially high in the Sea of Okhotsk and the western Bering Sea, which are the possible source areas of the glacial NPIW production. In these regions, an increase in brine release due to the marked increase in sea ice, the excessive evaporation over precipitation, and the reduction in river discharge contribute to the increase in surface salinity. In short, reduction in freshwater input to the northern North Pacific is mainly responsible for the increase in the production and outflow of glacial NPIW.

Introduction

- North Pacific Intermediate Water (NPIW) is characterized by a salinity minimum at 500-700 m with relatively narrow density range from 26.7 to 26.9 kg m^{-3}.
- Some lines of geological and geochemical evidence have suggested that during glacial time the NPIW production was larger and deeper (*Boyle*, 1997).
- In this study, the glacial ocean circulation and property changes of the intermediate or deep water masses in the North Pacific are examined using a coupled model.

Model

- Version: CCCma CGCM2 (*Flato and Boer,* 2001)
- H-Resolution: T32 (3.75 degree) for atmosphere and 1.875 degree for ocean
- V-Resolution: 10 levels in atmosphere, 29 levels in ocean
- Sea ice thermodynamics and dynamics
- Interactive cloud parameterization, GM mixing scheme, vegetation

Experiments

Control Experiment

- CO_2: 330 ppm
- Present land mask
- Present topography
- Present orbital parameters
- Present vegetation

Glacial Experiment

- CO_2: 235 ppm
- LGM land mask
- LGM topography
- Present orbital parameters
- Present vegetation

Results

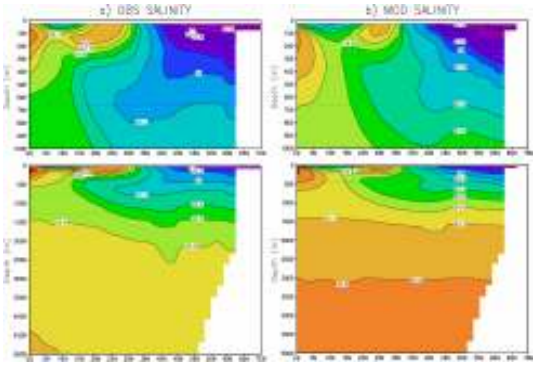

Fig. 1 Annual-mean meridional sections of salinity zonally averaged over the Pacific for the a) observed and b) simulated in the control. Observed data are from *Levitus et al.* (1994).

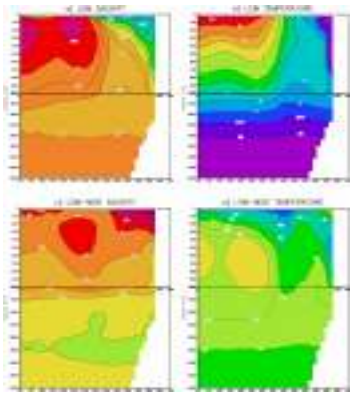

Fig. 2 Zonally averaged annual-mean meridional sections over the Pacific for a) salinity and b) potential temperature simulated in the glacial experiment, and the change between the glacial and control for c) salinity and d) potential temperature.

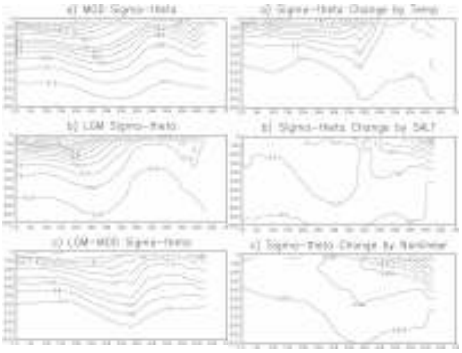

Fig. 3 Annual-mean meridional sections of zonally averaged over the Pacific of the potential density for the a) control and b) glacial, and c) the change. (kg m^{-3})

Fig. 4 Annual-mean meridional sections zonally averaged over the pacific for the potential density change due to a) temperature, b) salinity, and c) nonlinear term.

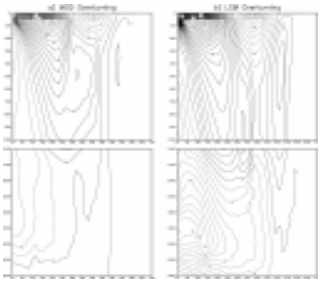

Fig. 5 Annual-mean meridional stream function for the North Pacific domain simulated in the a) control and b) glacial. (Sv=106 m^3 s^{-1}).

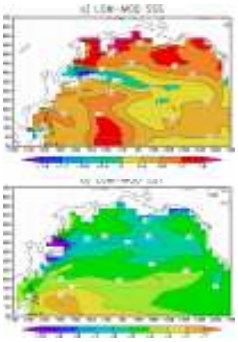

Fig. 6 The change in annual-mean a) sea surface salinity (SSS) and b) sea surface temperature (SST) in the North Pacific.

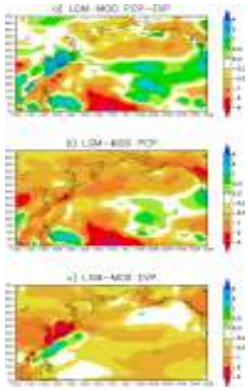

Fig. 7 The change in annual-mean a) precipitation minus evaporation b) precipitation, c) evaporation. (mm/day)

Summary

- With glacial boundary conditions, salinity in upper layers of the North Pacific markedly increases, while potential temperature decreases.
- The increase in salinity and decrease in temperature leads to the increase in potential density, reducing the stability of the upper water column in the northern North Pacific.
- The weaker glacial water column instability leads to the increase in overturning circulation in the North Pacific. In the glacial, the NPIW production increases to 3 Sv and reaches deep layers more than 2,000 m and its outflow propagates close to the Equator.

References

- Boyle, E. A., Characteristics of the deep ocean carbon system during the past 150,000 years: ΣCO_2 distribution, deep water flow patterns, and abrupt climate change. *Proc. Natl. Acad. Sci. USA*, 94, 8300-8307, 1997.
- Flato, G. M., and G. J. Boer, Warming asymmetry in climate change simulations. *Geophys. Res. Lett.*, 28, 195-198, 2001.
- Levitus, S., R. Burgett, and T. P. Boyer, World ocean atlas 1994 vol 3: salinity. *NOAA Atlas NESIDIS 3*, US Department of Commerce, 99 pp, 1994.