Role of Southern Ocean in glacial atmospheric CO2 reduction

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Atmospheric carbon dioxide concentration ($pCO2^{atm}$) during glacial periods is known to be considerably lower than during interglacial periods. However, previous studies using an ocean general circulation model (OGCM) fail to reproduce this. Therefore, the detailed mechanism is still unclear.
Paleoclimate proxy data of the Last Glacial Maximum indicate high salinity and long water mass residence time in the deep Southern Ocean, suggesting that salinity stratification was enhanced and more carbon was stored there. The Southern Ocean has been recognized as a key region for carbon uptake during glacial periods. Here, we conducted numerical experiments using an OGCM to investigate the role of the Southern Ocean process in the variation of $pCO2^{atm}$; we evaluate the glacial response of ocean carbon cycles under the high salinity and long water mass age in the glacial Southern Ocean. We found that deep water formation in East Antarctica is required to explain high salinity in the South Atlantic. Contrary to previous estimates, saltier deep Southern Ocean resulted in increased $pCO2^{atm}$. This is because Antarctic Bottom Water flow increased and residence time of carbon decreased in the deep Pacific Ocean. On the other hand, weakening of vertical mixing contributed to the increase of the vertical gradient of dissolved inorganic carbon and decrease of $pCO2^{atm}$. However, we show that it is unable to explain the full magnitude of recorded reduction of glacial $pCO2^{atm}$ in our simulations which include the above-mentioned contribution of the Southern Ocean process in addition to SST and SSS changes, ocean circulation changes, and iron fertilization changes [*Kobayashi et al.*, 2015].
Carbonate compensation process acts to keep whole ocean alkalinity over the millennium timescale and affects the long-term variation of carbon cycle. Previous studies reported that it amplifies the variation of glacial-interglacial ocean carbon cycle. Our previous experiments assumed that particles such as particulate organic matter and calcium carbonate dissolved immediately when they reached ocean floor; therefore, the $pCO2^{atm}$ variation arises from carbonate compensation process was not included. As a next step, by using an OGCM coupled with a sediment model, we try to explicitly evaluate the role of carbonate compensation process. In the speech, we hope to report the results of numerical experiments performed by the newly developed sediment model.

Keywords: carbon cycle, glacial/interglacial, Southern Ocean, meridional overturning circulation , sediment model

