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Role of Southern Ocean stratification in glacial atmospheric CO2 reduction evaluated by a three-dimensional OGCM

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Atmospheric carbon dioxide (CO_2) concentration 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. Paleoclimate proxy data of the Last Glacial Maximum indicate high salinity (>37.0 psu) and long water mass residence time (>3,000 years) in the Southern Ocean, suggesting that salinity stratification was enhanced and more carbon was stored there. The reproducibility of salinity and water mass age is considered insufficient in previous OGCMs simulations, which might affect the reproducibility of atmospheric CO_2 concentration. This study investigated the role of enhanced stratification in the Southern Ocean in the variation of atmospheric CO_2concentration using an OGCM. 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 atmospheric CO_2 concentration. 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 atmospheric CO_2concentration by up to 18 ppmv. However, we show that it is unable to explain the full magnitude of recorded reduction of glacial atmospheric CO_2 concentration by the contribution of the Southern Ocean. Our findings indicate that detailed understanding of the impact of enhanced stratification in the Southern Ocean on the Pacific Ocean might be crucial to understanding the mechanisms behind the variations of the glacial-interglacial ocean carbon cycle.

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