Simulations of glacial ocean carbon cycle with parameterizations of brine rejection process and stratification-dependent vertical diffusivity

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Paleo-ocean reconstructions supporting the Southern Ocean hypothesis, in which carbon storage in the deep Southern Ocean increases during the glacial ages, has not been sufficiently reproduced by previous paleoclimate modeling studies. In this study, we apply parameterizations of brine rejection process during sea ice production and stratification-dependent vertical diffusivity to an ocean general circulation model and attempt to reproduce oceanic properties reconstructed from paleo-ocean proxy data at the Last Glacial Maximum (LGM). An LGM simulation including the parameterization of brine rejection expresses high bottom-water salinity associated with larger sea ice production at the LGM, and reproduces the reconstructed salinity distribution. Moreover, by considering the stratification dependence of vertical diffusivity in the global ocean, the increase in water mass ages due to the reduced vertical mixing in the glacial Southern Ocean increases water mass ages in the entire deep ocean. As a result, more carbon is stored in the deep ocean and the vertical gradient of carbon enlarges. This redistribution of carbon reduces atmospheric carbon dioxide concentration (pCO_2). In addition, subsequent response of carbonate compensation amplifies the glacial reduction of atmospheric pCO_2. By introducing these two parameterizations, the LGM simulation successfully reproduces the glacial ocean state assumed in the Southern Ocean hypothesis. As a consequence, the simulated glacial reduction of atmospheric pCO_2 finally gets close to 100 ppm.

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