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Weak Atlantic Meridional Overturning Circulation and Enhanced Iron Fertilization Maximize Glacial Ocean Carbon Storage

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Circulation changes have been suggested to play an important role in the sequestration of atmospheric CO_2 in the glacial ocean. However, previous studies have resulted in contradictory results regarding the strength of the Atlantic Meridional Overturning Circulation (AMOC) and three-dimensional, quantitative reconstructions of the glacial ocean constrained by multiple proxies remain scarce. Here we simulate the modern and glacial ocean using a global, physical-biogeochemical, three-dimensional model constrained simultaneously by δ^{13}C, radiocarbon, and δ^{15}N to explore the effects of AMOC differences and Southern Ocean iron fertilization on the distributions of these isotopes and ocean carbon storage. We show that δ^{13}C and radiocarbon data sparsely sampled at the locations of existing glacial sediment cores can be used to reconstruct the modern AMOC accurately. Applying this method to the glacial ocean we find that a surprisingly weak (6-9 Sv or about half of today's) and shallow AMOC maximizes carbon storage and best reproduces the sediment isotope data. Increasing the atmospheric soluble iron flux in the model's Southern Ocean intensifies export production, carbon storage, and further improves agreement with δ^{13}C and δ^{15}N reconstructions. Our best fitting model, which explains most of the decrease in glacial atmospheric CO_2, is a significant improvement compared with previous studies, and suggests that both circulation changes and iron fertilization were necessary to enhance glacial ocean carbon storage.