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Southern control of interhemispheric synergy on marine carbon sequestration during glacial cycles

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The mechanisms of atmospheric CO2 draw-down by ~90 ppm during glacial cycles have been one of the most contentious questions in the past several decades. Processes in the Southern Ocean (SO) have been suggested to be at the heart, while the North Atlantic (NA) is recently proposed to be critical during glacial periods as well. However, in a full course of glacial cycles, the individual and synergic roles of these two regions remain enigmatic. Using a state-of-the-art biogeochemical model (MITgcm-REcoM2) associated with an interactive CO_2 module, we examined the impact of the onset of individual mechanisms and combinations of them on atmospheric CO_2. Here we show that SO controls carbon sequestration in both hemispheres. In sensitivity runs with respect to mechanisms happening during glacial inceptions, cooling in SO contributes to a larger portion of CO_2 draw-down than cooling in NA, by shortening the surface water exposure time, while the early sea ice expansion tends to weaken the carbon uptake. The efficiency of surface carbon storage in the North Atlantic depends on the volume of Antarctic bottom water and reaches its maximum when the glacial stratification is well developed during glacial maxima. SO cooling and sea ice expansion strongly promote the formation of AABW and the full development of the glacial stratification. Furthermore, increased dust deposition during the glacial maxima raises the contribution of the Southern Ocean in the global biological carbon pump, leading to a higher efficiency of the biological carbon pump. And the maximal expanded sea ice suppresses local carbon leakage.