Sea-ice control on glacial-interglacial circulation changes, deep ocean ventilation and carbon storage

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Paleoceanographic reconstructions indicate that the Atlantic Meridional Overturning Circulation (AMOC) was likely shallower at the Last Glacial Maximum (LGM, ~20,000 years ago) and that the volume occupied by Antarctic Bottom Water (AABW) was larger than today. Ocean-sea-ice simulations forced by atmospheric cooling, show that this circulation change is driven by the resulting Antarctic sea-ice expansion. At the LGM, stronger sea-ice formation/export enhances buoyancy loss rates via brine rejection, increasing stratification and causing the AMOC shoaling.

Such glacial-interglacial rearrangements in water masses distribution, lead to reduced deep ocean ventilation and increased atmospheric carbon sequestration at the LGM. The abyssal cell and AABW become more isolated from the surface as a result of two connected factors: 1) weaker mixing with North Atlantic waters due to a shallower cell interface and 2) abyssal waters reaching the surface only under sea ice around Antarctica, where air-sea gas exchange is strongly reduced. These physical changes alone are sufficient to explain about half of the glacial atmospheric pCO_2 drawdown (80-90 ppm). Increasing biological activity, which simulates the stronger glacial dust fluxes, further enhances carbon storage in the deep ocean.