The role of sea ice and buoyancy fluxes in shaping glacial and modern overturning circulation

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Sea ice represents a key control on air-sea fluxes and deep-water formation at high latitudes. The resulting brine rejection in the Southern Ocean plays an important role in Antarctic Bottom Water production, shaping the abyssal branch of the global Meridional Overturning Circulation (MOC) and stratification in all ocean basins.

Changes in Antarctic sea ice are thought to have driven the major rearrangements undergone by the MOC between glacial and interglacial climates, also associated with the atmospheric carbon dioxide swings observed in the paleoclimate record. However, the lack of a quantitative understanding of the physical mechanisms leading to the inferred glacial-interglacial reorganization in water masses distribution, challenges our understanding of past and present climate and inevitably shakes our confidence in future projections.

In idealized ocean-only simulations for the Last Glacial Maximum (LGM, ~20 kyrs ago), increased sea ice expansion and buoyancy loss around Antarctica lead to enhanced deep ocean stratification. This results in a weakening and shoaling of the inter-hemispheric overturning circulation, which is consistent with proxy evidence for the LGM. By contrast, fully-coupled climate simulations from the CMIP5/PMIP3 archive exhibit substantial discrepancies in their representation of the glacial MOC, both between different models and with proxy reconstructions. Such inconsistencies may cast some doubts on the reliability of these models, which are also used to simulate future climate scenarios. These differences in LGM deep ocean circulation are shown to be related to the representation of Antarctic sea ice in different models and amplified by the short integration time of most simulations. For instance, the deepening of the Atlantic MOC found in several LGM simulations, in striking disagreement with the proxy archive, is argued to be a transient artefact.