Dynamical controls on the production of bottom and deep waters in the Last Glacial Maximum Atlantic

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Proxy measurements of ocean tracers at the Last Glacial Maximum (LGM, ca. 23-19 ka) suggest that the western Atlantic Ocean was filled dominantly by Antarctic Bottom Water (AABW), with a lesser role for North Atlantic Deep Water (NADW) relative to the modern. Proposed explanations for a shoaled NADW-AABW boundary include changes in the strength and/or structure of the Atlantic meridional overturning circulation (AMOC), possibly driven by some combination of changes in surface buoyancy forcing, wind stress, and abyssal mixing. Given the complexity of the AMOC – which is incompletely understood in the modern ocean, let alone in the geologic past – it remains unclear which (if any) process is most important for changing the watermass geometry of the glacial Atlantic. Improving our knowledge of these dynamics is important for our understanding of the climate system, as increased reservoirs of AABW could contribute to reduced atmospheric concentrations of carbon dioxide during glacial periods.

This work uses the adjoint capability of the MITgcm ocean model to infer "ideal perturbations" by which changes in wind stress, surface air temperature, and precipitation can increase the presence of AABW in the western Atlantic. Integrating the model forward under these perturbations illustrates dynamical pathways by which the boundary between deep and bottom waters may be deepened or shoaled. Changes in winds, temperature, and precipitation derived to increase AABW all increase surface density in the Southern Ocean poleward of the isopycnal dividing upper and lower overturning cells, with an important mediating role for Southern Ocean sea ice. Increased AABW is accompanied by decreased strength and vertical extent in the upper AMOC cell and increased strength and extent in the lower cell. We explore the global consequences of shoaling AABW in the Atlantic and discuss the likelihood of different mechanisms for LGM watermass geometry changes in light of hypothesized glacial-interglacial changes in the atmospheric state.