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Attenuated carbon sequestration by Weddell Sea dense waters over the 21st century – an assessment with FESOM-REcoM

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Deep and bottom water formation regions have long been recognized to be efficient vectors for carbon transfer to depth, leading to carbon sequestration on time scales of centuries or more. Precursors of Antarctic Bottom Water (AABW) are formed on the Weddell Sea continental shelf as a consequence of buoyancy loss of surface waters at the ice-ocean or atmosphere-ocean interface, which suggests that any change in water mass transformation rates in this area affects global carbon cycling and hence climate. Many of the models previously used to assess AABW formation in present and future climates contained only crude representations of ocean-ice shelf interaction. Numerical simulations often featured spurious deep convection in the open ocean, and changes in carbon sequestration have not yet been assessed at all. Here, we present results from the global model FESOM-REcoM, which was run on a mesh with elevated grid resolution in the Weddell Sea and which includes an explicit representation of sea ice and ice shelves. Forcing this model with ssp585 scenario output from the AWI Climate Model, we assess changes over the 21st century in the formation and northward export of dense waters and the associated carbon fluxes within and out of the Weddell Sea. We find that the northward transport of dense deep waters (σ_2>37.2 kg m^{-3} below 2000 m) across the SR4 transect, which connects the tip of the Antarctic Peninsula with the eastern Weddell Sea, declines from 4 Sv to 2.9 Sv by the year 2100. Concurrently, despite the simulated continuous increase in surface ocean CO_2 uptake in the Weddell Sea over the 21st century, the carbon transported northward with dense deep waters declines from 3.5 Pg C yr^{-1} to 2.5 Pg C yr^{-1}, demonstrating the dominant role of dense water formation rates for carbon sequestration. Using the water mass transformation framework, we find that south of SR4, the formation of downwelling dense waters declines from 3.5 Sv in the 1990s to 1.6 Sv in the 2090s, a direct result of the 18% lower sea-ice formation in the area, the increased presence of modified Warm Deep Water on the continental shelf, and 50% higher ice shelf basal melt rates. Given that the reduced formation of downwelling water masses additionally occurs at lighter densities in FESOM-REcoM in the 2090s, this will directly impact the depth at which any additional oceanic carbon uptake is stored, with consequences for long-term carbon sequestration.