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The Late Pliocene Atlantic Meridional Overturning Circulation and State of the Arctic Gateways

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Reconstructions of the late Pliocene (mid-Piacenzian, ∼3.3 – 3.0 million years ago) sea surface temperature (SST) find much warmer conditions in the North Atlantic than modern. The much warmer SSTs, up to 8.8˚C from sites with good dating and replicates from several different types of proxies, have been difficult for climate models to reproduce. Even with the slow feedbacks of a reduced Greenland ice sheet and expansion of boreal forests to the Arctic Ocean over Canada and Eurasia, models cannot warm the North Atlantic sufficiently to match the reconstructed SSTs. An enhancement of the Atlantic Meridional Overturning Circulation (AMOC) during the late Pliocene, proposed as a possible mechanism based on ocean core records of δ^{13}C, also is not present in the model simulations.

Here, we present Community Earth System Model (CESM) simulations using a new reconstruction of late Pliocene paleogeography that has the Bering Strait (BS) and Canadian Arctic Archipelago (CAA) Straits closed. We find that the closure of these small Arctic gateways strengthens the AMOC, by inhibiting freshwater (FW) transport from the Pacific to the Arctic Ocean and from the Arctic Ocean to the Labrador Sea, leading to warmer sea surface temperatures in the North Atlantic. The cutoff of the short export route through the CAA results in a more saline Labrador and south Greenland Sea with increased deep convection. At the same time, as all FW now leaves the Arctic east of Greenland, there is a freshening of and decreased deepwater formation in the Norwegian Sea. Overall, the AMOC strengthens, even more than with just a closed BS.

This past time period has implications for a future Earth under more responsible scenarios of emissions. Late Pliocene atmospheric carbon dioxide concentrations are estimated to have ranged between 350 and 450 ppmv and the paleogeography is relatively similar to modern. Our study indicates that the state of the Arctic gateways may influence the sensitivity of the North Atlantic climate in complex ways, and better understanding of the state of these Arctic gateways for past time periods is needed. The late Pliocene may be a better process than geologic analogue to study the ability of models to realize the full sensitivity to processes and feedbacks that may affect the Earth system sensitivity in the future.