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The nonlinear North Atlantic-Arctic ocean response to CO_2 forcing

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Most climate models project an increase in oceanic energy transport towards high northern latitudes in future climate projections, but the physical mechanisms are not yet fully understood. To obtain a more fundamental understanding of the processes that cause the ocean heat transport to increase, we carried out a set of sensitivity experiments using a coupled atmosphere-ocean general circulation model. Within these experiments, atmospheric CO_2 levels are instantaneously set to one-fourth to four times current values. These model integrations, each with a length of 550 years, result in five considerably different quasi-equilibrium climate states.
Our simulations show that poleward ocean heat transport in the Atlantic sector of the Arctic at 70ºN increases from 0.03 PW in the coldest climate state to 0.2 PW in the warmest climate state. This increase is caused primarily by changes in sea ice cover, in horizontal ocean currents owing to anomalous winds in response to sea ice changes, and in ocean advection of thermal anomalies.
Surprisingly, at subpolar latitudes, the subpolar gyre is found to weaken toward both the warmer and colder climates, relative to the current climate. This nonlinear response is caused by a complex interplay between seasonal sea ice melt, the near-surface wind response to sea ice changes, and changes in the density-driven circulation.
The Atlantic Meridional Overturning Circulation (AMOC) and its associated heat transport even oppose the total ocean heat transport towards the Arctic in the warmest climate. Going from warm to cold climates, or from high to low CO_2 concentrations, the strength of the AMOC initially increases, but then declines towards the coldest climate, implying a nonlinear AMOC-response to CO_2-induced climate change.
Evidently, the North Atlantic-Arctic ocean heat transport depends on an interplay between various (remote) coupled ocean-atmosphere-sea ice mechanisms that respond in a nonlinear way to climate change.