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Diagnosing the AMOC slowdown in a coupled model: a cautionary tale

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It is now established that the increase in atmospheric CO2 is likely to cause a weakening, or perhaps a collapse of the Atlantic Meridional Overturning Circulation (AMOC). To investigate the mechanisms of this response in CMIP5 models, Levang and Schmitt (2020) have estimated offline the geostrophic streamfunction in these models, and decomposed the simulated changes into a contribution caused by the variations in temperature and salinity. They concluded that under a warming scenario, and for most models, the weakening of the AMOC is fundamentally driven by temperature anomalies while freshwater flux changes actually act to stabilize it.

However, given that both ocean temperature and salinity are expected to respond to a forcing at the ocean surface, it is unclear to what extent the diagnostic is informative about the nature of the forcing. To clarify this question, we used the Earth system Model of Intermediate Complexity (EMIC) cGENIE, which is equipped with the C-GOLDSTEIN friction-geostrophic model (Marsh et al. (2011)). First, we reproduced the experiments simulating the RCP8.5 warming scenario and observed that cGENIE behaves similarly to the majority of the CMIP5 models considered by Levang and Schmitt (2020), with the response dominated by the changes in the thermal structure of the ocean.

Next, we considered hysteresis experiments associated with (1) water hosing and (2) CO2 increase and decrease. In all experiments, changes in the ocean streamfunction appear to be primarily caused by the changes in the temperature distribution, with variations in the 3-D distribution of salinity compensating only partly for the temperature contribution. These experiments reveal also limited sensitivity to changes in the ocean's salinity inventory. That the diagnostics behave similarly in CO2 and freshwater forcing scenarios suggests that the output of the diagnostic proposed in Levang and Schmitt (2020) is mainly determined by the internal structure of the ocean circulation, rather than the forcing applied to it.

Our results illustrate the difficulty of inferring any information about the applied forcing from the thermal wind diagnostic and raise questions about the feasibility of designing a diagnostic or experiment that could identify which aspect of the forcing (thermal or haline) is driving the weakening of the AMOC.

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