Deciphering the climate impacts of a weakened Atlantic Meridional Overturning Circulation during the 21st century

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Multidecadal variability of the Atlantic Meridional Overturning Circulation (AMOC) plays a vital role in Earth's climate variability. Climate change has the potential to alter the causes and characteristics of AMOC multidecadal variability. Here we use a coupled climate model to simulate AMOC multidecadal variability under three distinct atmospheric CO2 concentrations: Last Glacial Maximum, preindustrial, and quadruple preindustrial levels. Firstly, we discover that AMOC multidecadal variability exhibits a shortened period and a reduced amplitude with increasing atmospheric CO2. We find that these changes in AMOC variability are largely related to enhanced ocean stratification in the subpolar North Atlantic with increasing CO2 which in turn changes the characteristics of westward propagating oceanic baroclinic Rossby waves. Our analysis indicates that the shortened period is primarily due to the increased speed of free oceanic Rossby waves, and the reduced amplitude is mainly due to the reduced magnitude of atmospherically-forced oceanic Rossby waves. Mean flow effects, in the form of eastward mean zonal advection and westward geostrophic self-advection, need to be considered as they largely increase the speed of Rossby waves and hence allow for a better estimate of the changes in the period and amplitude of AMOC variability. Secondly, to explore the possible linkage between atmospheric variability and AMOC fluctuations under each CO2 concentration in a qualitative manner, we analyze the relationship between the North Atlantic Oscillation (NAO) and the AMOC and find a significant negative correlation between the two only under the preindustrial levels where the NAO leads the AMOC by 3–11 years.