Path Dependence of Atlantic Meridional Overturning Circulation Weakening: A Geostrophic Shear Approach

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The Atlantic Meridional Overturning Circulation (AMOC) is an ocean circulation system that plays a crucial role in regulating the global climate and its response to anthropogenic forcing. The path-dependence of AMOC is investigated within four Shared Socioeconomic Pathways (SSPs) with an emphasis on independent effects of temperature-driven and salinity-driven density changes. To provide a straightforward link between the density field and AMOC strength, the geostrophic shear relation is verified, constrained, then used to approximate AMOC. The CESM2-WACCM Global Climate Model submissions to the Coupled Model Intercomparison Project 6 (CMIP6) ensemble are used for analysis. Diagnosis of the model output AMOC with the reconstructed AMOC at 33.5 °N yields a range of weakening trends from 11.8 to 14.5 Sv (1 Sv = 1*10^6 m^3/s), which overestimates the true range by 2-3 Sv. T-tests of the regression slopes show that given the substantial interannual variability, the reconstruction does indeed reasonably reproduce AMOC trend. Decomposition of the thermally-driven and salinity-driven AMOC variability reveals that throughout all SSP climate scenarios, AMOC weakening is driven primarily by increasing temperatures in intermediate depths (300 to 1000 meters). Further, divergence between AMOC trends in the four SSP scenarios is limited (within 0.7σ), suggesting that AMOC weakening trends and mechanisms within the next century are not particularly sensitive to near-future forcing pathways. This supports a growing body of evidence that suggests long term changes in the AMOC mean state significantly lag external forcings. Future analyses may apply this framework to a large-scale model ensemble.

Awards Won:
National Oceanic and Atmospheric Administration - NOAA: First Award of $1500.00