North Atlantic–centered salinity advection organizes multicentennial AMOC variability in a three-dimensional planetary geostrophic ocean model

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ABSTRACT

Multicentennial variability of the Atlantic Meridional Overturning Circulation (AMOC) occurs in many long climate-model integrations, but its origin remains difficult to isolate because oceanic, atmospheric, and sea-ice processes interact across a wide range of timescales. Here, we use a three-dimensional planetary geostrophic ocean model in an idealized two-hemisphere basin to examine the oceanic response to stochastic surface buoyancy forcing in the absence of wind forcing.

Fifty independent 10,000-year integrations are analyzed for each of four experiments, in which salinity or temperature perturbations are applied at northern or southern high latitudes with matched first-order surface-density tendencies. Under northern salinity forcing, the leading overturning EOF explains 88.0% of the variance, and both its principal component and the AMOC index exhibit enhanced spectral power at periods of 150–500 years. Phase composites show alternating salinity anomalies extending from the low-latitude western boundary pathway toward the eastern northern high-latitude sinking region and subsequently into the deep return flow. The two diagnosed linear advection terms play complementary roles. Mean-flow advection of salinity anomalies is associated with delayed phase reversal, whereas anomalous-flow advection of the climatological salinity field reinforces the contemporaneous overturning anomaly.

All four experiments exhibit enhanced AMOC power within the same multicentennial band, while the response amplitude decreases in the order northern salinity, northern temperature, southern salinity, and southern temperature forcing. Within this idealized framework, North Atlantic–centered salinity advection appears to organize the multicentennial AMOC response to both local and remote stochastic buoyancy perturbations.

KEYWORDS: Atlantic Meridional Overturning Circulation; multicentennial variability; salinity advection; planetary geostrophic ocean model