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Converging constraints on the glacial Atlantic overturning circulation from multiple proxies

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The Atlantic overturning circulation plays a critical role in inter-hemispheric transport of heat, carbon, and nutrients, and its potential collapse under anthropogenic forcing is thought to be a major tipping point in the climate system. As such, painstaking efforts have been dedicated to a better understanding of the Atlantic circulation's past variability and mean-state under different boundary conditions. Yet, despite decades of research many uncertainties remain regarding the state of the ocean circulation over the past 20,000 years, during which Earth's climate was propelled out of the last ice age. Here, we employed the Bern3D intermediate complexity model, which is equipped with all major water mass tracers ($\Delta^{14}C$, $\delta^{13}C$, $\delta^{18}O$, εNd, Pa/Th, nutrients, and temperature), to search for converging constraints on the often conflicting interpretations of paleo-reconstructions from individual proxies focusing on the Last Glacial Maximum (LGM). By varying formation rates of northern- and southern-sourced waters we explore a wide range of circulation states and test their ability to reproduce the spatial patterns of newly compiled proxy data of the LGM. Generally, we find that late-Holocene to LGM anomalies give more consistent pictures of proxy distributions than absolute values, since systematic biases, that plague some of the proxies, cancel out. This has the additional advantage that also systematic model biases are minimized. Considering this, we find that the previously opposing neodymium and stable carbon isotope-based interpretations of the glacial water mass structure can be reconciled when non-conservative effects are appropriately taken into account. Furthermore, combining the information from all proxies indicates some shoaling of glacial northern-sourced water, yet not to the same extent as previous studies suggested.