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A current take on past overturning

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Deep overturning circulation in the North Atlantic strongly influences the global climate system. Combined proxy record compilations and modelling refine our understanding of the behaviour of this circulation over the last 20,000 years.

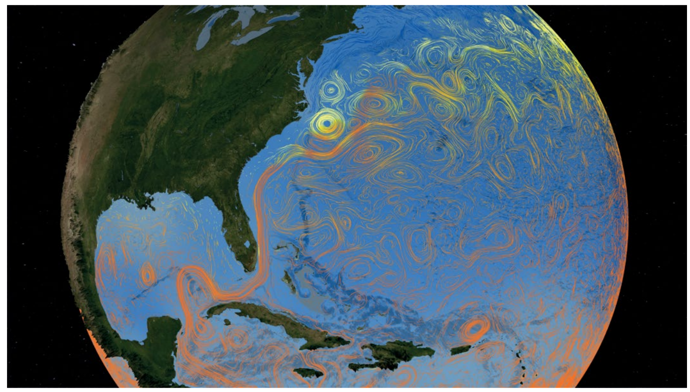

Fig. 1 | Modelled surface circulation and temperature in the northwestern Atlantic. Pöppelmeier and colleagues[1] combine paleoceanographic proxy records from the North Atlantic (pictured here) and models to show that the Atlantic Meridional Overturning Circulation was shallow and weak during the Last Glacial Maximum, and that it did not fully adjust to a series of abrupt climate events during the subsequent deglaciation.

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Winds and evaporation cool the salty North Atlantic and trigger the descent of water from the surface to the deep ocean. Part of Atlantic Meridional Overturning Circulation (AMOC), this deep overturning process has wide-ranging impacts throughout the global climate system, influencing variables such as heat distribution, nutrient and carbon cycling, and tropical rain belt position. Past overturning circulation fluctuations present an opportunity to test the performance of Earth system models that underpin future projections for how the system will respond to climate change. While there are abundant geological indications for large-scale changes to this circulation in the past, this evidence sometimes supports a range of possible interpretations. This is especially the case for the overturning circulation during the deglaciation that followed the Last Glacial Maximum between about 22,000 and 10,000 years ago. As they report in *Nature Geoscience*, Pöppelmeier et al.[1] tackle this challenge by developing a framework combining four compilations of independent proxies with paleoclimate modelling to figure out how the AMOC changed through this major climate transition.

The paleoceanographer's toolbox relies on a mix of biological, chemical and physical proxies that reflect environmental conditions in the ancient ocean. Sediment from cores, collected thousands of feet below the ocean surface, are an especially useful archive when reconstructing the state of deep overturning circulation in the North Atlantic (Fig. 1). Each proxy contains valuable information while also being limited by inherent uncertainties, leading to a hazy picture when interpreted in isolation.

The fact that sufficient proxy data are available to conduct such a data-model comparison is an achievement of the paleoceanographic community as a whole. Efforts to publicly archive data have accelerated over the past decade, in large part because the community supported efforts by funding agencies and publishers to require the deposition of data in repositories. Each data set is the result of multiple scientists who sometimes took years to plan and conduct field expeditions and months-to-years to analyse returned cores, often by a cadre of graduate students and technicians. Over the last decade and a half, scientists working in both small collaborations and large international networks have spent countless hours collecting data into public archives and coherent datasets that could be used for future research. Pöppelmeier et al.[1] benefited from these trends; the neodymium isotopes, stable carbon isotopes, radiocarbon data, and $^{231}Pa/^{230}Th$ data were either completely or partly curated by these recent data compilation efforts[2–5].

Earlier studies concluded that the AMOC may have shut off in the past[6,7], though recent evidence points towards less drastic changes during the Last Glacial Maximum and deglaciation[5,8,9]. Despite a growing consensus, the evidence has not been 100% consistent[10] and some thorough analyses have left niggling uncertainties in AMOC intensity during the Last Glacial Maximum[5]. By comparing the data to a range of model simulations that differed in water mass geometry and AMOC overturning strength, Pöppelmeier et al. were able to reconcile the data and find a well-constrained picture of AMOC that was shallower and ~30% weaker during the Last Glacial Maximum.

They further constrain the deglacial evolution of AMOC by comparing the observations to a suite of transient model runs starting from the Last Glacial Maximum state. Previous models employed boundary conditions and forcing factors consistent with Earth's past conditions and let simulations come to equilibrium in order to explore the physics of the system. However, Earth's climate changed quickly during the last deglaciation. It was so rapid that it's likely the ocean did not have time to equilibrate to the forcing and feedback. So, the use of a transient model by Poppelmeier et al. that explicitly includes the paleoceanographic proxies for the data-model comparison, represents a step forward. Indeed, the authors point out that the 1,200-year cold snap known as the 'Younger Dryas' was too short for the water mass properties in the North Atlantic to equilibrate, explaining why it has been difficult for the paleoclimate community to reach consensus on the ocean state at this time.

Given that models are an imperfect simulation of reality, one has to wonder whether the results of the present study are somewhat model-dependent. Modelling the AMOC is difficult; some of the key processes function at scales finer than the resolution of most models and thus modellers rely on parameterizations. Further, explicitly modelling the paleoclimate and paleoceanographic variables that are captured by the proxies within climate models is still a relatively new endeavour, with few variables and models available for this kind of data-model comparison.

The work by Poppelmeier et al. is an important step towards better understanding AMOC during the last time the Earth went through a major warming episode. Efforts to apply predictive climate models to well-constrained past perturbations provide a test for model climate sensitivity and the ability to simulate abrupt climate change. Such work builds confidence in our ability to simulate the complex dynamics of a rapidly changing future world.

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Competing interests

The authors declare no competing interests.