

Atlantic exceptionalism in the twentieth century

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The North Atlantic is exceptional in cooling during the twentieth century while the world warmed. Here we look back on an influential 2015 study that linked this cooling to a weakening of the Atlantic Meridional Overturning Circulation and consider the wider implications that this may have for climate, ecosystems and society.

The surface temperature of planet Earth tells a number of stories. Its overall rise since the early industrial period is the leading benchmark for our changing climate. Although the pace of warming varies across regions, one persistent exception lies in the subpolar North Atlantic, where a long-term cooling anomaly stands out (Fig. 1a). Known as the North Atlantic warming hole or the ‘cold blob’, this cold anomaly was used, in 2015, by Rahmstorf and colleagues¹, as evidence of the twentieth century weakening of the Atlantic Meridional Overturning Circulation (AMOC) or Gulf Stream System. This evidence for an earlier weakening of the AMOC than projected by climate models² points to a critical uncertainty in the climate system.

The AMOC is a system of ocean currents, including the Gulf Stream, that moves vast amounts of heat meridionally – or more specifically, northwards – in the Atlantic, contributing to keeping high-latitude Atlantic temperatures 10–15 °C (Fig. 1b) warmer than the zonal average. The concept of this system being a critical component of the climate system dates from the nineteenth rather than the twentieth century. By the mid-twentieth century, the climatic importance of the circulation in the Atlantic was recognized with Stommel³ noting, “There is scarcely any more firmly rooted idea in the mind of the layman than the notion that the Gulf Stream keeps the European climate warm”. Palaeoclimate discoveries in the 1980s raised concerns about AMOC stability: abrupt temperature changes identified in ice cores, particularly the Younger Dryas event around 11,000 years ago, were linked to large disruptions in North Atlantic overturning⁴.

A consistent pattern of climate impact drivers has been linked with a weakening AMOC: a cooling in the high North Atlantic region relative to neighbouring regions, precipitation change, including drying in the Atlantic-Europe sector and a southwards shift of the tropical rainbelt, and an increase in storminess in the mid-latitude North Atlantic. Many of these climate feedbacks in response to AMOC change have been seen from early⁵ to more recent modelling studies that consider background warming⁶. Many of these patterns were also present in the 1970s when the Atlantic cooled markedly relative to the global average⁷. And there are associated risks for society and ecosystems, with additional sea-level rise along the North American east coast⁸, losses in fisheries⁹, agriculture¹⁰ and forest regions through

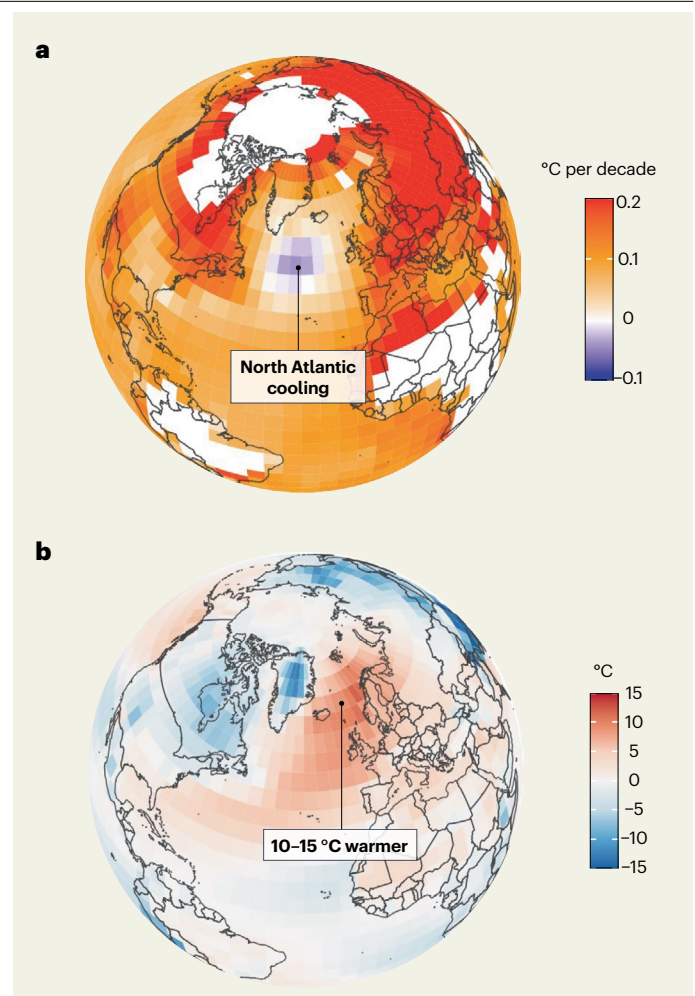


Fig. 1 | Long-term trends and zonal anomalies in surface temperatures.

a, Trends in surface temperature from 1900 to 2024 showing the North Atlantic cooling. White areas have less than 20 years of data required for trend calculation. **b**, Surface temperature deviation from the zonal mean. High-latitude Atlantic temperatures are 10–15 °C warmer than the zonal average, which is broadly attributed to the AMOC. Data from HadCRU5.02 (ref. 15). Map generated with R and RStudio using the *rnaturalearth* package (<https://www.naturalearthdata.com/>).

droughts, or modification of other climate change impacts associated with AMOC weakening.

However, the relationship between AMOC strength and North Atlantic sea surface temperatures (SSTs) is not straightforward. There

are, after all, many processes that can influence SSTs independently of ocean circulation, including atmospheric aerosol forcing, air–sea heat exchanges shaped by atmospheric dynamics, and cloud feedbacks. In climate models, future climates with a substantially weakened AMOC show a corresponding lack of warming in the North Atlantic, but this relationship is not so clear in the twentieth century¹¹. It is debated whether there are times when the AMOC is tightly linked to North Atlantic SSTs and times when it is not¹². The resolution of this debate is an important one, as many studies have built on the conclusions of Rahmstorf and colleagues¹. For example, the 2023 study of Ditlevsen and Ditlevsen¹³ warned of a potential collapse of the AMOC in the mid-twentieth century based on rising autocorrelation in an SST-based AMOC time series. The conclusions of that study are controversial and have been challenged¹⁴ but, for the concerned non-scientist, the stakes in the resolution of this debate are high.

For policymakers and the public, there are many challenges in interpreting the scientific discourse that has stemmed, in one way or another, from Rahmstorf and colleagues¹. On the one hand, the suggestion that the AMOC may have weakened earlier than expected is striking, and – despite the lack of scientific support for catastrophic interpretations – may prompt public fears reminiscent of the abrupt cooling portrayed in the 2004 film *The Day After Tomorrow*. On the other hand, in a world where global warming remains the dominant and overwhelming signal of climate change, some might be tempted to view some regional cooling as a form of respite. In this landscape, one of the few definite policy statements has been Iceland's declaration in 2025 of AMOC weakening as an existential threat (<https://go.nature.com/3P3p3EI>). It is timely then that international efforts (<https://go.nature.com/4lrflTb>) are underway to build a community consensus on AMOC science: understanding whether the AMOC is weakening, why it is weakening, and what this means for global and

regional climate impacts; and to translate this information for the public and policymakers alike.

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Competing interests

The authors declare no competing interests.