

Gulf Stream System at its weakest in over a millennium

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In more than 1,000 years, the Atlantic Meridional Overturning Circulation (AMOC), also known as Gulf Stream System, has not been as weak as in recent decades. This is the result of a new study by scientists from Ireland, Britain and Germany. The researchers compiled so-called proxy data, taken mainly from natural archives like ocean sediments or ice cores, reaching back many hundreds of years to reconstruct the flow history of the AMOC. They found consistent evidence that its slowdown in the 20th century is unprecedented in the

past millennium; it is likely linked to human-caused climate change. The giant ocean circulation system is relevant for weather patterns in Europe and regional sea levels in the U.S.; its slowdown is also associated with an observed cold blob in the northern Atlantic.

"The Gulf Stream System works like a giant conveyor belt, carrying warm surface water from the equator up north, and sending cold, low-salinity deep water back down south. It moves nearly 20 million cubic meters of water per second, almost 100 times the Amazon flow," explains Stefan Rahmstorf from the Potsdam Institute for Climate Impact Research PIK, initiator of the study to be published in *Nature Geoscience*. Previous studies by Rahmstorf and colleagues showed a slowdown of the [ocean](#) current of about 15% since the mid-20th century, linking it to human-caused [global warming](#), but a robust picture about its long-term development has up to now been lacking: This is what the researchers provide with their review of results of proxy data studies.

"For the first time, we have combined a range of previous studies and found they provide a consistent picture of the AMOC evolution over the past 1600 years," says Rahmstorf. "The study results suggest that it has been relatively stable until the late 19th century. With the end of the little ice age in about 1850, the ocean currents began to decline, with a second, more drastic decline following since the mid-20th century." Already the 2019 special report on the oceans of the Intergovernmental Panel on Climate Change (IPCC) concluded with medium confidence "that the Atlantic Meridional Overturning Circulation (AMOC) has weakened relative to 1850-1900."

"The new study provides further independent evidence for this conclusion and puts it into a longer-term paleoclimatic context," Rahmstorf adds.

From temperature to flow speed changes: the art of

reconstructing past climate changes

Because ongoing direct AMOC measurements only started in 2004, the researchers applied an indirect approach, using so-called proxy data, to find out more about the long-term perspective of its decline. Proxy data, as witnesses of the past, consist of information gathered from natural environmental archives such as tree rings, ice cores, [ocean sediments](#), and corals, as well as from historical data, for instance from ship logs.

"We used a combination of three different types of data to obtain information about the ocean currents: temperature patterns in the Atlantic Ocean, subsurface water mass properties and deep-sea sediment grain sizes, dating back from 100 to ca. 1600 years. While the individual proxy data is imperfect in representing the AMOC evolution, the combination of them revealed a robust picture of the overturning circulation," explains Levke Caesar, part of the Irish Climate Analysis and Research Unit at Maynooth University and guest scientist at PIK.

As proxy records in general are subject to uncertainties, statistician Niamh Cahill from Maynooth University in Ireland tested the robustness of the results in consideration of these. She found that in nine of the 11 data sets considered, the modern AMOC weakness is statistically significant. "Assuming that the processes measured in proxy records reflect changes in AMOC, they provide a consistent picture, despite the different locations and time scales represented in the data. The AMOC has weakened unprecedentedly in over 1000 years," she says.

Why is the AMOC slowing down?

An AMOC slowdown has long been predicted by climate models as a response to global warming caused by greenhouse gases. According to a number of studies, this is likely the reason for the observed weakening.

The Atlantic overturning is driven by what the scientists call deep convection, triggered by the differences in the density of the ocean water: Warm and salty water moves from the south to the north where it cools down and thus gets denser. When it is heavy enough the water sinks to deeper ocean layers and flows back to the south. Global warming disturbs this mechanism: Increased rainfall and enhanced melting of the Greenland Ice Sheet add fresh water to the surface ocean. This reduces the salinity and thus the density of the water, inhibiting the sinking and thus weakening the flow of the AMOC.

Its weakening has also been linked to a unique substantial cooling of the northern Atlantic over the past hundred years. This so-called cold blob was predicted by climate models as a result of a weakening AMOC, which transports less heat into this region.

The consequences of the AMOC slowdown could be manifold for people living on both sides of the Atlantic as Levke Caesar explains: "The northward surface flow of the AMOC leads to a deflection of water masses to the right, away from the U.S. east coast. This is due to Earth's rotation, which diverts moving objects such as currents to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. As the current slows down, this effect weakens and more water can pile up at the US east coast, leading to an enhanced sea level rise."

In Europe, a further slowdown of the AMOC could imply more extreme weather events like a change of the winter storm track coming off the Atlantic, possibly intensifying them. Other studies found possible consequences being extreme heat waves or a decrease in summer rainfall. Exactly what the further consequences are is the subject of current research; scientists also aim to resolve which components and pathways of the AMOC have changed how and for what reasons.

"If we continue to drive global warming, the Gulf Stream System will weaken further—by 34 to 45% by 2100, according to the latest generation of climate models," concludes Rahmstorf. This could bring us dangerously close to the tipping point at which the flow becomes unstable.

More information: L. Caesar, G. D. McCarthy, D. J. R. Thornalley, N. Cahill, S. Rahmstorf (2020): Current Atlantic Meridional Overturning Circulation weakest in last millennium. *Nature Geoscience*. [DOI: 10.1038/s41561-021-00699-z](https://doi.org/10.1038/s41561-021-00699-z)

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