A crucial ocean circulation is showing signs of instability. Its shutdown would have serious impacts on our weather.

By **Angela Dewan**, CNN

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Whales swim among icebergs near Greenland. Scientists say a critical ocean circulation in the North Atlantic is showing signs of instability, which could have major implications for Earth's climate.

(CNN)A crucial system of currents in the Atlantic Ocean that helps control temperatures in the Northern Hemisphere and has implications for the entire planet's weather systems is showing signs of instability due to human-made climate change, scientists say.

Its collapse would have dire consequences for our weather and life on Earth.

The Atlantic Meridional Overturning Circulation (AMOC) -- which the Gulf Stream is a major part of -- helps maintain the energy balance in the Atlantic Ocean. It is often described as a "conveyor belt" that takes warm surface water from the tropics and distributes it to the north Atlantic. The colder, saltier water then sinks and flows south.

A study, published Thursday in Nature and Climate Change, warned of "an almost complete loss of stability of the AMOC over the course of the last century. Researchers say it could be close to a collapse from a strong circulation to a weak circulation, though the threshold for such a collapse is still uncertain.

Scientists have warned for years that the circulation is weakening. Heavy rain and melting ice sheets are making the water in the North Atlantic Ocean less salty, which makes it lighter and less likely to sink. If the water in this region becomes too light, the entire circulation could be disrupted.

Global weather patterns are critically linked to the circulation and its transport of heat and nutrients around the planet. A collapse of this system would result in significant and abrupt changes, including fast sea level rise, more extreme winters in Western Europe and disruptions to monsoon systems in the tropics.

It could also have a cascading effect and destabilize other components of the Earth's climate system, including the Antarctic ice sheet and the Amazon rainforest.

This scenario was the premise for the 2004 climate science fiction film "The Day After Tomorrow," in which a series of extreme weather disasters strike after climate change caused the AMOC to collapse.
The circulation is weaker than it has been in around 1,000 years, scientists had previously said, but they did not know whether it had actually been destabilized or undergoing natural changes. This week's study used eight datasets looking at surface temperatures and salinity in the North Atlantic over a period of 150 years, and found global warming was driving the destabilization.
"The difference is crucial," the study's author, Niklas Boers from the Potsdam Institute for Climate Impact Research, told CNN in an email.

"Imagine a chair, which can be either shifted (with all four legs remaining on the ground) or tilted. Both change the position of the chair (corresponding to the change in mean AMOC strength), but in the first case the stability of the chair won't be affected, while in the latter case there exists a critical point. If we tilt the chair just slightly further, it will fall down. My results suggest that what is happening to the AMOC is more likely to be a tilting than only a shifting, so the AMOC has moved toward the critical threshold at which it may collapse," he said.
Boers added that he himself was surprised by his findings that the AMOC had been destabilized and was "moving toward its critical threshold, at which it could abruptly collapse."
A collapse of the circulation would mean significant cooling in Europe, Beors said, "but maybe more concerning is the effect of an AMOC collapse on the tropical monsoon systems of South America, Western Africa, and India; especially in Western Africa, an AMOC collapse could lead to permanent drought conditions."

Boers recognizes in his study that he and other scientists still don't know if and when the current might collapse, but he called on the world to reduce greenhouse gas emissions "as much and as quickly as possible."

"Every gram of extra greenhouse gas in the atmosphere will increase to the probability of an AMOC collapse in the future, so emitting as little as possible, both on individual but of course also on collective and international level, is the key."

The study comes ahead of a major report by the UN's International Panel on Climate Change on Monday, which has been years in the making and is expected to provide the most conclusive look yet at the extent of human-made climate change. It will also likely paint a picture of what the future could look like, depending on what action the world takes to reduce its greenhouse gas emissions.

Climate crisis: Scientists spot warning signs of Gulf Stream collapse

A shutdown would have devastating global impacts and must not be allowed to happen, researchers say

Melting freshwater from Greenland's ice sheet is slowing down the AMOC earlier than climate models suggested. Photograph: Ulrik Pedersen/NurPhoto/REX/Shutterstock

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Climate scientists have detected warning signs of the collapse of the Gulf Stream, one of the planet's main potential tipping points.

The research found "an almost complete loss of stability over the last century" of the currents that researchers call the Atlantic meridional overturning circulation (AMOC). The currents are already at their slowest point in at least 1,600 years, but the new analysis shows they may be nearing a shutdown.

Such an event would have catastrophic consequences around the world, severely disrupting the rains that billions of people depend on for food in India, South America and West Africa; increasing storms and lowering temperatures in Europe; and pushing up the sea level in the eastern North America. It would also further endanger the Amazon rainforest and Antarctic ice sheets.

The complexity of the AMOC system and uncertainty over levels of future global heating make it impossible to forecast the date of any collapse for now. It could be within a decade or two, or several centuries away. But the colossal impact it would have means it must never be allowed to happen, the scientists said.

"The signs of destabilisation being visible already is something that I wouldn't have expected and that I find scary," said Niklas Boers, from the Potsdam Institute for Climate Impact Research in Germany, who did the research. "It's something you just can't [allow to] happen."

It is not known what level of CO2 would trigger an AMOC collapse, he said. "So the only thing to do is keep emissions as low as possible. The likelihood of this extremely high-impact event happening increases with every gram of CO2 that we put into the atmosphere".

Scientists are increasingly concerned about tipping points – large, fast and irreversible changes to the climate. Boers and his colleagues reported in May that a significant part of the Greenland ice sheet is on the brink, threatening a big rise in global sea level. Others have shown recently that the Amazon

rainforest is now emitting more CO2 than it absorbs, and that the 2020 Siberian heatwave led to worrying releases of methane.

The world may already have crossed a series of tipping points, according to a 2019 analysis, resulting in "an existential threat to civilisation". A major report from the Intergovernmental Panel on Climate Change, due on Monday, is expected to set out the worsening state of the climate crisis.

Boer's research, published in the journal Nature Climate Change, is titled "Observation-based early-warning signals for a collapse of the AMOC". Ice-core and other data from the last 100,000 years show the AMOC has two states: a fast, strong one, as seen over recent millennia, and a slow, weak one. The data shows rising temperatures can make the AMOC switch abruptly between states over one to five decades.

The AMOC is driven by dense, salty seawater sinking into the Arctic ocean, but the melting of freshwater from Greenland's ice sheet is slowing the process down earlier than climate models suggested.

Boers used the analogy of a chair to explain how changes in ocean temperature and salinity can reveal the AMOC's instability. Pushing a chair alters its position, but does not affect its stability if all four legs remain on the floor. Tilting the chair changes both its position and stability.

Eight independently measured datasets of temperature and salinity going back as far as 150 years enabled Boers to show that global heating is indeed increasing the instability of the currents, not just changing their flow pattern.

The analysis concluded: "This decline [of the AMOC in recent decades] may be associated with an almost complete loss of stability over the course of the last century, and the AMOC could be close to a critical transition to its weak circulation mode."

Levke Caesar, at Maynooth University in Ireland, who was not involved in the research, said: "The study method cannot give us an exact timing of a possible collapse, but the analysis presents evidence that the AMOC has already lost stability, which I take as a warning that we might be closer to an AMOC tipping than we think."

David Thornalley, at University College London in the UK, whose work showed the AMOC is at its weakest point in 1,600 years, said: “These signs of decreasing stability are concerning. But we still don’t know if a collapse will occur, or how close we might be to it.”

Gulf Stream current at its weakest in 1,600 years, studies show

This article is more than 3 years old

Warm current that has historically caused dramatic changes in climate is experiencing an unprecedented slowdown and may be less stable than thought - with potentially severe consequences

Scene from The Day After Tomorrow showing the Statue of Liberty covered in ice. In the film a rapid shutdown of the Amoc current causes the temperatures to plummet overnight. In reality the change will be much slower, but still dramatic.

Photograph: 20th Century Fox/Kobal/REX/Shutterstock

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The warm Atlantic current linked to severe and abrupt changes in the climate in the past is now at its weakest in at least 1,600 years, new research shows. The findings, based on multiple lines of scientific evidence, throw into question

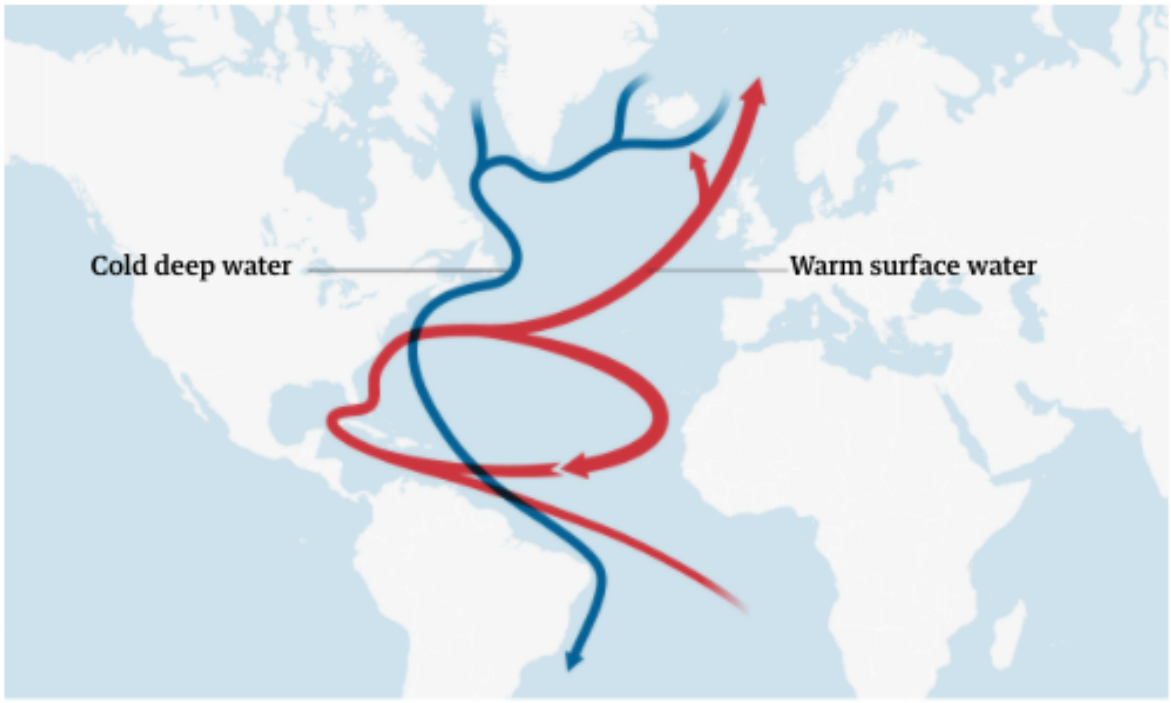
previous predictions that a catastrophic collapse of the Gulf Stream would take centuries to occur.

Such a collapse would see western Europe suffer far more extreme winters, sea levels rise fast on the eastern seaboard of the US and would disrupt vital tropical rains. The new research shows the current is now 15% weaker than around 400AD, an exceptionally large deviation, and that human-caused global warming is responsible for at least a significant part of the weakening.

The current, known as the Atlantic Meridional Overturning Circulation (Amoc), carries warm water northwards towards the north pole. There it cools, becomes denser and sinks, and then flows back southwards. But global warming hampers the cooling of the water, while melting ice in the Arctic, particularly from Greenland, floods the area with less dense freshwater, weakening the Amoc current.

Scientists know that Amoc has slowed since 2004, when instruments were deployed at sea to measure it. But now two new studies have provided comprehensive ocean-based evidence that the weakening is unprecedented in at least 1,600 years, which is as far back as the new research stretches.

Ocean circulation in the Atlantic is driven by warm surface currents and cold deep-water return flows



“Amoc is a really important part of the Earth’s climate system and it has played an important part in abrupt climate change in the past,” said Dr David Thornalley, from University College London who led one of the new studies. He said current climate models do not replicate the observed slowdown, suggesting that Amoc is less stable that thought.

During the last ice age, some big changes in Amoc led to winter temperatures changing by 5-10C in as short a time as one to three years, with major consequences for the weather over the land masses bordering the Atlantic. “The [current] climate models don’t predict [an Amoc shutdown] is going to happen in the future – the problem is how certain are we it is not going to happen? It is one of these tipping points that is relatively low probability, but high impact.”

The study by Thornalley and colleagues, published in Nature, used cores of sediments from a key site off Cape Hatteras in North Carolina to examine Amoc over the last 1600 years. Larger grains of sediment reflect faster Amoc currents and vice versa.

They also used the shells of tiny marine creatures from sites across the Atlantic to measure a characteristic pattern of temperatures that indicate the strength of

Amoc. When it weakens, a large area of ocean around Iceland cools, as less warm water is brought north, and the waters off the east coast of the US get warmer.

The second study, also published in Nature, also used the characteristic pattern of temperatures, but assessed this using thermometer data collected over the last 120 years or so.

Both studies found that Amoc today is about 15% weaker than 1,600 years ago, but there were also differences in their conclusions. The first study found significant Amoc weakening after the end of the little ice age in about 1850, the result of natural climate variability, with further weakening caused later by global warming.

Drastic cooling in North Atlantic beyond worst fears, scientists warn

The second study suggests most of the weakening came later, and can be squarely blamed on the burning of fossil fuels. Further research is now being undertaken to understand the reasons for the differences.

However, it is already clear that human-caused climate change will continue to slow Amoc, with potentially severe consequences. “If we do not rapidly stop global warming, we must expect a further long-term slowdown of the Atlantic

overturning," said Alexander Robinson, at the University of Madrid, and one of the team that conducted the second study. He warned: "We are only beginning to understand the consequences of this unprecedented process – but they might be disruptive."

A 2004 disaster movie, The Day After Tomorrow, envisaged a rapid shutdown of Amoc and a devastating freeze. The basics of the science were portrayed correctly, said Thornalley: "Obviously it was exaggerated – the changes happened in a few days or weeks and were much more extreme. But it is true that in the past this weakening of Amoc happened very rapidly and caused big changes."