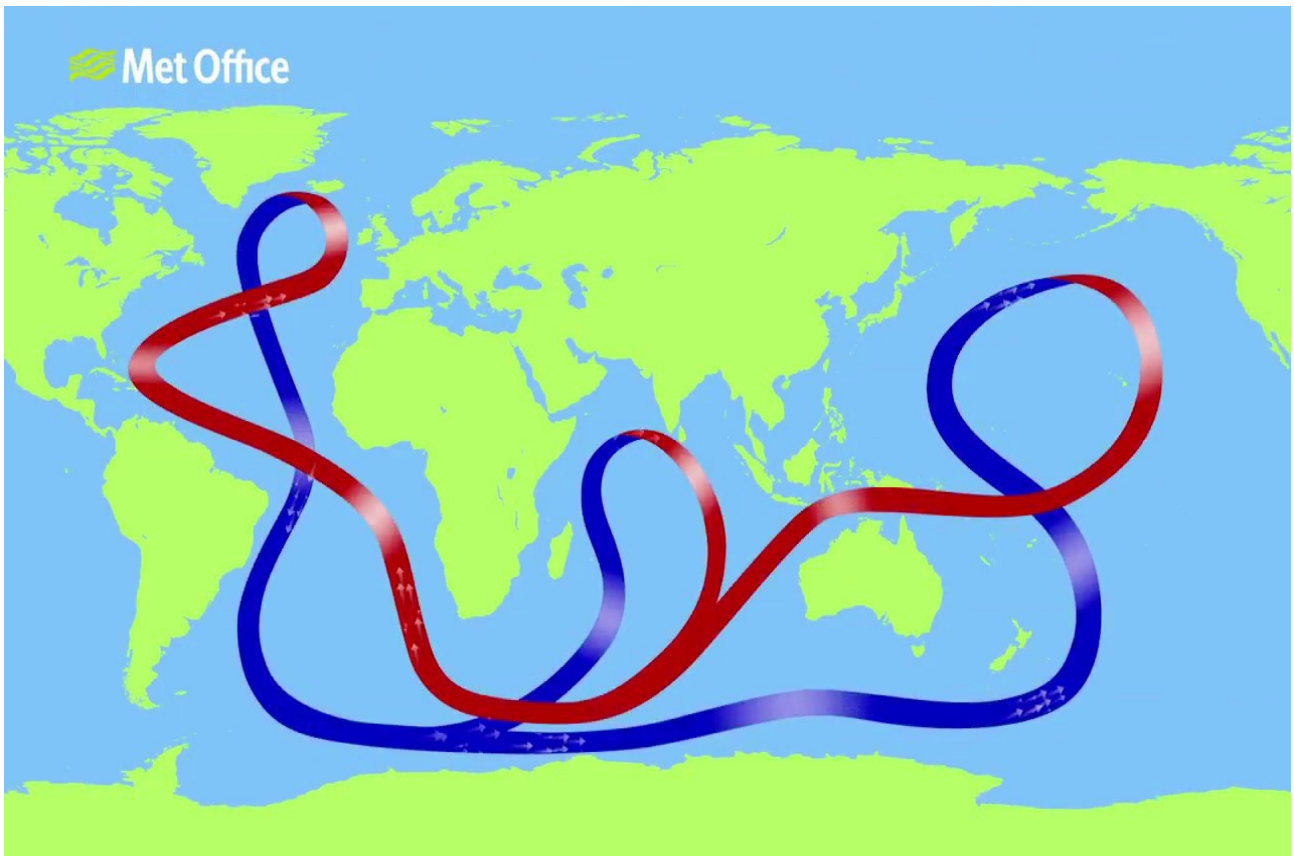

A study published last week in **Nature Climate Change** notes that this circulation, known officially as the Atlantic Meridional Overturning Circulation (AMOC), is losing its stability. According to the IPCC's Report (AR6) released on August 9, it is very likely that AMOC will **decline over the 21st century**.

In the course of the last century, the AMOC may have evolved from relatively stable conditions to a point close to a critical transition.

Nature article
https://www.nature.com/articles/s41558-021-01097-4.epdf?sharing_token=0npUt_7bH99OXHj8Z98cDtRgN0jAjWel9jnR3ZoTv0ODQw4Na6S4LwvIIwjZ_S3NdBoG6pi8c5NBfIwoUKp1VK_OHHszXMnB3OMoyz8L8emOhG-hoDsJyn1YMubz_IampYbIRg_8P9vjnfIPPzRQwm6m9BfwEGfoLu0JsB4E2trSfyu4r947mOz1oZQlyxQx_CJUBVsjAuaOw5pS--XB4YFmNl9rrlpFeYJwCaR0tKA=&tracking_referrer=www.washingtonpost.com

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Summary from NOAA

Circuit takes about 1,000 years to complete

https://oceanservice.noaa.gov/education/tutorial_currents/05conveyor2.html

Thermohaline circulation drives a global-scale system of currents called the “global conveyor belt.” The conveyor belt begins on the surface of the ocean near the pole in the North Atlantic. Here, the water is chilled by arctic temperatures. It also gets saltier because when sea ice forms, the salt does not freeze and is left behind in the surrounding water. The cold water is now more dense, due to the added salts, and sinks toward the ocean bottom. Surface water moves in to replace the sinking water, thus creating a current.

This deep water moves south, between the continents, past the equator, and down to the ends of Africa and South America. The current travels around the edge of Antarctica, where the water cools and sinks again, as it does in the North Atlantic. Thus, the conveyor belt gets "recharged." As it moves around Antarctica, two sections split off the conveyor and turn northward. One section moves into the Indian Ocean, the other into the Pacific Ocean.

These two sections that split off warm up and become less dense as they travel northward toward the equator, so that they rise to the surface (upwelling). They then loop back southward and westward to the South Atlantic, eventually returning to the North Atlantic, where the cycle begins again.

The conveyor belt moves at much slower speeds (a few centimeters per second) than wind-driven or tidal currents (tens to hundreds of centimeters per second). It is estimated that any given cubic meter of water takes about 1,000 years to complete the journey along the global conveyor belt. In addition, the conveyor moves an immense volume of water—more than 100 times the flow of the Amazon River (Ross, 1995).

The conveyor belt is also a vital component of the global ocean nutrient and carbon dioxide cycles. Warm surface waters are depleted of nutrients and carbon dioxide, but they are enriched again as they travel through the conveyor belt as deep or bottom layers. The base of the world’s food chain depends on the cool, nutrient-rich waters that support the growth of algae and seaweed.

What will happen if Gulf Stream collapses?

It would **disrupt monsoon seasons and rains in places like India, South America and West Africa**, affecting crop production and creating food shortages for billions of people. The decline of the Amazonian rainforest and the Antarctic ice sheets would also be put into fast forward.3 days ago

Cold blob south of Greenland (aka "warming hole")

https://www.nature.com/articles/s41558-020-0819-8

https://www.carbonbrief.org/scientists-shed-light-on-human-causes-of-north-atlantics-cold-blob

https://en.wikipedia.org/wiki/Cold_blob

AMOC is driven by ocean temperature and salinity differences. The major possible mechanism causing the cold ocean surface temperature anomaly is based on the fact that freshwater decreases ocean water salinity, and through this process prevents colder waters sinking. Observed freshwater increase originates probably from Greenland ice melt.
https://www.google.com/search?q=Where+does+the+cold+blob+come+from?&tbm=isch&source=iu&ictx=1&fir=JBYO6Qxt6z7MrM%2Csy9xZ2NG3kx-QM%2C_&vet=1&usg=AI4_-kTJaXTmuFVCTURBeQ11BMgfxlXXcg&sa=X&ved=2ahUKEwiS6ZHEuafyAhXSyYUKHQCuCLEQ9QF6BAgSEAE#imgrc=HnbASCEDr1hRZM&imgdii=Tx_c3v-LHSdwbM

video of earth' relative temps over last 15 0 years
https://yubanet.com/scitech/nasa-noaa-analyses-reveal-2019-second-warmest-year-on-record/

Cold blob”emerged “ in 2014
https://sciencenordic.com/climate-denmark-greenland-science-special/melting-greenland-ice-has-not-slowed-down-ocean-circulation/1435691

There's mounting evidence, which this study further supports, that a major ocean current called the "Atlantic Meridional Overturning Circulation (AMOC) — which acts somewhat like a conveyor belt as it transports warm tropical water up into the North Atlantic Ocean — is slowing down. Scientists suspect the slowdown is driven by "off-the-charts" melting of the Greenland ice sheet, which has resulted in freshwater pouring into the North Atlantic Ocean.

https://mashable.com/article/cold-blob-atlantic-ocean-climate-change

Feature

The Global Conveyor Belt

The global conveyor belt is a system of ocean currents that transport water around the world. While wind primarily propels surface currents, deep currents are driven by differences in water densities in a process called thermohaline circulation. Density depends on both the temperature (thermo) and salinity (haline) of the water. Along this conveyor belt, heat and nutrients are moved around the world in a leisurely 1000-year cycle.
https://www.nationalgeographic.org/media/global-conveyor-belt

Images global current conveyor belt

One of the main impacts of the slowing ocean circulation is on sea levels, especially those of the US East Coast.

"The northward surface flow of the AMOC leads to a deflection of water masses to the right, away from the US East Coast. This is due to Earth's rotation that 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," said Levke Caesar, one of the authors of the report.

Sea-level rise is already happening due to factors like melting ice sheets and warming oceans. According to the National Oceanic and Atmospheric Administration (NOAA), water levels have risen by eight to nine inches (20-22.8cm) on average within the past 140 years.

The rate at which these waters are rising has also increased in recent years.

"The pace of global sea-level rise more than doubled from 1.4mm per year throughout most of the twentieth century to 3.6mm per year from 2006-2015," said NOAA.

A further slowdown of global ocean circulation, especially along the crucial Gulf Stream current off the eastern coastline of the US, could combine with the already accelerating sea-level rise to make major Northeastern cities even more vulnerable to flooding.

https://www.9news.com.au/world/cold-blob-slowing-down-atlantic-ocean-currents-drastic-climate-changes-research-says/9ead0abc-7ca1-42da-920f-809d6ab62924

In its 2019 “Special Report on the Ocean and Cryosphere in a Changing Climate,” the U.N. Intergovernmental Panel on Climate Change projected that the AMOC would weaken during this century, but total collapse within the next 300 years was only likely under the worst-case warming scenarios.

The new analysis suggests “the critical threshold is most likely much closer than we would have expected,” Boers said.

The “restoring forces,” or feedback loops, that keep the AMOC churning are in decline, he said. All the indicators analyzed in his study — including sea surface temperature and salt concentrations — have become increasingly variable.

Physical oceanographers like him are also trying to confirm the AMOC slowdown through direct observations. But the AMOC is so big and complex that it will probably take years of careful monitoring and data collection before a definitive measurement is possible.

“Yet everyone also realizes the jeopardy of waiting for that proof,” de Menocal said.

After all, there are plenty of other indications that Earth’s climate is in unprecedented territory. This summer, the Pacific Northwest was blasted by a heat wave scientists say was “virtually impossible” without human-caused warming. China, Germany, Belgium, Uganda and India have all experienced massive, deadly floods. Wildfires are raging from California to Turkey to the frozen forests of Siberia.

The world is more than 1 degree Celsius (1.8 degrees Fahrenheit) warmer than it was before humans started burning fossil fuels, and it’s getting hotter all the time.

And the apparent consequences of the AMOC slowing are already being felt. A persistent “cold blob” in the ocean south of Greenland is thought to result from less warm water reaching that region. The lagging Gulf Stream has caused exceptionally high sea level rise along the U.S. East Coast. Key fisheries have been upended by the rapid temperature swings, and beloved species are struggling to cope with the changes.

Why is the ocean cooling near Greenland?

Scientists suspect the slowdown is driven by "off-the-charts" melting of the Greenland ice sheet, which has resulted in freshwater pouring into the North Atlantic Ocean. The influx of water can have a momentous effect. It **reduces the salinity of the ocean**, which makes the water less dense.Jul 1, 2020

Now, less cold water in the North Atlantic naturally sinks down, which hinders the flow of new tropical warmers from streaming into this oceanic region (because the cooler waters, now more buoyant, didn't clear out of the way). Ultimately, this means there's less heat traveling into the North Atlantic, which helps sustain the cold blob, said Paul Keil, a lead author of the research and a PhD candidate at the Max Planck Institute for Meteorology in Germany.

If the AMOC does completely shut down, the change would be irreversible in human lifetimes, Boers said. The “bi-stable” nature of the phenomenon means it will find new equilibrium in its “off” state. Turning it back on would require a shift in the climate far greater than the changes that triggered the shutdown.

https://www.washingtonpost.com/climate-environment/2021/08/05/change-ocean-collapse-atlantic-meridional/

Nature article published Aug 9 2021

https://www.nature.com/articles/s41558-021-01097-4.epdf?**sharing_token**=0npUt_7bH99OXHj8Z98cDtRgN0jAjWel9jnR3ZoTv0ODQw4Na6S4LwvIIwjZ_S3NdBoG6pi8c5NBfIwoUKp1VK_OHHszXMnB3OMoyz8L8emOhG-hoDsJyn1YMubz_IampYbIRg_8P9vjnfIPPzRQwm6m9BfwEGfoLu0JsB4E2trSfyu4r947mOz1oZQlyxQx_CJUBVsjAuaOw5pS--XB4YFmNl9rrlpFeYJwCaR0tKA%3D&tracking_referrer=www.washingtonpost.com

A collapse from the currently attained strong to the weak mode would have severe impacts on the global climate system and further multi-stable Earth system components. Observations and recently suggested fingerprints of AMOC variability indicate a gradual weakening during the last decades, but estimates of the critical transition point remain uncertain. Here, a robust and general early-warning indicator for forthcoming critical transitions is introduced. Significant early-warning signals are found in eight independent AMOC indices, based on observational sea-surface temperature and salinity data from across the Atlantic Ocean basin. These results reveal spatially consistent empirical evidence that, in the course of the last century, the AMOC may have evolved from relatively stable conditions to a point close to a critical transition

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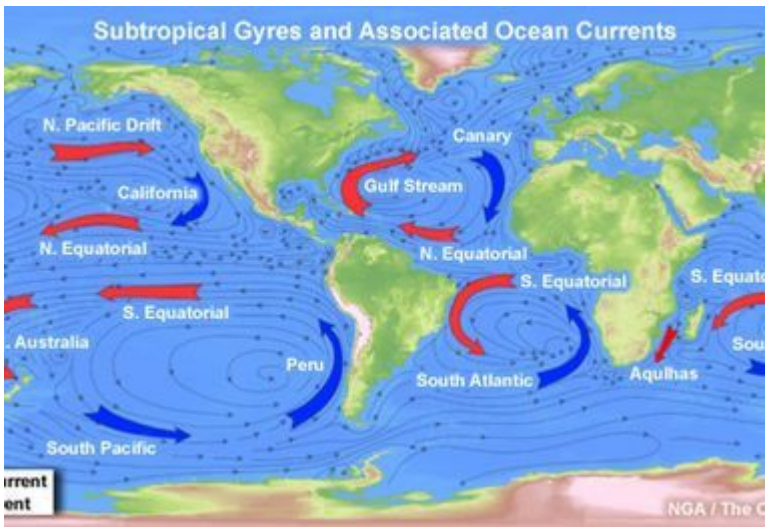
Published: 15 Feb 2021

A 30-year reconstruction of the Atlantic meridional overturning circulation shows no decline [caveats]

European report says no AMOC decline today but there was one observed between 2004 and 2012 by the RAPID-MOCHA-WBTS (RAPID – Meridional Overturning Circulation

and Heatflux Array – Western Boundary Time Series, hereafter RAPID array) with this weakened state of the AMOC persisting until 2017. Climate model and paleo-oceanographic research suggests that the AMOC may have been declining for decades or even centuries before this; however direct observations are sparse prior to 2004, giving only "snapshots" of the overturning circulation. Previous studies have used linear models based on upper-layer temperature anomalies to extend AMOC estimates back in time; however these ignore changes in the deep circulation that are beginning to emerge in the observations of AMOC decline. Here we develop a higher-fidelity empirical model of AMOC variability based on RAPID data and associated physically with changes in thickness of the persistent upper, intermediate, and deep water masses at 26◦ N and associated transports. We applied historical hydrographic data to the empirical model to create an AMOC time series extending from 1981 to 2016. Increasing the resolution of the observed AMOC to approximately annual shows multi-annual variability in agreement with RAPID observations and shows that the downturn between 2008 and 2012 was the weakest AMOC since the mid-1980s. **However, the time series shows no overall AMOC decline as indicated by other proxies and high-resolution climate models.** Our results reinforce that adequately capturing changes to the deep circulation is key to detecting any anthropogenic climate-change-related AMOC decline.
https://os.copernicus.org/articles/17/285/2021/

Other major currents



https://www.nationalgeographic.org/topics/resource-library-ocean-currents/?q=&page=1&per_page=25

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https://doi.org/10.1038/s41558-021-01097-41
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Potsdam Institute for Climate Impact Research (PIK) February 25 2021

https://www.sciencedaily.com/releases/2021/02/210225113357.htm

Never before in over 1000 years the Atlantic Meridional Overturning Circulation (AMOC), also known as Gulf Stream System, has been as weak as in the last 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 is relevant for weather patterns in Europe and regional sea-levels in the US; its slowdown is also associated with an observed cold blob in the northern Atlantic.

"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 9 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.

Aug 9 Nature Climate Change Report **Use this link to access report for free**

https://www.nature.com/articles/s41558-021-01097-4.epdf?sharing_token=ZBCHbmgBvyxHwZZAoD-aktRgN0jAjWel9jnR3ZoTv0ODQw4Na6S4LwvIIwjZ_S3NdBoG6pi8c5NBfIwoUKp1VK_OHHszXMnB3OMoyz8L8emOhG-hoDsJyn1YMubz_IampYbIRg_8P9vjnfIPPzRQwm6m9BfwEGfoLu0JsB4E2trSfyu4r947mOz1oZQlyxQxyoXOu03aTmtGUqCnZDEggJoOU7-wifR6G4MJ7RyOcuM%3D&tracking_referrer=www.washingtonpost.com