The major Atlantic current that keeps Northern Europe warm could have new variations and tipping points

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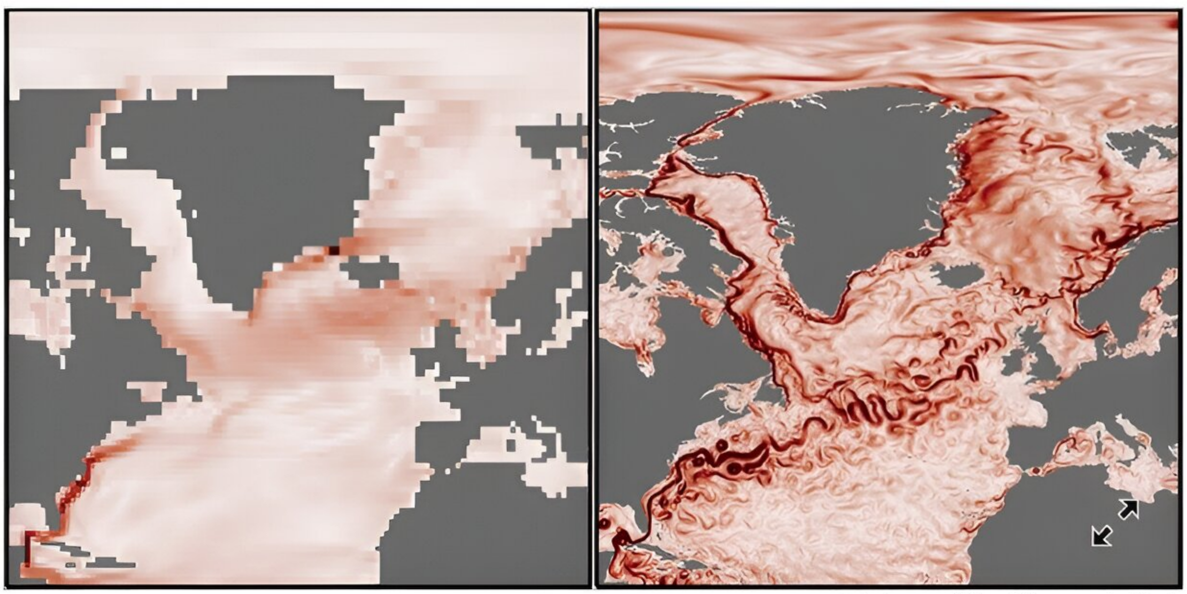

The AMOC's current speeds in (left) a low-resolution climate model and (right) this paper's high-resolution model. Credit: Physics Magazine via APS

Northern Europe is relatively warm given its place on the globe. For example, although north of most major Canadian cities, London is warmer than all of them (even Vancouver in British Columbia). But this warmth could disappear by the turn of the century thanks to global warming.

That's because a major ocean current, the Atlantic Meridional Ocean Current (AMOC), which runs from the Gulf of Mexico to about Svalbard, Norway, could cease to run. Today it carries enormous amounts of warm water to the north Atlantic, where it cools, sinks and sharply changes direction, moving off the eastern coast of Greenland, then through the mid-Atlantic (and under the northeastern-bound AMOC) and on to the southern Atlantic Ocean. The heat it releases in the process keeps northern European ports ice-free.

Under global warming, the saline northeastern AMOC mixes with cool freshwater from the melting Arctic, and with increased rainfall characteristic of global warming. This freshwater reduces the current's density and salinity, so its cooling and sinking in the northern Atlantic is reduced, and thus its southward flow is reduced.

In 1995, climate modelers projected that the AMOC's circulation would stop by 2200. Observations have been available since 2004, and indeed parts of the AMOC do appear to be slowing down.

But until now, climate models have not been able to peer closely at the AMOC, including its many streams and gyres and inputs.

Now, using a climate model that takes a more detailed look at the AMOC, scientists have a better view of its future, finding details earlier models missed. In this new, more resolute model, the AMOC abruptly collapses in some regions, and unexpectedly increases in others. The findings are published in the journal *Physical Review Letters*.

"Our high-resolution model study uncovers a startling twist: the Atlantic Meridional Overturning Circulation (AMOC) may strengthen in the subarctic Atlantic due to warming," said Gerrit Lohmann, a co-author on the study from the Alfred Wegener Institute at the Helmholtz Center for Polar and Marine Research at the University of Bremen in Germany, "defying the widespread belief that this vital current system is uniformly weakening."

The large global climate models used for climate change projections typically divide the land and ocean into 100 kilometer by 100 kilometer areas, to accommodate time and computing availability. As "low resolution" models, they can miss smaller physical features, such as eddies and gyres in the ocean.

Lohmann and collaborators used a recently-developed high resolution climate model called the Community Earth System Model which reduced the prior grid sizes of 1° of latitude and longitude on each side to 0.1°, or about 17 kilometers.

They assumed the atmosphere's carbon dioxide level would increase at a high rate—the IPCC's RCP 8.5 scenario, with carbon dioxide increasing quickly over the century to a level of about 1,250 parts per million (ppm) in 2100.

Both the high- and low-resolution models showed an overall slowdown in the AMOC, by about 8 million cubic meters of water per second from 2000 to 2100, with a sharp decline near the year 2020. (By comparison, the AMOC's total flow rate is an estimated 15 to 20 million cubic meters of water per second, transporting about 1.3 million billion joules of energy per second.) But on a smaller, more regional scale, parts of the AMOC collapsed abruptly, and in other parts even strengthened over time.

"Advanced climate models now reveal that, under extreme greenhouse gas emissions (RCP 8.5), the AMOC could experience sharp declines in some areas while paradoxically increasing in the Arctic," Lohmann said. "This unexpected regional strengthening occurs despite an overall weakening trend in AMOC activity."

Besides regional variations and ocean eddies, the high-resolution model showed tipping points that were unknown from lower resolution studies.

A tipping point is when a system suddenly changes from one kind of state to another—a threshold where an additional small change causes the system to suddenly transition to a new state. For example, you can eat and eat while wearing pants, but at some point the bottom of your pants are suddenly going to rip, and they will forever after be in a different condition. That's a tipping point for pants.

Subsystems of the climate system have tipping points; for example, studies of Greenland Ice Sheet's past have estimated it will experience a tipping point when the Earth has warmed about 2.5°C above the preindustrial level. When the tipping point is reached, the melting of the entire ice sheet could be inevitable.

The scientists found that at the smaller scales, parts of the AMOC have tipping points that do not appear in previous models of the general AMOC.

"The findings highlight the urgent need to incorporate regional dynamics into AMOC forecasts, as these localized shifts could have profound impacts on climate and marine ecosystems," said Lohmann.

"As we face an uncertain climatic future, these insights underscore the critical importance of advancing climate models to anticipate and respond to dramatic changes in our planet's systems." What's more, the feedback between the overall AMOC and small scale AMOC "could change in the future," he said.

More information: Ruijian Gou et al, Atlantic Meridional Overturning Circulation Decline: Tipping Small Scales under Global Warming, *Physical Review Letters* (2024). DOI: 10.1103/PhysRevLett.133.034201