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From: Deirdre Des Jardins <ddj@cah2oresearch.com>
Sent: Tuesday, April 30, 2024 8:53 AM
To: Delta Council ISB <DeltaCouncilISB@deltacouncil.ca.gov>

Subject: Stefan Rahmstorf on the risk of reaching a tipping point for the Atlantic Meridional Overturning Circulation

Dear Delta Independent Science Board members,

The current generation of global climate models (CMIP5 and CMIP6) fail to capture the tipping point for the Atlantic Meridional Overturning Circulation. (AMOC). Research in the last few years (and since the 2021 IPCC report) shows the risk of tipping is much larger and earlier than previously thought. Climate mitigation and climate adaptation planning in California needs to consider this known limitation of global climate models.

German physicist Stefan Rahmstorf, who has done foundational research on the AMOC, wrote a wonderfully clear and accessible article explaining the AMOC, its tipping point, and the new research

IS THE ATLANTIC OVERTURNING CIRCULATION APPROACHING A TIPPING POINT? | OCEANOGRAPHY (TOS.ORG)

Some key bits:

FIFTY TIMES THE HUMAN ENERGY USE

In this article, I discuss the Atlantic branch of the global overturning circulation, a major player in past and quite likely future climate change. It is called the AMOC (short for Atlantic Meridional Overturning Circulation). Its northward flow of warm surface waters and deep cold return flow makes the South Atlantic a curiosity: it transports heat from the southern high latitudes toward the equator, from cold to warm (Figure 1). All other ocean basins behave “normally,” by moving excess heat away from the sun-soaked tropics.

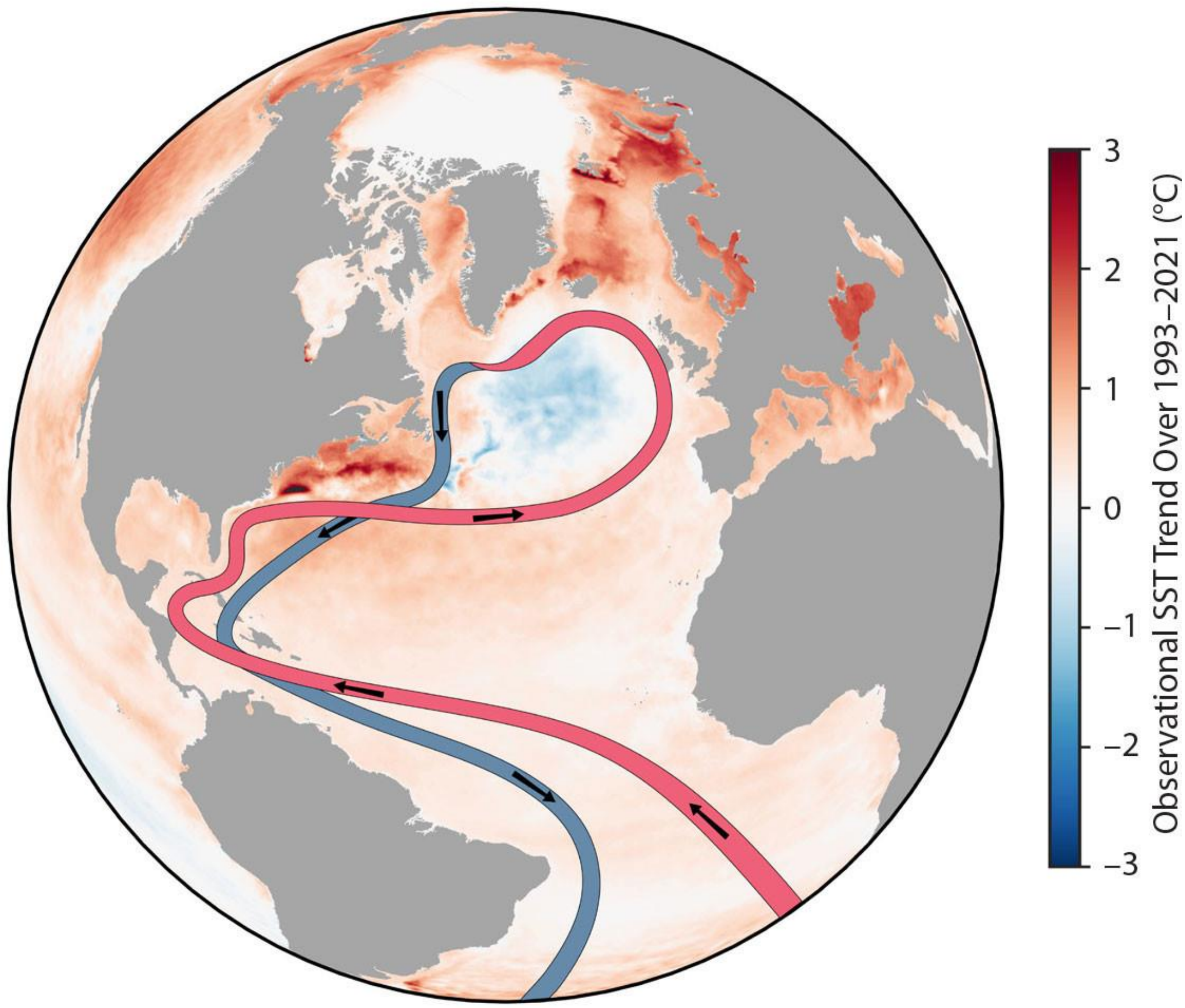

FIGURE 1. This graphic shows a highly simplified schematic of the Atlantic Meridional Overturning Circulation (AMOC) against a backdrop of the sea surface temperature trend since 1993 from the [Copernicus Climate Change Service](). *Image credit: Ruijian Gou*. [> High res figure]()

In the North Atlantic, the overturning circulation moves heat at a rate of one petawatt (1015 Watt; Trenberth et al., 2019), about 50 times the energy use of all humankind, or 3.5 times the rate of global ocean heat uptake in recent decades due to human-caused global warming (Z. Li et al., 2023). It delivers heat all the way up to the region south of Greenland and Iceland, and some even further north past Iceland into the Nordic Seas. There, it generously gives away its heat to the cold winds above until the water is so cold and dense that it sinks into the abyss, down to between 2,000 and 3,000 m depth. There it “flows as a great river, down the full length of the Atlantic" (Broecker, 1987). The heat released to the atmosphere makes the North Atlantic region much too warm for its latitude, particularly downwind of the ocean (Figure 2). It is also the main reason why the Northern Hemisphere is on average ~1.4°C warmer than the Southern Hemisphere, and why the thermal equator, the latitude where Earth is the hottest, is located at ~10° north of the geographic equator (Feulner et al., 2013).

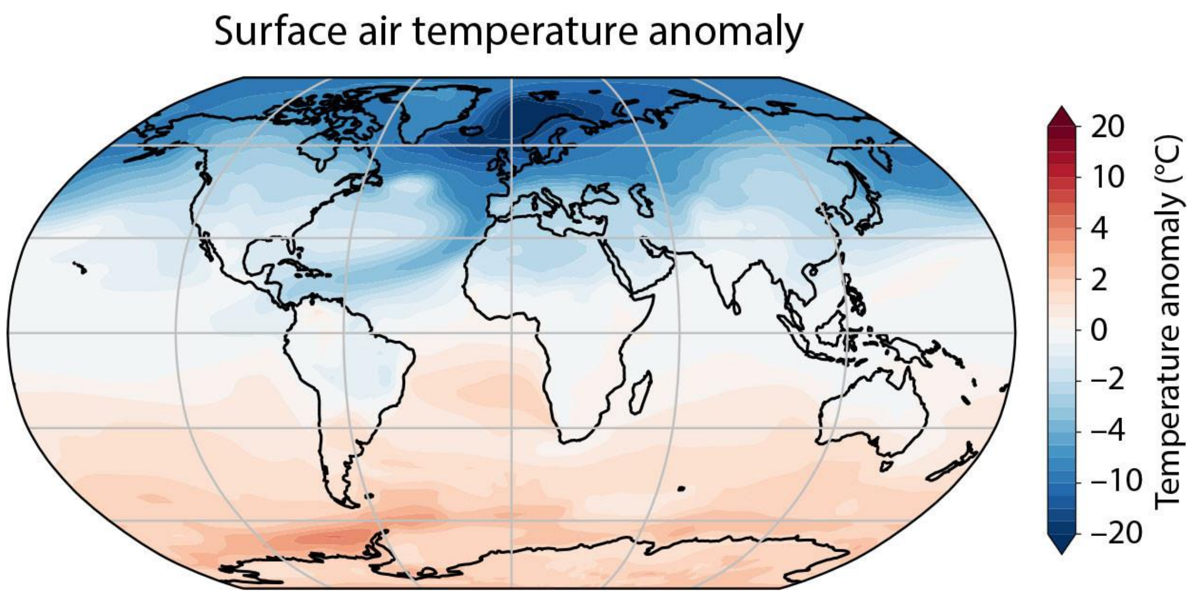

FIGURE 2. "The Earth's climatic system currently works in a way beneficial to northern Europe," the late Wally Broecker wrote (Broecker, 1987). This map shows what the world would be like without the AMOC. Nearly the entire Northern Hemisphere would be colder, especially Iceland, Scandinavia, and Britain. ***Figure by R. van Westen, adapted from van Westen et al. (2024)*****. > High res figure**

Temperature is not the only key ingredient of the AMOC—the second factor is salinity: the saltier the water, the denser it is. Salinity is therefore an important factor for the sinking described above. Hence, this overturning circulation is also called *thermohaline* circulation, meaning a circulation driven by temperature and salinity differences, in contrast to circulation driven by wind and tidal currents. While temperature has a stabilizing influence on the AMOC, salinity has the power to destabilize it.

WHERE IS THAT TIPPING POINT?

… observational data suggest the real AMOC is in the bistable regime, meaning relatively close to the critical point. In contrast, in most models, the AMOC is in the monostable regime, far away from the tipping point (see the review by Weijer et al., 2019). The reason is apparently subtle biases in the Atlantic salinity distribution in the models. This salinity distribution can be nudged toward more realistic, observed salinity values, rather than letting the salinity evolve freely under the influence of computed rainfall, evaporation, and ocean currents. When this was done in a climate model, the AMOC collapsed in a scenario of doubling CO2 concentration, while it remained stable in the original unadjusted model (Liu et al., 2017).

Boers (2021) analyzed four temperature and four salinity data series that have been linked to AMOC strength and concluded there is "strong evidence that the AMOC is indeed approaching a critical, bifurcation-induced transition." In another study, Michel et al. (2022) used 312 paleoclimatic proxy data series going back a millennium and found a "robust estimate, as it is based on sufficiently long observations, that the Atlantic multidecadal variability may now be approaching a tipping point after which the Atlantic current system might undergo a critical transition." In 2023, Danish researchers made news headlines with their "warning of a forthcoming collapse of the AMOC," starting any time between 2025 and 2095 and most likely around the middle of this century (Ditlevsen and Ditlevsen, 2023). A recent study by the Dutch group at Utrecht University—one of the world's leading research groups on AMOC stability—introduced a "new physics-based early warning signal [which] shows AMOC is on tipping course" (van Westen et al., 2024).

All of these predictions have their limitations—for example, changes in the variability might conceivably have other reasons than an approaching tipping point. But the fact that all these studies, using different methods, point in the same direction, toward a risk that is much larger and earlier than we had thought until a few years ago, is a major concern. My assessment of these early warning signal studies is that by the time they can provide a reasonably reliable warning of an impending AMOC tipping, it will be too late to prevent it. In this situation, the only responsible policy reaction is to be guided by the precautionary principle (i.e., the responsibility to protect the public from harm when scientific investigation has found a plausible risk).

To some extent, tipping may even depend on the vagaries of weather. In NASA's climate model, in 10 simulations using the same "middle-of-the-road" greenhouse warming scenario (SSP2–4.5) with under 3°C global warming, the AMOC collapses in two but recovers after significant weakening in eight; the difference is merely stochastic internal variability (Romanou et al., 2023). This is also part of the nature of tipping points.

Apart from a full shutdown of the AMOC, there is still the second type of tipping point to consider, the one where convection shuts down in one region. That happens in a surprising number of climate models, and so far hasn't gotten the public attention it deserves. The first documented case, the British Hadley Centre model, was published in 1999 (Wood et al., 1999). Of the latest model generation (CMIP6), in four out of the 35 models, subpolar gyre convection breaks down—and all four are in the group of the 11 best models in terms of reproducing the vertical density profiles in the subpolar gyre (Swingedouw et al., 2021). That's in 36% of those high-quality models. In the previous model generation (CMIP5), that number was 45%. What's more, it typically happens as soon as the year 2040 and for moderate emission scenarios—even without properly accounting for Greenland melt. Thus, a collapse of convection in the subpolar gyre, resulting in rapid AMOC weakening and abrupt regional cooling, must be considered a high risk urgently requiring attention.

IMPLICATIONS: UNCERTAINTY IS NOT OUR FRIEND

The risk of a critical AMOC transition is real and very serious, even if we cannot confidently predict when and whether this will happen. We have already left behind the stable Holocene climate in which humanity has thrived (Osman et al., 2021), and the latest IPCC report warns us that beyond 1.5°C of global warming, we move into the realm of "high risk" with respect to climate tipping points (IPCC, 2023).

Also at risk is the Southern Hemisphere equivalent of the northern Atlantic deep-water formation: the Antarctic bottom-water formation. A recent study by Australian researchers concluded that the increasing meltwater inflow around Antarctica is set to dramatically slow down the Antarctic overturning circulation, with a potential collapse this century (Q. Li et al., 2023). That will slow the rate at which the ocean takes up CO_2 (hence, more will accumulate in the atmosphere), and it will reduce the oxygen supply for the deep sea.

A full AMOC collapse would be a massive, planetary-scale disaster. We *really* want to prevent this from happening.

In other words: we are talking about risk analysis and disaster prevention. This is not about being 100% or even just 50% sure that the AMOC will pass its tipping point this century; the issue is that we'd like to be 100% sure that it won't. That the IPCC only has "medium confidence" that it will not happen this century is anything but reassuring, and the studies discussed here, which came after the 2021 IPCC report, point to a much larger risk than previously thought.

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"We aren't just failing to address the growing climate crisis to come; we're unprepared even for the impacts already here—in part because they keep surprising us with their intensity and in part because we can't seem to fathom our genuine vulnerability." – David Wallace Wells
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