OCEANOGRAPHY

Fresh news from the Atlantic

The Atlantic overturning circulation plays a key role in large-scale climate but how it varies is not well known. Now a study proposes that the weakening it may have experienced in the late 1970s is unprecedented over the last millennium.

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The Atlantic Ocean is the stage for one of the greatest oceanographic characters: the Atlantic Meridional Overturning Circulation (AMOC). This large-scale oceanic circulation links the surface and deep ocean through convection processes occurring in the North Atlantic. It brings warm waters from the tropics to the North Atlantic, where they cool, sink and return southwards at depth[1]. The associated net transport of heat plays a pivotal role in the climate of the regions bordering the Atlantic. For example, decadal variability of this circulation is believed to influence changes in Atlantic hurricane activity[2] or frequency of droughts in the Sahel, in Africa[3]. Nevertheless, past changes in the AMOC are still not well understood due to the very short period of available reconstructions. A few estimates for the last 50 years propose that a substantial weakening of the AMOC has occurred in the 1970s[4], followed by a recovery in the 1990s[5]. Writing in *Nature Climate Change*, Stefan Rahmstorf and colleagues[6] report that the AMOC minimum in the late 1970s may have been the lowest over the last millennium.

To reach such a conclusion, the authors examine recent changes in the AMOC in the context of a much longer time period. This is achieved by the development of a new AMOC index — an indicator of its strength — based on sea surface temperature (SST) anomalies in the North Atlantic compared with SST averaged over the Northern Hemisphere to remove the influence of external radiative forcings, such as solar variations or volcanic eruptions. The index is validated using a climate model simulation, where all physical variables, including AMOC, are available. Then, a reconstruction of North Atlantic SST over the last millennium[7] — based on indirect evidence, mainly from continental proxies (such as tree-ring measurements) alongside an extrapolation method for covering ocean basins — allows application of this index with real data. From this, the authors find that the minimum AMOC strength observed in the late 1970s was never matched in the last millennium, and as such represents an exceptional event.

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Iceberg in the North Atlantic. According to Rahmstorf *et al.*[6], the melting of the Greenland ice sheet over the twentieth century may have lead to an exceptional weakening of the oceanic circulation in the North Atlantic in the 1970s. This photo was taken off the tip of Greenland, during an OVIDE oceanographic cruise in 2010.

The occurrence of this minimum is confirmed in other ocean circulation indicators, such as isotopic measurements from corals collected in the western Atlantic, which are very sensitive to nutrient supply brought by the Atlantic circulation[6]. Furthermore, analysis of the frequency characteristics of the AMOC reconstruction for the last millennium shows large variability over 20–30 year time periods. These findings may lead to new insights for improving decadal prediction, a topic under study in many institutes[8].

So what causes this exceptional weakening? The attribution appears very tricky and would deserve dedicated model simulations to estimate the role of natural and anthropogenic forcing or internal variability intrinsic to the climate system. Rahmstorf *et al.*[6] do not develop such a framework but still formulate an interesting hypothesis. Based on a recent reconstruction of mass balance for the Greenland ice sheet covering the whole of the twentieth century[9], they suggest that the melting, which started early in the century, has released enough fresh water to freshen the North Atlantic surface ocean, reduce its density and therefore convection and AMOC strength.

Classical interpretation concerning the 1970s AMOC minimum is instead related to the so-called great salinity anomalies. Large events freshening the surface ocean occurred

in the North Atlantic in the early 1970s, 1980s and 1990s. The 1970s event was very large and has been associated with a sea-ice pulse coming from the Arctic through Fram Strait into the North Atlantic. This sea ice melts in the Labrador Sea, decreasing the surface salinity and density there, leading ultimately to an AMOC weakening. It makes sense that the combination of both factors (Greenland melting and sea-ice pulse) could have piled up to explain the extreme minimum reported here[6].

Nevertheless, climate model simulations (even with greater glacial melting in Greenland than observed) found lower sensitivity of the AMOC[10] than reported by Rahmstorf and colleagues. Thus, a further implication from this study[6] is that current climate models may greatly underestimate AMOC sensitivity to melt from the Greenland ice sheet. Consequently, model projections that propose a moderate AMOC weakening in the coming century[11] may be flawed.

Caveats of the Rahmstorf *et al.* study moderate this claim. Paleoclimate reconstructions are very useful to provide broader insight, here on decadal to centennial AMOC variations, but they usually exhibit an important loss of variance as we move back in time. This is related with a smoothing effect of the indirect indicators, which filters out high frequency signals. This drawback from past reconstructions can clearly affect the main conclusions of the paper, which remain to be taken very cautiously.

The results from Rahmstorf *et al.* may shed light on the so-called warming hole in the Atlantic. Indeed, when looking at the SST trend over the past century, it is surprising to notice that the North Atlantic is slightly cooling while most of the rest of the ocean is warming[11]. The long-term weakening trend of the AMOC over the twentieth century, as reported here, may explain this feature, through a decrease in heat transport in the North Atlantic.

A new weakening of the AMOC was monitored over the last decade[12]. Rahmstorf *et al.* results also put this new fluctuation into a broader context, which may indicate that the 1990s recovery was just a short-term increase into a longer-term decrease that may have started a century ago. ❐

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