CLIMATE SCIENCE

Atlantic slowdown boosts surface warming

The circulation system of the North Atlantic Ocean has weakened and is predicted to weaken further in the coming decades. An analysis suggests that this decline could lead to accelerated global surface warming. SEE LETTER P.387

GERARD D. MCCARTHY & PETER W. THORNE

Global surface temperatures rose steadily from 1975 to 1998, but this growth then slowed somewhat for about 15 years — an event that gained popular attention[1] as a 'hiatus'. Since then, we have experienced the four warmest years on record, which has served to dampen popular interest in the event. However, because climate change is a complex response to slowly varying external drivers, it is important to fully understand past climate behaviour and the underlying causes. On page 387, Chen and Tung[2] report that the system of ocean currents known as the Atlantic Meridional Overturning Circulation (AMOC) can explain changes in rates of global surface warming. Rather than the conventional picture of a vigorous AMOC associated with elevated surface temperatures in the Atlantic Ocean, the authors emphasize the role of the AMOC in taking heat from the surface and storing it in the deep ocean.

The connection between the AMOC and variations in the heat content of the subpolar North Atlantic Ocean has long been acknowledged. The AMOC transports heat northwards to the subpolar North Atlantic and to the Greenland, Iceland and Norwegian Seas. There, through a range of processes, deep water is formed that moves as a southward cold flow. This conveyor belt of northward-flowing, warm, shallow water and southward-flowing, cold, deep water defines the AMOC.

Relative to latitudinal averages, surface temperatures could be 5 °C cooler in the subpolar North Atlantic Ocean and up to 10 °C cooler in the Norwegian Sea if the AMOC were absent[3]. Consequently, a strong AMOC is typically associated with warming in the Northern Hemisphere. This association is consistent with evidence from palaeoclimatology that suggests that, during the most recent ice age, warmer periods coincided with a vigorous AMOC and colder periods coincided with a weak AMOC[4].

Chen and Tung's study emphasizes a different role for the AMOC in the modern climate. Atmospheric concentrations of greenhouse gases are currently being increased at a rate that is unprecedented in millennia and most likely millions of years. As a result, the role that climate mechanisms might have had in the past might not be a good guide to their current or future role. The authors contend that half of the heat arising from ever-increasing greenhouse-gas concentrations is stored in the deep waters of the North Atlantic when the AMOC is increasing, thereby reducing overall global surface warming (Fig. 1).

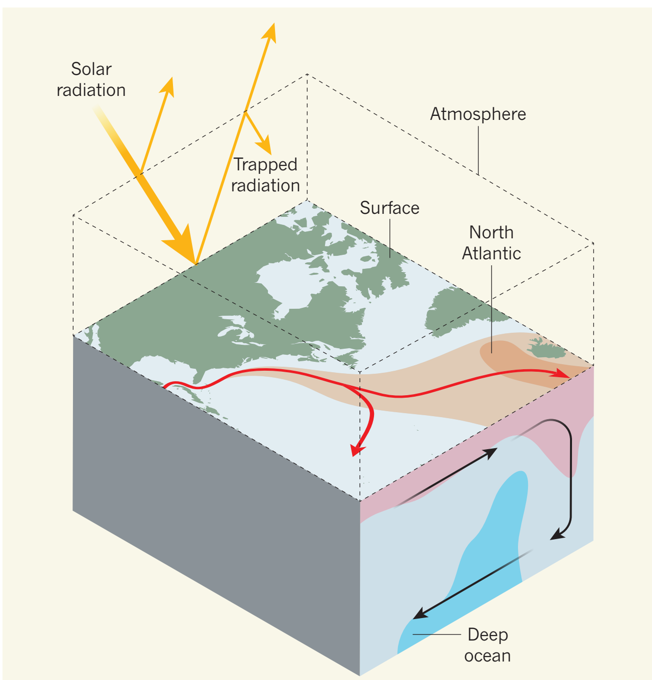

Figure 1 | The role of Atlantic circulation in the modern climate. Increasing atmospheric concentrations of greenhouse gases mean that more incoming solar radiation is trapped in the atmosphere, a consequence of which is surface warming. Chen and Tung[2] report that the ocean circulation system known as the Atlantic Meridional Overturning Circulation (AMOC) can offset this warming. The AMOC transports heat northwards (red arrows) in the North Atlantic Ocean; the light- and dark-orange colours indicate regions that are 5 °C and 10 °C warmer, respectively, than latitudinal averages. The authors emphasize the role of the AMOC in transporting heat from the surface to the deep ocean (black arrows); the pink and blue colours indicate regions where heat increases and decreases, respectively, when the AMOC is increasing (based on Fig. 2a of ref. 2).

The authors show that a cycle of increasing and then decreasing AMOC from the 1940s to the mid-1970s coincided with a period of global-warming slowdown; a quiescent period of weak AMOC from the mid-1970s to the late 1990s coincided with rapid global warming; and an increase in AMOC strength from the late 1990s to 2005 and a decrease thereafter coincided with the 'hiatus' in global warming (see Fig. 3 of the paper[2]).

When the causes of the 'hiatus' were first being investigated, the Atlantic was not an obvious place to look. The focus was on the Pacific Ocean because the tropical Pacific was one of the only places where surface temperatures did not rise during this period[5]. Understanding of the event developed as several factors were taken into account, including the effect of changes in ocean heat content across multiple ocean basins[6]. Chen and Tung now bring focus to the North Atlantic. Their work suggests that the warm surface temperatures there were indicative of an increasing AMOC and that the associated increase in ocean heat uptake played a key part in the 'hiatus'.

One of the main caveats of Chen and Tung's study is that, by necessity, the authors used proxies for AMOC strength because no direct observations of sufficient length exist. There are only four observatories that measure the AMOC across the full width of the Atlantic: SAMBA at 34.5°S, RAPID at 26°N, NOAC at 47°N and OSNAP between 53°N and 60°N. The longest-running, RAPID, was deployed in only 2004. These observatories need to be maintained for many decades if we are to fully understand the role of the AMOC in our changing climate.

There is much to be done to determine how the AMOC affects surface temperature in different regions and on different timescales. For instance, Chen and Tung highlight the potential role of the Southern Ocean in heat uptake in the period since 2005. Such a feature could be part of a see-saw pattern of alternating heat uptake by the North Atlantic and Southern Ocean.

There is also a distinct difference between the effects of decadal AMOC variability and of an AMOC collapse on global temperatures. Although the prospect of the AMOC passing a tipping point and collapsing is considered unlikely, it is not impossible, and an event this dramatic could lead to global surface cooling[7]. The threshold between a weak AMOC that reduces ocean heat uptake, allowing global surface temperatures to rise unabated, and a very weak or collapsed AMOC that causes cooling in the North Atlantic and global surface warming to slow or stop will be a key point of debate.

The AMOC is deemed "very likely" to weaken in the coming decades[1]. Indeed, the Atlantic has seen muted rises in surface temperature relative to the global ocean over the past few decades. This relative lack of warming has been interpreted as a fingerprint of AMOC decline, potentially linked to anthropogenic climate change[8]. Whether the AMOC observatories will document the predicted decline remains to be seen, but they have already observed that the AMOC is in a weakened state[9]. Chen and Tung predict that such a weak AMOC will result in a period of rapid global surface warming that could last for more than two decades. ■

Gerard D. McCarthy *and* **Peter W. Thorne** *are at the Irish Climate Analysis and Research Units (ICARUS), Department of Geography, Maynooth University, Maynooth, Ireland.*
e-mails: gerard.mccarthy@mu.ie; peter.thorne@mu.ie

1. Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC, 2014).
2. Chen, X. & Tung, K.-K. *Nature* **559**, 387–391 (2018).
3. Jackson, L. C. *et al. Clim. Dyn.* **45**, 3299–3316 (2015).
4. Kosaka, Y. & Xie, S.-P. *Nature* **501**, 403–407 (2013).
5. Medhaug, I., Stolpe, M. B., Fischer, E. M., & Knutti, R. *Nature* **545**, 41–47 (2017).
6. Broecker, W. S. *Oceanography* **4**, 79–89 (1991).
7. Drijfhout, S. *Sci. Rep.* **5**, 14877 (2015).
8. Caesar, L., Rahmstorf, S., Robinson, A., Feulner, G. & Saba, V. *Nature* **556**, 191–196 (2018).
9. Smeed, D. A. *et al. Geophys. Res. Lett.* **45**, 1527–1533 (2018).

BIODIVERSITY

Speciation far from the madding crowd

New species of marine fishes are found to emerge at a faster rate in high-latitude oceans, which have lower densities of species, than in the species-rich tropics. Are the tropics too crowded for new species to take hold? **SEE LETTER P.392**

ARNE O. MOOERS & DAN A. GREENBERG

The tropics are, like many cities, hot, busy and crowded. It was previously thought[1] that these conditions in the tropics generate a hotbed for the formation of new species (speciation). Species diversity is remarkably high in the tropics and declines toward the poles. However, newly developed tools to measure speciation rates, coupled with ever-growing global data sets, have enabled the surprising finding that terrestrial speciation rates for the past few million years are similar across different latitudes[2] or increase outside the tropics[3]. On page 392, Rabosky *et al.*[4] document a speciation rate for marine fishes at high latitudes that is twice the speciation rate in tropical seas. This high speciation rate in cold, species-poor waters poses an interesting conundrum for evolutionary biologists and ecologists.

There are two potential drivers of high speciation rates in the tropics. First, the elevated temperatures in the region both speed up metabolism, increasing the number of mutations, and decrease generation times. This is a potentially powerful combination, producing more of the variation necessary for evolution and the possibility of faster evolution. A second possible driver is ecological opportunity. The energy-rich tropics offer abundant resources that can support many different niches. And the tropics are so rich in species that the interactions of members of a single species with its competitors, predators and parasites might differ from place to place, leading to different adaptations and eventual divergence into new niches[1]. Although this narrative makes for a compelling theory, Rabosky and colleagues' discovery suggests a different story, at least for marine fishes.

The authors gathered genetic data for 11,638 species of marine and freshwater fish, along with information on inferred evolutionary relationships based on taxonomic groupings for 19,888 additional fish species for which genetic data were not available. Using these data, and information from 139 dated fossil fishes, the authors generated a large set of plausible phylogenetic trees detailing the evolutionary relationships between all living marine fishes, and, crucially, estimates of when different lineages diverged from one another. These dated trees enable speciation rates to be inferred on the basis of the branching patterns of the tree. Species connected by short branches, and with many close relatives, have high speciation rates, whereas species that are separated by long branches and that have few close relatives have low speciation rates.

Most taxonomic groups are made up of lineages with both low and high speciation rates. The marine fishes in the authors' large phylogenetic trees were no exception, with

50 Years Ago

More than 7,000 people died in traffic accidents last year in Britain and nearly 94,000 were seriously injured … The causes and possible preventative measures were the subject of a recent conference … A police traffic superintendent is reported to have said that the defect which causes nearly every accident lies in "the nut holding the wheel". One contributor pointed out that road engineers should not assume that drivers are omniscient. "If asked to make more than one decision at a time, they will fail; if faced with a situation which can be misinterpreted, someone will eventually find the wrong meaning". The effect of human fallibility is easily apparent in the statistics … during the last three months of 1967 … after the breathalyser test came into operation … driver and passenger casualties fell by 19 per cent, motor cyclist casualties by 16 per cent and pedal cyclists by 14 per cent.
From *Nature* 20 July 1968

100 Years Ago

The utility of forests to a nation is one of the economic factors to its well-being which have been brought to an unforeseen prominence during the world-war: and perhaps to no other European nation has this … development proved so startling, because so totally unsuspected, as to ourselves. Our woods were not grown from the commercial aspect — sport, amenity, and shelter to crops and stock were their main *raison d'être*. We did not consider it necessary to grow woods for purely commercial reasons — that is, for the sake of the timber and pit wood and paper pulp, etc … We obtained our requirements in these commodities by importing them from abroad, and relied on the Navy being able to safeguard these imports. We have now discovered our mistake and are paying for it.
From *Nature* 18 July 1918