

OCEANOGRAPHY

Sea change

The Atlantic meridional overturning circulation delivers warmth to high latitudes and carbon to depth. Historical temperature and salinity records call into question the traditional view that these waters form a single coherent conveyor system of currents.

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Warm surface water travels northwards in the Atlantic ocean, raising the temperature of western Europe. After giving up its heat to the overlying atmosphere, some of this water sinks and returns southwards at depth; the remainder flows south in the overlying surface layer (Fig. 1). Model simulations suggest that this system of currents, coined the Atlantic meridional overturning circulation (MOC), has slowed slightly since the mid-nineties¹. Predictive models suggest that this trend is set to continue over the next century². Writing in *Nature Geoscience*, Lozier and colleagues³ use historical records of pressure, temperature and salinity in the North Atlantic to show that during the latter half of the twentieth century, the overturning circulation weakened in subtropical waters, but strengthened in subpolar waters.

The strength of the Atlantic MOC is presently assessed by measuring total northward transport of water across the 26° N latitude line in the upper layer of the Atlantic Ocean. An extensive array of instruments at this latitude has provided daily estimates of the strength and variability of the overturning circulation since 2004⁴. These observations, together with numerical simulations, suggest that the Atlantic MOC is highly variable on weekly to intra-annual timescales.

Thus, long and highly resolved records are required to discern significant long-term trends. Unfortunately, the only available observational estimates of the MOC during the past century are derived from a few sparse transects of temperature and salinity measurements across the Atlantic Ocean⁵.

Lozier *et al.*³ show that past changes in the Atlantic MOC are latitude-specific, using hydrographic data collected between 1950 and 2000. They combined spatially extensive records of pressure, temperature and salinity with a numerical model to estimate the strength of the overturning circulation over two time periods: 1950–1970 and 1980–2000. What they found was not a spatially coherent change in the Atlantic MOC, but instead a small but significant

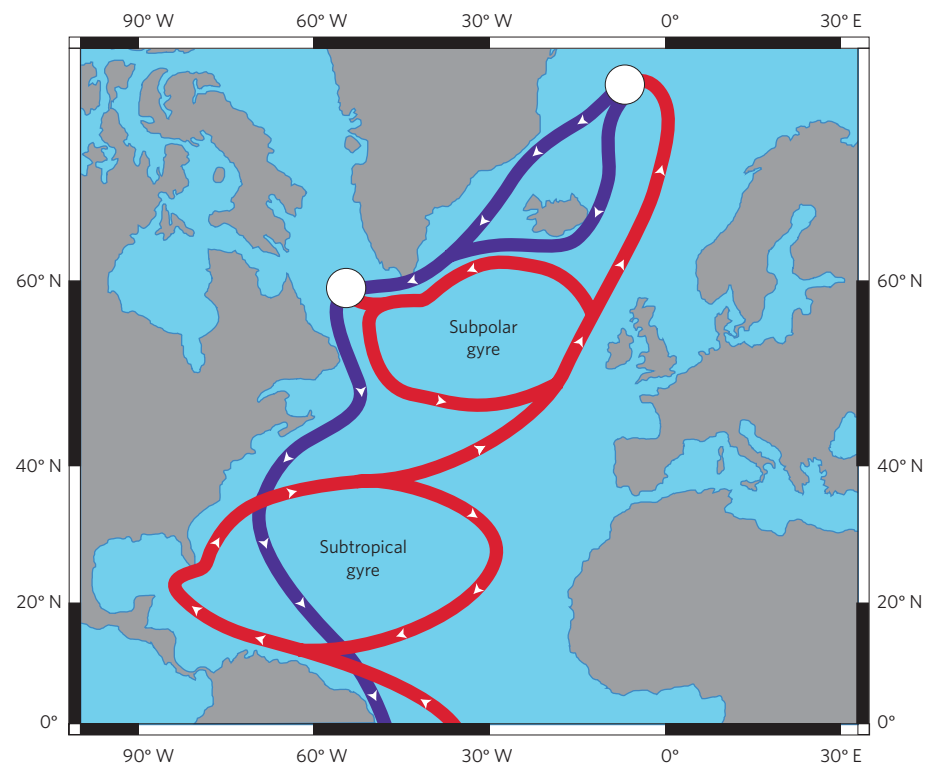


Figure 1 | The Atlantic MOC. Warm surface waters (red) flow northwards in the Atlantic MOC, losing heat to the atmosphere. At convection sites (white circles), they sink and return southwards at depth (dark blue). Lozier *et al.*³ use Atlantic Ocean pressure, temperature and salinity records to show that the Atlantic MOC weakened in the region of the subtropical gyre, but strengthened in the region of the subpolar gyre, over the second half of the twentieth century.

decrease in strength in the subtropical gyre region between 10 and 40° N, and a small but significant increase in strength in the subpolar gyre region between 50 and 60° N. A change between two periods of time is, of course, not indicative of an overall trend. However, the fact that the sign of the change and its latitudinal pattern was consistent across a large number of random subsets of the data suggests that it corresponded to an underlying shift in ocean dynamics.

It is, perhaps, not surprising that changes in the overturning circulation are latitude-dependent. Weekly to seasonal variations in the strength of the Atlantic MOC change

substantially with both latitude and depth, according to numerical models⁶. The picture that emerges contradicts the traditional view of a coherent system of currents, whose strength is governed primarily by high-latitude cooling and convection on annual to decadal timescales, and by global energy sources such as winds and tides on longer timescales⁷. However, the impact of these localized circulation changes on climate — for example, northward heat transport or deep-water replenishment at the poles — remains uncertain.

The convention of characterizing the Atlantic MOC with only a single measure

neglects not only latitudinal variations. The strength of this circulation system is derived by integrating a complex three-dimensional system of currents along latitude lines, and therefore also neglects variations in circulation with longitude. When modelling the Antarctic Circumpolar Current, such a two-dimensional view is highly misleading: there it suggests that surface water sinks to the deep ocean⁸, when in fact, it drops only a few hundred metres at most as Antarctic intermediate water is formed. Key processes, such as the convective mixing of surface and deep water, are also missed when only net downward or northward transport is considered⁹. The extent to which zonally integrated measures of the

Atlantic MOC similarly misinform climate studies in the North Atlantic is unclear.

Lozier *et al.*³ provide clear evidence for latitude-dependent changes in the Atlantic MOC. Combined with the limitations associated with zonal integration, their findings suggest the need for alternative measures of this circulation system that address the specific problem being studied. For the climate of western Europe, heat transport at a specific latitude may be the most informative property. For the carbon cycle, it would be more important to determine the rate at which deep water is replenished by surface waters. The overarching challenge for climatologists is to discern how a changing climate will affect each of these measures separately. □

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