enhances it. As the associated increased salt transport brings denser water into the sinking region and so helps the conveyor intensify, more heat is advected from lower latitudes by the same mechanism. This erodes the cold anomaly and eventually creates a warm pool in the same region. Geostrophy now requires an anticyclonic gyre which weakens the thermohaline circulation by carrying fresher and colder waters in the mid-ocean southwards, against the direction of the time-mean conveyor belt.

Budget calculations in this region indicate that the fluctuation is mainly due to periodically varying meridional fluxes of heat and salinity. Ocean-to-atmosphere exchange is important for heat (it slowly removes temperature anomalies) but not for salt; surface fluxes of fresh water vary only slightly during a cycle. This indicates that the fluctuation is mainly oceanic and could, with suitable surface boundary conditions, be simulated in ocean-only models. But classical 'mixed boundary conditions' (where heat fluxes are proportional to temperature anomalies, freshwater fluxes are constant) will not do the trick, as it is known that they thermally couple the atmosphere too tightly to the ocean. As Delworth and colleagues show, the persistence of sea-surface-temperature anomalies is a central part of the proposed mechanism and also acts to stabilize the North Atlantic circulation.

Although the fluctuations in the model are initiated at the sea surface, their effects can be traced both in the deep Atlantic and in the atmosphere of the Northern Hemisphere. Salinity and temperature profiles show changes that reach beyond 3 km depth in the sinking region between 52° and 72° N in the Atlantic. Surface air temperatures also follow the oceanic oscillation, and distinct anomaly patterns are expected, especially in winter months when a stronger thermohaline circulation transports enough heat northward to reduce ice cover. During that phase of the oscillation a negative pressure anomaly develops, centred southeast of Greenland, bringing a warming of about 1 °C over the northern North Atlantic and a significant cooling of about 1.5 °C over the Labrador Sea.

The modelled oscillation is distinctly irregular, a common feature in nonlinear dynamical systems. Although the first 200 years of the integration show a quasi-periodic cycle of 40–50 years, the periods are longer in the following 400 years. It seems that some preconditioning of the ocean at a particular location is required, and that the fluctuation itself may remove or add to it. Other model calculations also point at a centre of action in the northern North Atlantic and Labrador Sea^{4,5}, and they also show oscillations on timescales of 10–40 years, although these are due to somewhat different mechanisms.

What adds weight to the model results is that observational studies indicate distinct and coherent changes in the ocean and atmosphere in this century. A hard look at global-mean temperature records reveals interdecadal (60–70 year) cycles and increased variability in the region of the North Atlantic². A long-term cooling trend from the late 1950s to early 1970s, in the top 1,500 m of the Atlantic Ocean at 34° N, follows patterns of sea surface temperature and salinity anomalies^{6,7} that are similar to the modelled differences between times of strong and weak thermohaline circulation. Waters in the central Labrador Sea, too, have become cooler and fresher at intermediate depths during the past 25 years⁸, but with the coarse resolution of present models a direct comparison is not yet possible.

Perhaps the most intriguing piece of evidence for interdecadal cycles comes from a 1,480-year time series of summer temperatures reconstructed from tree-ring widths of pine from northern Fennoscandia⁹. The past 400 years of this proxy indicator show significant variance in the band of 30–40 years (see figure). Spectral analysis of sub-intervals indicates that these periods themselves are variable¹⁰, as in the numerical simulation. Delworth and colleagues' model could provide a natural mechanism for such cycles (previous interpretations have had to invoke some nonlinear interaction between solar forcing and atmospheric temperatures).

Given the paramount importance of the thermohaline circulation and its variability for the climate system, what should the next steps be? Enlarging the observational data set in key regions such as the North Atlantic and Labrador Sea area must be one priority. And numerical models must be refined to give a better representation of how deep water masses are formed and distributed, plus improved compatibility of atmospheric and oceanic heat, freshwater fluxes, and air–sea interaction. We will then gain more of a feel for the robustness of such cycles. □

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Electric squeezer

DAEDALUS has been musing on the pinch effect, which applies a sort of 'electric pressure' to the surface of a current-carrying wire. He argues that molecules adsorbed on the surface should feel this pressure too. Many catalytic chemical processes depend on high pressures. The chemical industry is overburdened with massive reaction vessels, heavy-gauge pipework, compressors and so on. Daedalus wants to use the pinch effect to dodge all this expensive complexity.

Imagine, he says, a wire suspended in a mixture of hydrogen and nitrogen, and coated with ammonia-synthesis catalyst. Pass a current through the wire, and its catalytic surface and the gas molecules adsorbed on it would feel the pinch pressure. A sufficiently heavy current would give a surface pressure high enough to combine the adsorbed gases into ammonia and to liquefy the product. If the wire were porous with a central duct, the liquid ammonia would be forced inwards as fast as it formed, and would run out of the ends of the duct in a steady stream. All the desperate high-pressure engineering of conventional synthesis would be neatly evaded.

The same trick would work in other pressure technologies, even outside the chemical industry. A porous pinch-effect wire in a refrigerant vapour could act as a silent freezer–compressor. In air it would form a simple, elegant and continuous dehumidifier, and an extractor of condensable polluting vapours. In both cases the wire would need a heat sink to the outside to remove both ohmic heating and latent heat of condensation: a small complication to an otherwise elegantly simple design.

Daedalus also reckons that the principle could revolutionize electric lighting. The old carbon-filament lamp rapidly deteriorated as its filament evaporated. The obvious answer is to drive so heavy a current through the filament that its surface pinch pressure exceeds the vapour pressure of the carbon. Evaporation would then be frustrated. Daedalus calculates that such a filament could be taken right up to 5,000 K, the melting point of carbon and almost as hot as the surface of the Sun. This brilliant new pinch-pressurized lamp will work on d.c. only, because the filament would evaporate during the zero current intervals in a.c. For the same reason, it will be restricted to tunnels, factories and security installations, where lamps run all the time: once lit, a pinch-pressurized lamp cannot be turned off. The instant the current ceases and the pinch pressure relaxes, the superheated filament will explode.

David Jones