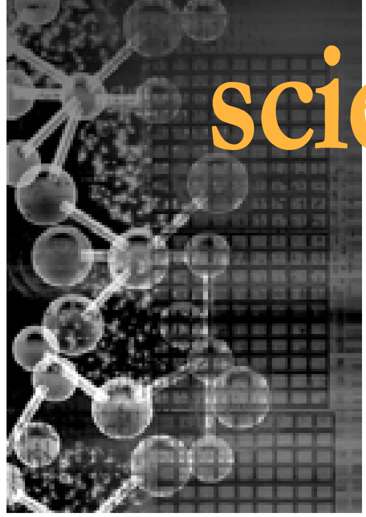

By Peter Symes

The Thermohaline Circulation Conveyor Belt

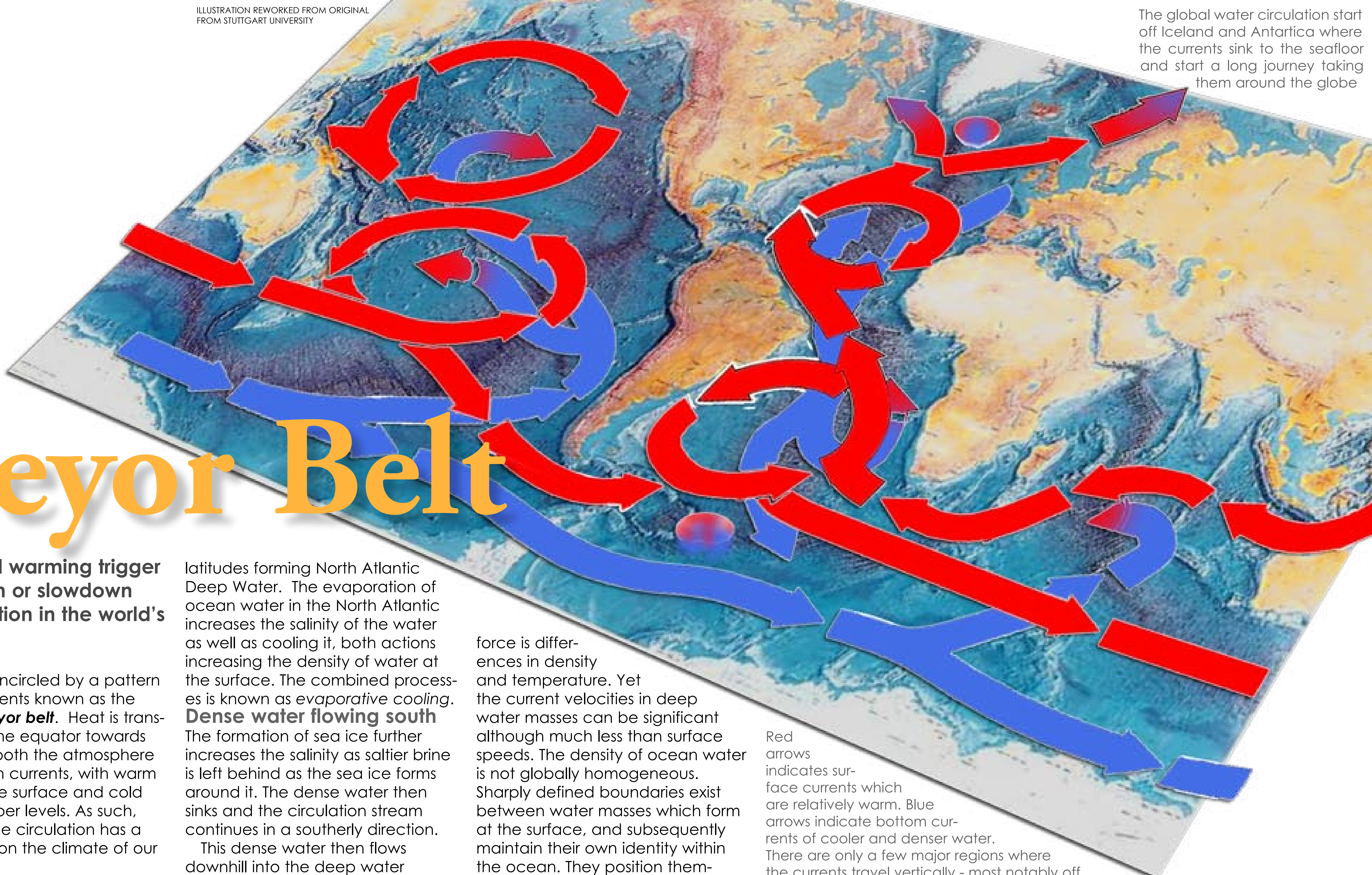

ILLUSTRATION REWORKED FROM ORIGINAL FROM STUTTGART UNIVERSITY

The global water circulation start off Iceland and Antartica where the currents sink to the seafloor and start a long journey taking them around the globe

Red arrows indicates surface currents which are relatively warm. Blue arrows indicate bottom currents of cooler and denser water. There are only a few major regions where the currents travel vertically - most notably off Greenland and Antartica where the currents sink

The **thermohaline circulation** is the term for the global density-driven circulation of the oceans. Term is derived from *thermo* (heat) and *haline* (salt), which together determine the density of sea water.

The vertical exchange of dense, sinking water with lighter water below it is known as *overturning*. Hence, another name, emphasizing the vertical nature and pole-to-pole character of this kind of ocean circulation, is the **meridional overturning circulation**.

Can global warming trigger a shutdown or slowdown the circulation in the world's oceans?

The globe is encircled by a pattern of ocean currents known as the ***ocean conveyor belt***. Heat is transported from the equator towards the poles by both the atmosphere and by ocean currents, with warm water near the surface and cold water at deeper levels. As such, the state of the circulation has a large impact on the climate of our planet.

Gulf Stream

The best known segment of this circulation is the Gulf Stream, a wind-driven gyre, which transports warm water from the Caribbean northwards where its effect in warming the atmosphere contributes to warming Europe, cooling all the while and eventually sinking at high latitudes forming North Atlantic Deep Water. The evaporation of ocean water in the North Atlantic increases the salinity of the water as well as cooling it, both actions increasing the density of water at the surface. The combined processes is known as *evaporative cooling*.

Dense water flowing south

The formation of sea ice further increases the salinity as saltier brine is left behind as the sea ice forms around it. The dense water then sinks and the circulation stream continues in a southerly direction.

This dense water then flows downhill into the deep water basins, steered by the bottom topography, only resurfacing in the northeast Pacific Ocean some 1200 years later. Extensive mixing therefore takes place between the ocean basins, reducing differences between them and making the oceans one global system.

In the deep ocean, where wind is absent, the predominant driving force is differences in density and temperature. Yet the current velocities in deep water masses can be significant although much less than surface speeds. The density of ocean water is not globally homogeneous. Sharply defined boundaries exist between water masses which form at the surface, and subsequently maintain their own identity within the ocean. They position themselves in layers according to their density, which depends on both temperature and salinity. This is known as "stratification"

Deep water masses

The dense water masses that sink into the deep basins are formed in quite specific areas of the North Atlantic and in the Southern Ocean. In the Norwegian Sea evaporative cooling predominates, and the resulting sinking water mass, called the North Atlantic Deep Water starts a slowly southward flowing current. The route of the deep water flow is through the Atlantic Basin around South Africa and into the Indian Ocean and on past Australia into the Pacific Ocean Basin. There is no corresponding flow from the Arctic Ocean Basin into the Pacific as the narrow Bering Strait is too shallow. By contrast in the Weddell Sea off the coast of Antarctica near the

It is not the thermohaline circulation that is the primary reason Western Europe is so temperate. Europe is warm mostly because it lies downwind of an ocean basin.

However, the thermohaline circulation does warm Western Europe by about 2 °C relative to the similarly located west coast of Canada.

edge of the ice pack, the effect the sinking water masses is predominantly caused by brine exclusion when the surface waters freeze. The resulting water mass, the Antarctic Bottom Water, then sinks and flows north into the Atlantic Basin. It is so dense it actually flows under the North Atlantic Deep Water. Once, flow into the Pacific is blocked, this time by the Drake Passage between the Antarctic Peninsula and the southernmost tip of South America forcing the current eastward.

Upwelling

What goes down must come up elsewhere. All these dense water masses sinking into the ocean basins displace the water above them, so that elsewhere water must be rising in order to maintain a balance. However, because this thermohaline upwelling is very widespread and diffuse, it has proven quite tricky to measure where upwelling occurs using current speeds, given all the other wind-driven processes going on in the surface ocean.

Deep waters do however have their own chemical signature and tracking trace elements of silicon from deep water there is clear indications, though not solid evidence, that the bulk of deep upwelling occurs in the North Pacific. A number of other models of ocean circulation place most of the deep upwelling in the Southern Ocean, associated with the strong winds in the open latitudes between South America and Antarctica. ■

So, Will The Gulf Stream Close Down?

In 2004 an analysis of satellite data demonstrated the North Atlantic Gyre, the northern swirl of the Gulf Stream, has been slowing markedly over time. Also The National Oceanography Centre in the UK found a 30% reduction in the warm currents that carry water north from the Gulf Stream from the last such measurement in 1992.

There is, however, presently no evidence for cooling in northern Europe or nearby seas but for quite the reverse. The bulk of available evidence seem to point that the Gulf Stream is relatively stable, whereas there is possibly a weakening of the North Atlantic drift.

In May 2005, investigations under the Arctic ice sheet found that the giant columns of sinking water, in which the cold dense water normally sinks down to the sea bed and is replaced by warm water, in turn generating the North Atlantic Drift had virtually disappeared. Out of normally seven to twelve giant columns, only two were found, both extremely weak.

This has led to some fear that global warming may be able to trigger the type of abrupt massive temperature shifts which occurred during the last ice age. It is also thought that it was large influxes of low density meltwater from the Greenland ice sheet leading to a disruption of deep water formation and subsidence in the extreme North Atlantic that eventually caused the climate period in Europe known as the Big Freeze which lasted for about 70 years in the 1300's.

It is very unlikely

It is, however, by no means clear that sufficient freshwater could be provided to interrupt thermohaline circulation. Present climate models indicate that it is not the case. While previous prehistoric shutdowns have caused cooling, the current overall climate is different; and sea-ice formation in particular is less because of overall global warming. Modelling also suggests that increase of fresh water flows large enough to shut down the thermohaline circulation should be at least an order of magnitude greater than currently estimated - and such increases are unlikely to become critical within the next hundred years.

In coupled Atmosphere-Ocean models the Termohaline Calculation tends to weaken somewhat rather than stop, and the warming effects outweigh the cooling, even locally. The North Atlantic is, actually, currently warmer than in the earlier measurements suggesting that either the circulation is not weakening, or that it does not have the hypothesised cooling effect - or that other factors are able to outweigh any cooling. ■