ORBIMAGE

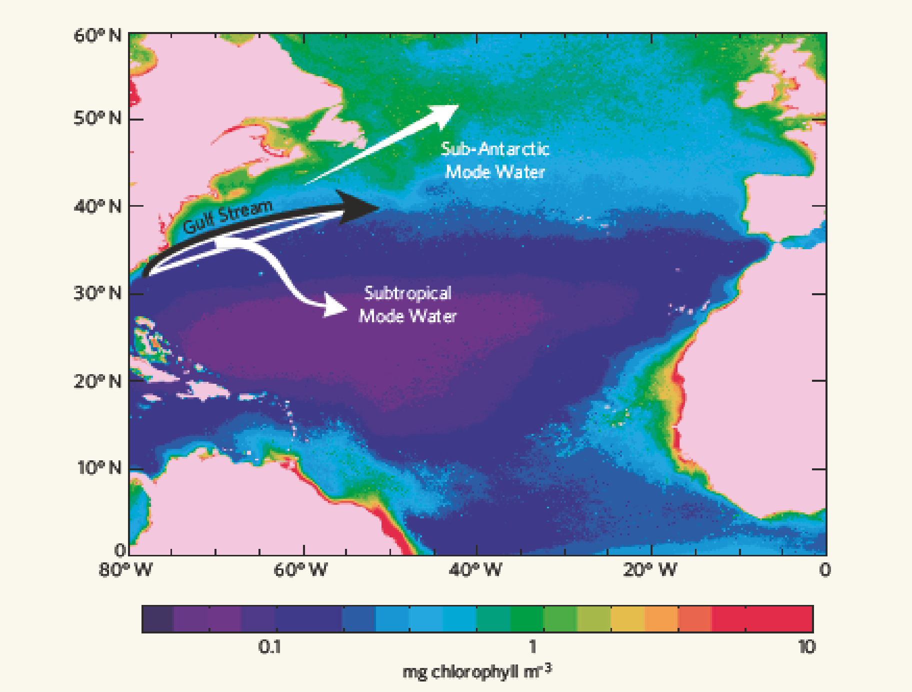

**Figure 1 | Distribution of surface chlorophyll in the North Atlantic.** Chlorophyll (as seen by the satellite-borne sensor SeaWiFS) is an index of phytoplankton biomass and therefore productivity. The region outlined in white shows where Subtropical Mode Water is formed. Palter and colleagues' explanation[1] of the western productivity minimum in the subtropical gyre is that it stems from the subsurface movement (lower white arrow) of nutrient-depleted Subtropical Mode Water from its site of formation. The western maximum in the subpolar gyre arises, by contrast, from the northern movement of nutrient-rich Sub-Antarctic Mode Water, and its delivery (upper white arrow) at the surface north of the Gulf Stream[4,5].

gyre (green region in Fig. 1). This is where nutrient levels in the subsurface reservoir come into the picture.

Palter *et al.*[1] show that the reservoir south of the Gulf Stream is fuelled laterally with Subtropical Mode Water, which forms to the north of the gyre and then circulates southwards beneath the surface. These subsurface water masses are particularly poor in nutrients, as measured in vertical profiles by the World Ocean Circulation Experiment. Palter *et al.* argue convincingly that the chlorophyll minimum in the western part of the subtropical gyre is the signature of this underlying, nutrient-depleted reservoir when it mixes with the surface waters (Fig. 1).

A likely explanation for the nutrient depletion in Subtropical Mode Water is that phytoplankton growth consumes nutrients on a large scale in winter, at the same time as the mode water is starting to subduct and embark on its subsurface journey. The remineralization process, which replenishes nutrients and occurs at depth, is inadequate to redress this initial nutrient loss on the timescales involved.

But how can winter phytoplankton growth be sustained before the onset of conditions that produce the especially vigorous burst of growth in spring? The answer may lie in a specific biological regime that pertains over the area of mode-water formation, in which light and nutrient limitations on growth are balanced in such a way that winter growth is greater than it is farther north and farther south. Such a 'mid-latitude regime' is evident in the northeast Atlantic[3], in a narrow band between 37° N and 43° N.

Complementary work by Williams *et al.*[4] fills in the picture in the subpolar gyre. They identify an opposite effect north of the Gulf Stream, in which mode waters are the primary cause of high phytoplankton productivity in the west of the subpolar gyre. In this case, it is the induction flux of nutrients that sustains the high productivity (Fig. 1) — induction is a subsurface-to-surface process and directly provides the sunlit layer with nutrients; subduction, by contrast, is a surface-to-subsurface process that affects the nutrient reservoir. This induction flux[4] covers a larger area on the western side than on the eastern side of the ocean basin, and so may also explain the east–west gradient in the subpolar gyre.

Using model diagnostics, Williams *et al.* go further, providing evidence that the induction flux is mainly composed of Sub-Antarctic Mode Water[5], which originates from the Southern Ocean and travels northwards along the western boundary of the Atlantic. This mode water is rich in nutrients, because it is formed in a 'high-nutrient, low-chlorophyll' region where low productivity is the norm.

This is not the end of the story. A further upshot of Palter and colleagues' investigations[1] is the recognition of a source of long-term variations, occurring on timescales of decades, driven by the slow cycle of mode waters. The authors suggest that a drop in the formation rate of Subtropical Mode Water was responsible for the large increase in phytoplankton production in the 1990s, compared with the 1960s, that was observed close to Bermuda (33° 22′ N, 64° 41′ W) downstream of mode-water formation. This is a counterintuitive proposal. Extended periods of cold winters

FLUID DYNAMICS

## Let us spray

The smaller a nozzle is, the faster water at the same initial pressure will spray out — and the smaller the emerging droplets will be. It is a commonplace phenomenon that often surprises, and sometimes delights (see picture). But what happens when the nozzle is very small? And what kind of nozzle produces the smallest droplets?

P. McGuinness and colleagues applied themselves to these questions (*J. Phys. D* **38**, 3382–3386; 2005). Their motivation was by no means a frivolous one: the answers are crucial to improving the resolution of inkjet printing, as well as being more generally applicable to industrial techniques requiring the manipulation of small liquid samples. In such cases, the high surface tension that develops at nozzles of micrometre diameters could limit the scope for reducing droplet size.

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So the authors tested different sizes and shapes of small nozzles, using numerical techniques based on the Young–Laplace equation, which relates the pressure difference at a gas–liquid interface to its geometry. For two-dimensional (planar) nozzles, a triangular opening with sides curved slightly inwards proved the best choice: compared with a conventional, circular opening at the same pressure, it provided a 16% reduction in droplet volume.

But the authors didn't stop there. By bending the corners of the curvilinear triangle up or down to form a non-planar nozzle tip, they were able to bring the reduction in volume to around 33%. As they point out, this adds another dimension to questions of small-droplet generation.

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