still unclear how bromine chemistry affects tropospheric ozone on the global scale. The geographical and temporal extents of the bromine perturbations observed to date are limited, and do not, by themselves, help answer this question. Moreover our understanding of the chemistry that both initiates the release of bromine (see for example ref. 15), and maintains it at high concentration, is not complete. Precise, vertically resolved measurements of the global distribution of BrO — an immense technical challenge — will ultimately be required. ☐

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Oceanography

Colour renewal from space

Raymond Sambrotto

Late last year, oceanographers gathered in San Francisco* to take stock of results from SeaWiFS — the 'Sea-Viewing Wide-Field-of-View Sensor', NASA's newest satellite-borne sensor primarily dedicated to ocean biology. Launched in 1997, the project has delivered a year's worth of information on the distribution and abundance of phytoplankton, the single-celled plants responsible for roughly half of the biological production on the planet (Fig. 1, overleaf). This production supports almost all marine life; and phytoplankton growth, and subsequent death and sinking, transports vast quantities of materials out of the surface waters. This biological pump is a central term in the cycling of many biologically active substances and a significant sink for atmospheric carbon dioxide. Among the goals for the new sensor are a better understanding of pump dynamics and the development of improved models to predict the ocean's part in reducing the increased atmospheric CO_2 that has built up during the industrial age.

SeaWiFS is a follow-up to the pioneering Coastal Zone Colour Scanner (CZCS), which ceased operating in 1986. A decade-long blackout of global ocean colour data followed until the Japanese Ocean Colour and Temperature Scanner, OCTS, went into orbit in 1996 (it failed in mid-1997, however). Estimates of ocean phytoplankton levels are based on changes in the optical properties of sea water caused by chlorophyll-*a*, the primary photosynthetic pigment. The relative spectral changes in the green and blue bands (about 555 and 443 nm, the minimum and maximum absorption bands for chlorophyll) are proportional to phytoplankton levels.

As an experimental project, CZCS established the feasibility of this approach. SeaWiFS has much more powerful and flexible observing capabilities. Unlike CZCS, it will relay data continuously and provide complete coverage of the globe every three days. There are several additional spectral bands to improve both correction for atmospheric conditions and the ability to extract information about auxiliary plant pigments, a feature that may make remote determination of taxonomic status possible. The signal-to-noise characteristics of the SeaWiFS radiometers have also been improved several-fold over those of the earlier instrument. The radiometric capabilities for sensing ocean colour will improve still more with the expected launch of MODIS (Moderate Resolution Imaging Spectroradiometer), by NASA later this year.

The expectations for the original CZCS project were meagre because several difficulties presented themselves. The sensor needed to fish out spectral changes in sunlight that enters, and then reflects back from surface water, a signal that is dwarfed by visible radiation from the atmosphere. There were additional uncertainties in building robust algorithms for estimating chlorophyll, given complications like the packaging of photosynthetic pigments in the cell[1]. Such algorithms were eventually developed[2], however, and CZCS revealed features that were expected[3] but never seen at the global scale — the high phytoplankton concentrations stretching thousands of miles along the Equator; the vast biological deserts of the

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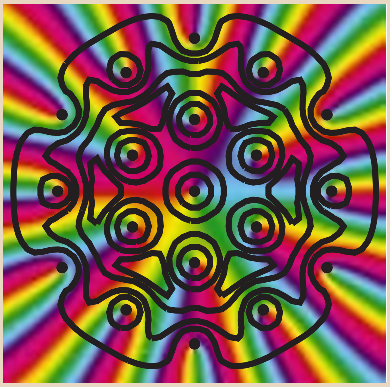
**Application of Sea-Viewing Wide-Field-of-View Sensor Measurements for Understanding Marine and Terrestrial Ecosystems,* American Geophysical Union 1998 Fall Meeting, San Francisco, 6 and 7 December 1998.

Bose–Einstein condensates

Visions of vortices

Sitting in a trap at temperatures so low that their quantum wavefunctions overlap is a weird enough state for most atoms to be in — now scientists want to get them in a spin. Elsewhere in this issue D. A. Butts and D. S. Rokhsar (*Nature* 397, 327–329; 1999) predict what would happen if a Bose–Einstein condensate (a gas of atoms so cold and so dense that the atoms act as one) were made to rotate.

Bose–Einstein condensation is also responsible for superfluidity in liquid helium, which has an unusual response to rotation. Unlike normal fluids, circulating flow in liquid helium always produces vortices. But, understanding rotation in superfluid helium is not straightforward because of the strong interactions between atoms. The advantage of using condensate gases is that the atoms are weakly interacting, making them simpler to study.



Butts and Rokhsar calculate that rotating a Bose gas will produce a series of stable states as the gas spins faster and faster, with a pinwheel pattern emerging at higher velocities (see picture). The black dots represent zero density of the condensate and correspond to vortices: the gas flows anticlockwise about each vortex, as shown by the order of the rainbow colours around each dot. The central vortices form a crystal-like lattice, which is similar to patterns seen in rotating superfluid helium.

The most striking feature of the spinning condensates is their lack of full rotational symmetry, and these predicted 'signatures' should help experimentalists searching for vortices in Bose–Einstein condensates.

Sarah Tomlin

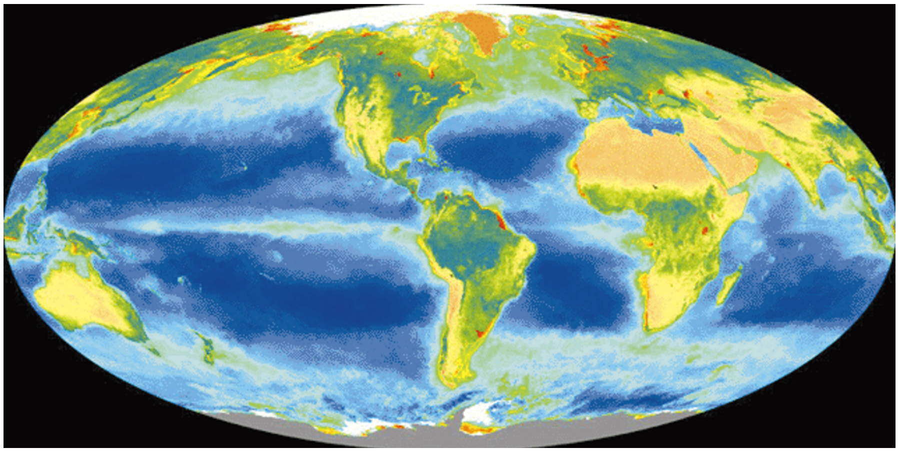


Figure 1 **The biosphere from space. This composite image, based on data from the SeaWiFS project (showing the geographical features of the ocean's plankton system) and the average terrestrial vegetation index (estimated from data provided by a separate sensor), identifies regions where most of the Earth's biological production takes place. SeaWiFS data are represented by a rainbow colour scheme, with dark blue for the lowest phytoplankton levels and orange and red for the highest. See ref. 5 for further details.**

subtropical gyres; and the intense production on continental shelves and in certain high-latitude regions.

Results presented at San Francisco reflected the improved quantitative abilities of SeaWiFS, as well as a broadening of the environmental topics addressed. Progress has been made in developing local algorithms with better precision for regions such as the California Current and the Southern Ocean. These modified algorithms do a better job correcting for regional atmospheric properties and Sun angle than does a generalized, single algorithm. Measurements of spectral absorption and backscatter ratios in Southern Ocean waters suggest that the optical properties differ from those assumed in previous models. Work also continues on ways to link chlorophyll estimates and photosynthetic parameters to estimate productivity rates as well as standing crop[4].

In an apt demonstration that one man's noise is another's signal, the SeaWiFS visible and near infrared bands have been used to track aeolian dust. Such aerosols are thought to transport trace metals (such as iron) needed for phytoplankton growth from land to open ocean regions, where they occur in very low concentrations. Ironically, the aerosol signal is part of the atmospheric correction made before estimating chlorophyll.

The obscuring effect of clouds remains a problem, one which is being tackled by combining SeaWiFS data with cloud-penetrating, active sensors such as imaging radar. Although radar returns an indirect index of phytoplankton levels based primarily on organic matter in surface waters, it may help fill in blind spots in productive high-latitude regions that are often hidden by clouds. The success of new sensors in clarifying ocean carbon flow will probably depend on improved numerical models to estimate the export of phytoplankton from surface waters. Several examples were discussed, most of them using ocean colour data to validate results of a phytoplankton–zooplankton–nitrogen biological model embedded in a physical representation of ocean dynamics. This work has provided increased resolution of the temporal variations in phytoplankton levels related to ocean dynamics along the Equator, and to regional changes in the Atlantic.

Finally, SeaWiFS data are being analysed statistically to identify the characteristic spatial scales in which patches of higher production occur. As data become available, this study will also address the temporal scales on which these patches form and disperse. Such analyses are becoming ever more rigorous and go hand-in-hand with the improved sensor capabilities. Together they will make the next decade a productive one for understanding the ecological dynamics of the sea. □

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erratum

In Christopher Chyba's article "Origins of life: Buried beginnings" (*Nature* 395, 329–330; 1998) the proposal that life could have originated at hydrothermal vents, because of the chemical reducing power of iron and nickel sulphides present at such sites, should have been attributed to G. Wächtershäuser, *Microbiol. Rev.* 52, 452–484 (1988).

Daedalus

Ultra-light glazing

Glass-blowing only works because the viscosity of molten glass rises as its temperature falls. If a section becomes too thin, it cools and becomes more viscous; the hotter regions around it stretch preferentially, and soon match it in thickness. The principle also works in the drawing of very fine glass fibres; but fails, sadly, in the drawing of thin glass sheet. Adequate thermal uniformity cannot be maintained over its width.

In this connection Daedalus recalls the wonderful stability and uniformity of a simple soap film. If a region is suddenly thinned, its surface tension rises, and hauls it back to a safe thickness. So Daedalus is seeking a 'soap' for molten glass. To have the right surface activity, its molecules must combine a glass-loving grouping with one that is incompatible with glass. A silicate or charged silicone moiety should have the thermal stability for the first role; a good candidate for the second is buckminsterfullerene. Like graphite, it must be utterly incompatible with glass; it has a high (indeed, unknown) melting point; and it can carry side-chains for coupling to the silicon unit. DREADCO's chemists are now at work on the project.

Detergent-laden molten glass will be tricky to handle. Opticians, for whom even tiny bubbles in the melt are a headache, will be horrified by its tendency to froth and foam. (Insulation engineers, however, will welcome glass froth as a product in its own right.) From a free surface of the melt, ultra-thin glass film will simply be pulled between fast-running parallel wires. It will set to a uniform thickness governed by the molecular interaction between its faces, probably a fraction of a micrometre. Thin glass films are amazingly flexible and tenacious, and Daedalus is confident of many new uses for his product. Books with glass pages and fired-in print will endure down the ages, and ultra-thin glass cells will transform chemical spectroscopy. Two-dimensional glass lasers and optical conductors will open new areas of photonics and communications; tough interference filters, beam-splitters, anti-reflection layers and photographic film will invade optics. But the major use will be for glazing. Laminated to both faces of a tough polycarbonate sheet, glass film will give a splendid window material — transparent, hard and smooth as glass itself, unscratchable and unbreakable. Windows, the Achilles' heel of modern houses, shops, offices and vehicles, will be safely armoured at last.

David Jones