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

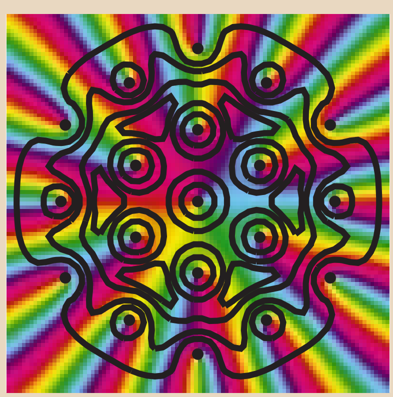
**Application of Sea-Viewing Wide-Field-of-View Sensor Measurements for Understanding Marine and Terrestrial Ecosystems,* American Geophysical Union 1998 Fall Meeting, San Francisco, 6 and 7 December 1998.

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