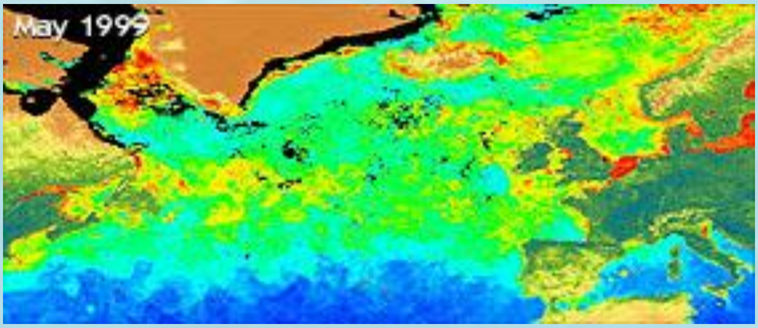
SCIENCE FOCUS: THE NORTH ATLANTIC BLOOM

The North Atlantic Bloom

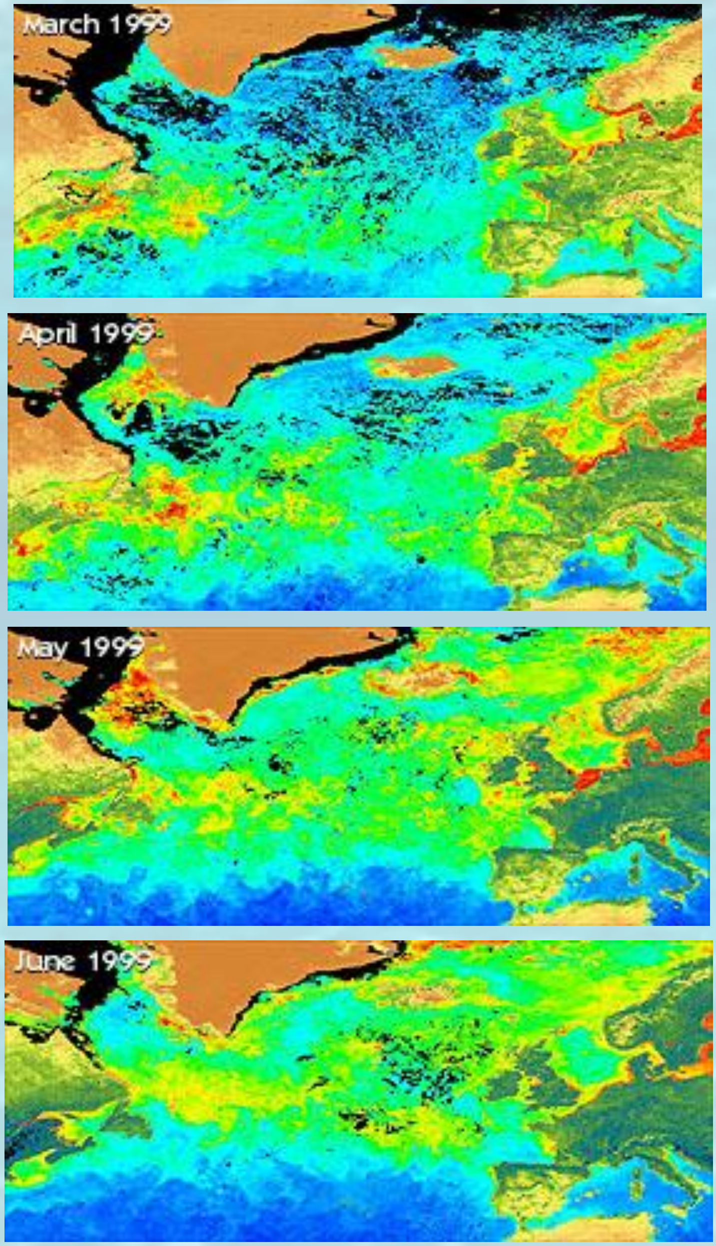


The Big Picture...

Every March, one of the ocean's grandest biological events begins just north of the Sargasso Sea and Bermuda. As days in the northern Hemisphere begin to lengthen, phytoplankton respond by initiating heightened photosynthetic activity, leading to the explosive growth of phytoplankton populations called a "bloom". Utilizing nutrient concentrations that have increased over the winter, this explosion of phytoplankton growth sweeps from the Sargasso northward like a green wave, until the entire northern Atlantic Ocean is covered with a blanket of teeming, microscopic oceanic plant life. The wave rolls northward, past Iceland, into the far reaches of the North Sea, toward Spitzbergen and the fjords of Norway.

Sounds simple, doesn't it?

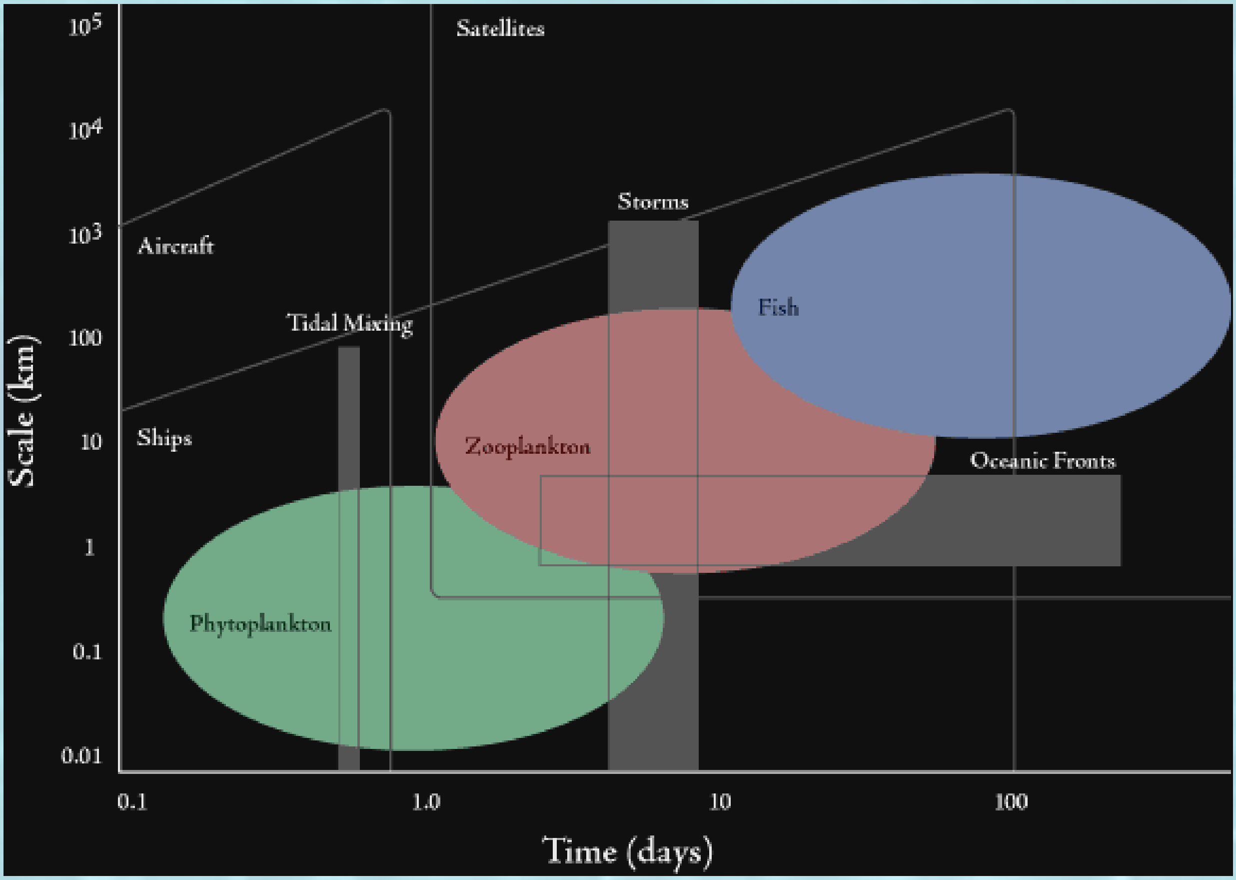
Truthfully, the spring phytoplankton bloom is one of the most widespread changes in the oceanic biosphere, and it occurs every spring in the North Atlantic. That much is clear and obvious. But the picturesque (and exaggerated) language of the opening paragraph smooths over the actual facts of the North Atlantic Bloom — it proceeds not as a simple wave, but in bursts and outbreaks that wax and wane from day to day, depending on the clouds, the currents, the winds, and the waves. The North Atlantic Bloom is an ideal illustration of the importance of resolution in remote sensing, and of the importance of scale in the consideration of phenomena in the marine environment. From a distance, or when averaged over longer periods of time and larger areas of the sea, oceanic processes can appear fairly uniform and easy to understand. But when the scale is reduced, the picture becomes a bit more muddled, and complete understanding is harder to obtain.



The progression of the North Atlantic Bloom during the months of spring and early summer in the Northern Hemisphere is easily seen in images of monthly SeaWiFS ocean color data. The resolution of the SeaWiFS Level 3 monthly data is about 9 kilometers. Notice that in these monthly images, large patches of the ocean are more productive than nearby regions. This "patchiness" is obvious, even though SeaWiFS daily observations have been averaged over time to produce the monthly images. Patchiness is even more pronounced in SeaWiFS 8-day composite images, though there are larger areas where no data was obtained due to the presence of persistent clouds.

Oceanographers employ the word "patchiness" to describe this characteristic pattern of ocean biological productivity. Another term for it is "mesoscale phenomena," which describes processes that generate features between 10-1000 km in size. "Mesoscale" actually means "intermediate size". SeaWiFS provides the opportunity to watch the variability of mesoscale phenomena in the oceans for two reasons: the spatial extent of its observations, and the frequency of observations over a particular area.

In an article published in 1981 in the magazine *Oceanus*, Dr. Wayne Esaias discussed the difficulty of observing patchiness in the oceans. Esaias used a simple diagram (shown in modified form here) to illustrate the temporal and spatial range of various phenomena in the oceans, and the capability of various observational platforms (research vessels, instrumented buoys, aircraft, satellites, etc.) to observe them.

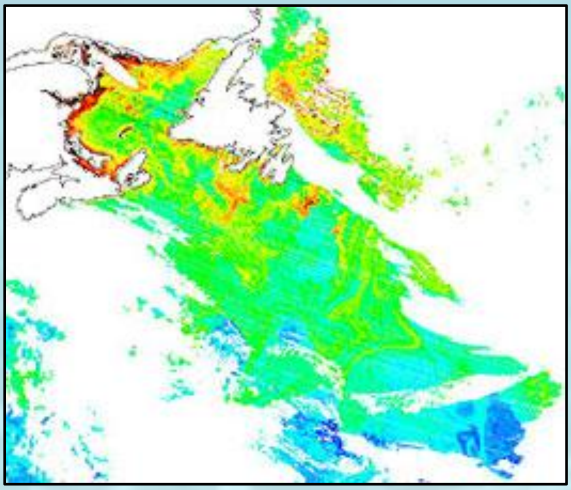


This diagram illustrates the approximate spatial and temporal ranges for a variety of oceanic phenomena, along with estimated observational capabilities of various research platforms. Three basic trophic levels (phytoplankton, zooplankton, and fish) are shown. Thus, aircraft observations are ideal for large-scale, high resolution regional (synoptic) characterizations, encompassing a single tidal cycle and population variability at a scale of 10-1000 meters. In contrast, satellites can best observe variability over 10-1000 kilometers, with a maximum temporal resolution of about 1 day. Ship observations can be at very high spatial resolution but are more limited in spatial range than aircraft or satellites.

...and Some Closeups

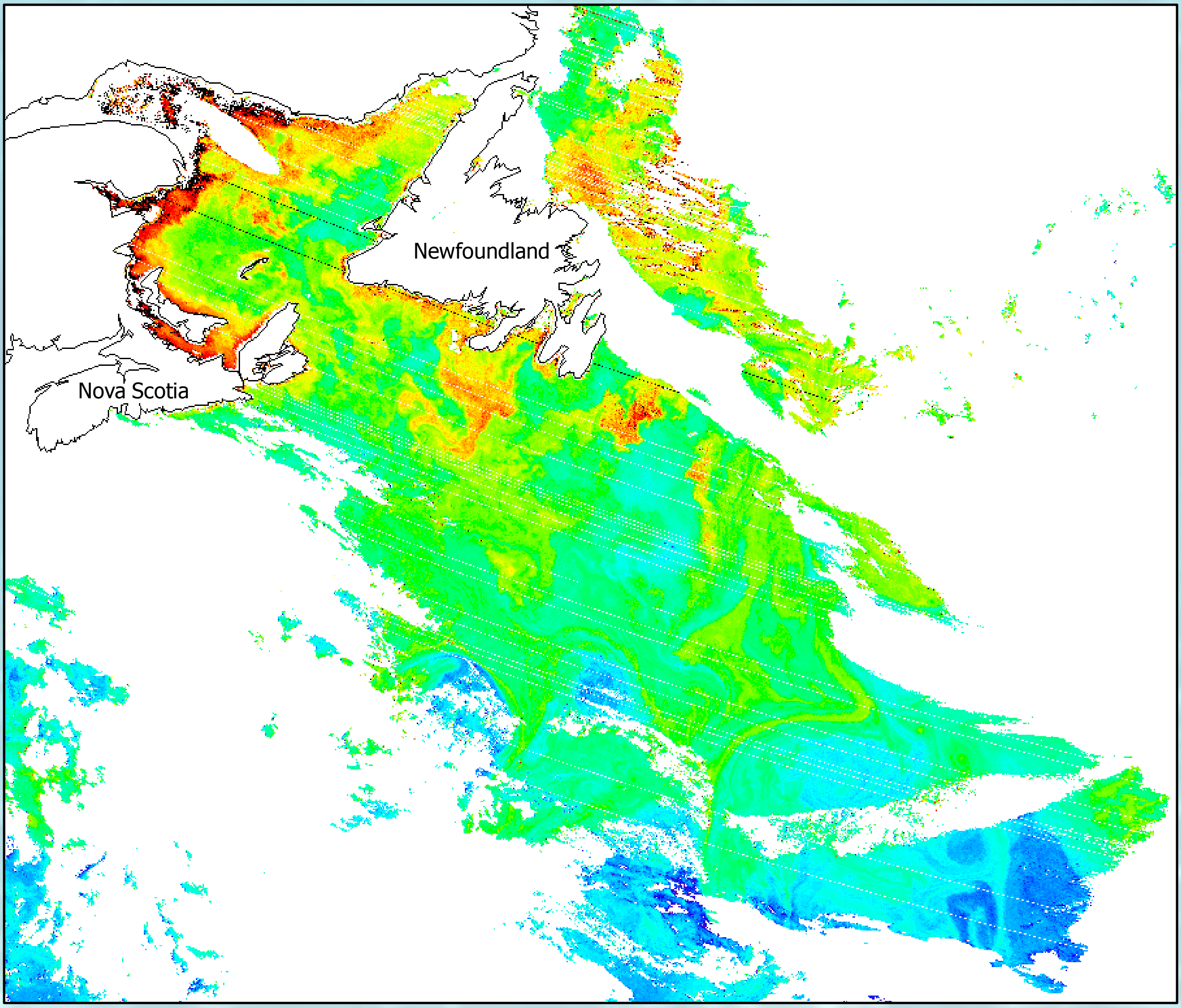
To get an idea of what "mesoscale" means, a fairly good analogy can be made with meteorological processes, i.e., the weather. For example, a cold front is a meteorological feature that is larger than the mesoscale. Yet the thunderstorms which form as a cold front moves across a continent are mesoscale phenomenon. Current weather forecasting models do a very good job of forecasting the movement of cold fronts and other large- (macro) scale features in the atmosphere. Where the models have trouble is at the mesoscale; accurately describing the location and intensity of the thunderstorm-sized features embedded in the cold front is still beyond the ability of current models.

Much like the ability of meteorologists to recognize the factors contributing to the formation of a weather front, oceanographers can describe the factors which foster the formation of the biological "front" that is the large-scale manifestation of the North Atlantic Bloom. The most important factors are increased daily solar irradiance, increasing sea surface temperature, and higher nutrient concentrations in surface waters.

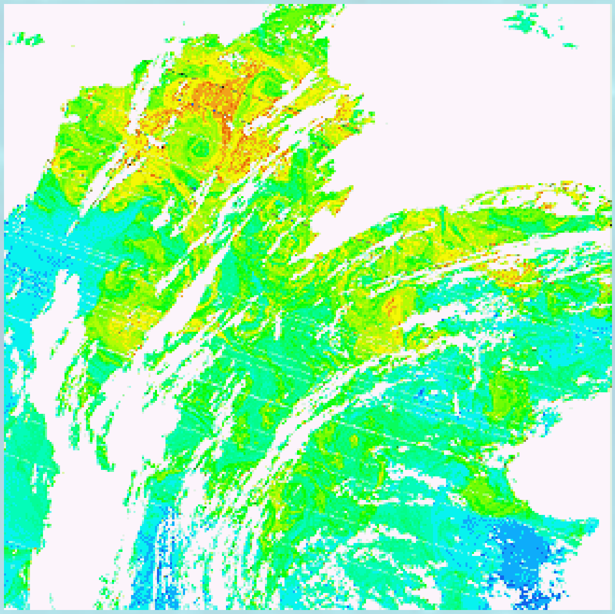


Two SeaWiFS images depicting chlorophyll *a* concentrations provide an even better illustration of the variable nature of this biological event. The first image is from May 4, 1999, south of Newfoundland, the roughly triangular island near the top left. (A larger version appears on the next page.) For comparison, an image made by combining the data from bands 1 (412 nm), 5 (555 nm) and 6 (670 nm) is also shown. This pseudo-true color image gives a good representation of how the human eye would view the scene from the altitude of the satellite. This comparison illustrates the sensitivity of the SeaWiFS radiometer, as the high concentrations of chlorophyll are virtually invisible to our eyes.

SeaWiFS chlorophyll a concentration image, May 4, 1999



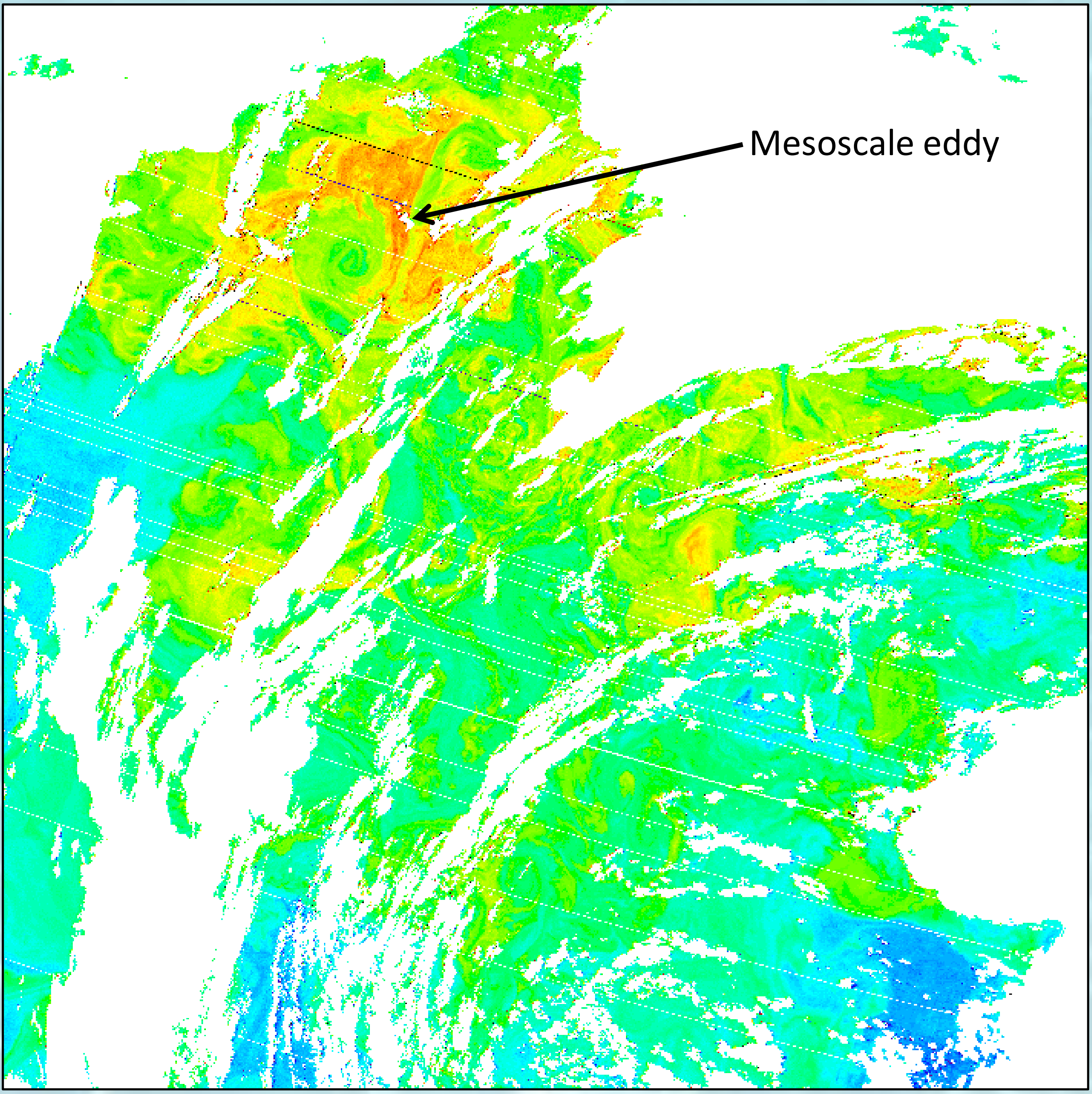
The second image of chlorophyll concentrations is of an area in the open Atlantic ocean, south of Greenland. This image was obtained on May 21, 1999, two weeks later than the previously shown image. Note that the prominent area of high productivity near the top left of the image wraps around a roughly circular circulation feature called an *eddy*. A larger version of this image appears on the next page.



The data for both of these images was obtained by the receiving station at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. These images provide a remarkable close-up of the North Atlantic Bloom in full bloom — and show how difficult it is to capture the daily progression of this event.

One of the main reasons for a mission like SeaWiFS, which provided daily observations of the ocean, is to observe progressively changing phenomena like the North Atlantic Bloom. The goal of oceanographers is to model these phenomena at increasingly higher and higher resolution, which will provide better quantification of the amount of carbon that is produced each spring in the North Atlantic. The only way to determine if the models match with reality, and if they are sensitive to the same variables that drive the phenomenon in nature, is to compare their predictions with the actual event. SeaWiFS provided data that could be used for such a comparison.

SeaWiFS chlorophyll a concentration image, May 21, 1999



Reference
Esaias, Wayne E., 1981: Remote Sensing in Biological Oceanography. *Oceanus*, Vol. 24, Number 3, 32-38.

Link
Data from the Joint Global Ocean Flux Study (JGOFS) North Atlantic Bloom Experiment (NABE): http://www1.whoi.edu/mzweb/nabe.htm

A note on the images: Data from SeaWiFS was broadcast to any station within receiving range. Because these data were obtained directly, occasionally the signal was lost, resulting in missing scan lines, which appear in the images shown here. Some of the factors affecting reception are atmospheric conditions and the distance from the satellite to the receiving station.

ACKNOWLEDGMENT
We gratefully acknowledge the assistance of Dr. Hugh Ducklow of the JGOFS program and the Virginia Institute of Marine Science and Dr. Wayne Esaias of NASA Goddard Space Flight Center in the preparation of this *Science Focus!* article.

SeaWiFS image produced by James Acker. Original page design by Robert Simmon. Accompanying text by James Acker.