Woods Hole Oceanographic Institution 1930

OCEAN explorer

For the Young Associates of Woods Hole Oceanographic Institution Vol. 4 No. 4 May 1995

Here's our home planet, as seen by a computer that got its data from satellites and earth-based instruments. The image combines the topography of continents and the Earth's vegetation.

THE SEA FROM SPACE

When astronauts first travelled to space in the early 1960s, they sent back photographs that showed us our home planet as it really is: a fragile, beautiful sphere, spinning in a lonely orbit in the universe's endless night. From outer space, it's easy to recognize that solutions to problems on the earth must be global, not local.

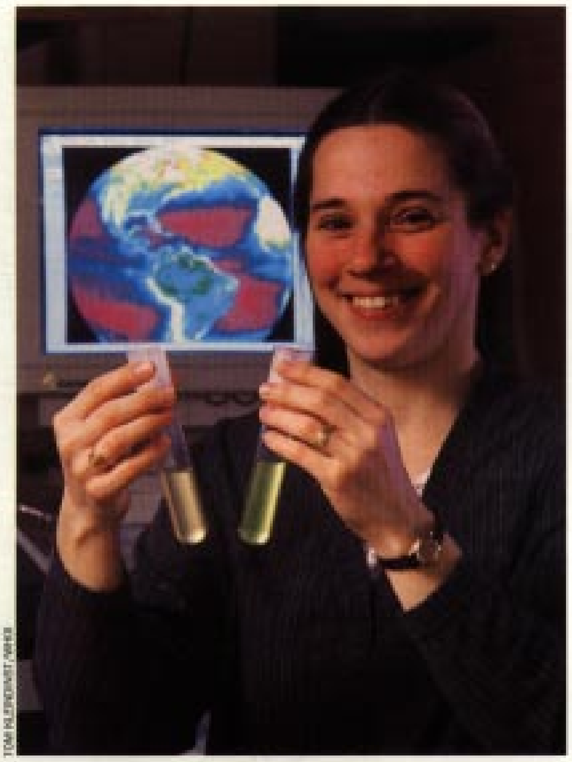
Oceanographers have always viewed the world ocean as one continuous system. They work to understand the effects of this system on the planet as a whole. They know, for example, that the ocean plays an important part in regulating the earth's climate.

Data collected over the last twenty years indicates that the earth's climate may be heating up, maybe because of natural temperature fluctuations, or maybe because of the release of carbon dioxide into the atmosphere caused by human activities, such as driving cars and operating factories.

Scientists need to know as much as they can about how the ocean affects climate. Studying the sea from space may someday help answer some big questions about how the world's ocean works.

This issue, *Ocean Explorer* will take you to the skies. You'll find out how oceanographers use pictures from space to grasp the Big Picture.

How can such tiny plants cover so much territory?



Heidi Sosik with cultures of phytoplankton.

"The stunning patterns hit you," says Heidi Sosik, a WHOI biologist. She's talking about the images she studies that were made by a sensor called CZCS (short for Coastal Zone Color Scanner). From 1979 to 1986, it circled the globe, sending home never-before seen pictures of phytoplankton growing on the sea surface. Scientists are still working to understand these images.

"You can go out for months on a ship and cruise around, but you just don't get that type of image," says Heidi. "The images really give a different perspective of the system as a whole."

Heidi studies the life of microscopic, one-celled drifting plants called phytoplankton that are the basis of the oceanic food chain. "They supply food for all the rest of the ecosystem," says Heidi. "If you're interested in food production, or how much food is available for fish or whales or even people, you need to know something about what controls the production of the plants."

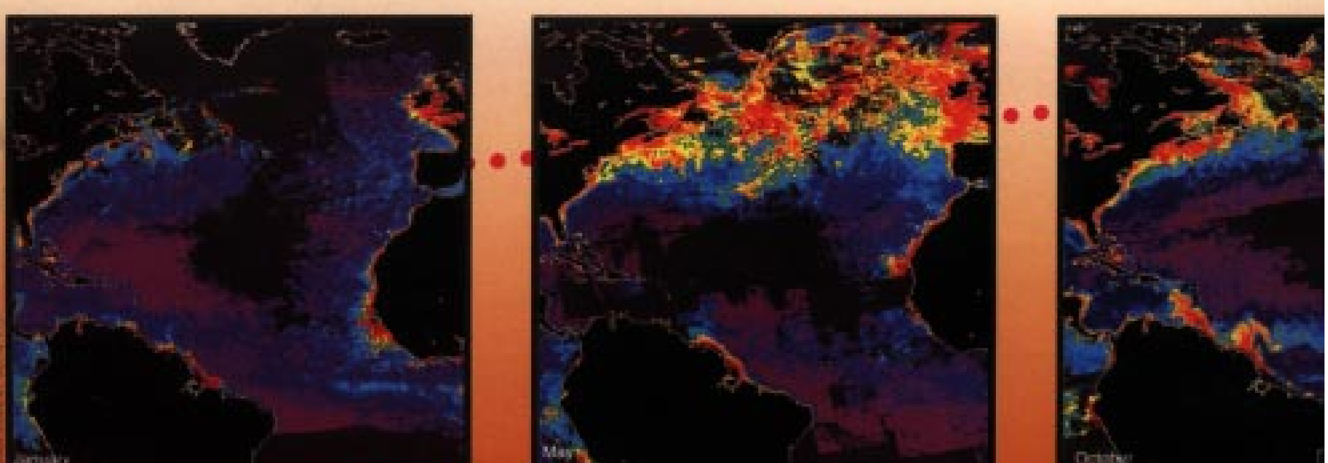
Because these microscopic phytoplankton take up carbon dioxide (CO_2), they also play a role in the global climate that it not yet well understood. Knowing where, when, and why large-scale blooms of these plants take place, and knowing how much CO_2 each plant absorbs will help answer big questions about how the earth as a whole uses CO_2.

"We're trying to understand how the types of material present in the ocean interact with sunlight," says Heidi. To do this, Heidi and her fellow scientists work on two scales—the gigantic and the microscopic.

FROM MACRO TO MICRO

On the gigantic scale, they study images taken by the Coastal Zone Color Scanner. Some of those images are shown on these pages.

How did the CZCS make its images? Pure ocean water appears deep blue. Added materials can change its color. Like all plants on earth, phytoplankton contain the chemical chlorophyll, which absorbs blue light and reflects green light.



Looking down on earth from high in space, the CZCS sensor was much more sensitive than the human eye, and could detect very subtle variations in ocean color, caused by phytoplankton and other material. When the images were processed, their colors were changed to make the variations as easy to see as possible.

"When all those beautiful images were processed, it was done with the assumption that all the phytoplankton were the same," she says. "It was the only thing we could do, basically. It was sort of a first cut. It was crude, but it was also extremely valuable."

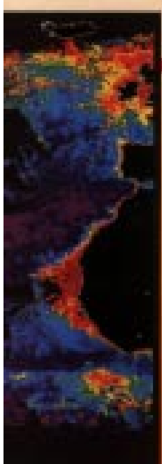
"You can go out for months on a ship and cruise around, but you just don't get that type of image."

She has learned through her own research that individual phytoplankton process CO_2 at varying rates, which are much too subtle for a distant satellite to record. To answer the questions that drive her research, she works with WHOI scientists Robert Olson and Alexander Chekalyuk to find ways to measure each organism's rate of photosynthesis (the process by which the plant converts light from the sun, CO_2 and water into food for itself).

Heidi looks forward to reaching this understanding, and inserting her own piece in the overall puzzle of global climate change.

HOPES FOR THE FUTURE

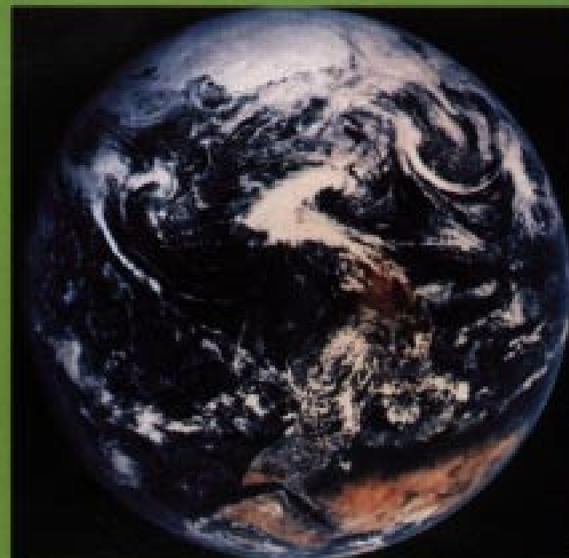
While much is learned from these images, the system is far from perfect. For one thing, new data stopped coming in 1986. Since that time, oceanographers have been studying the images that came back, trying to learn as much as they can from them. Many scientists are also looking forward to the launch of a new color sensor called SeaWiFS (which stands for Sea-viewing Wide Field-of-view Sensor). Another problem is that the data that was returned is too general for Heidi's needs.



THE RISE AND FALL OF PHYTOPLANKTON

In these three images, made by the Coastal Zone Color Scanner, you can see the rise and fall of phytoplankton blooms in the North Atlantic. The largest concentrations of phytoplankton appear as bright orange. In January, 1979 (left) there was relatively little phytoplankton growth. In May (center), the ocean was full of phytoplankton, particularly in the northern portions. By October (right), the plants had died away once again.

THE GREENHOUSE EFFECT AND THE OCEAN



In recent years, much attention has been paid to the role of so-called "greenhouse gases" in the earth's climate. These gases, most of which occur naturally in abundance, include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3).

The greenhouse gases rise through the troposphere, the layer of atmosphere closest to the earth (about 11 km above the earth's surface). At this level, these gases, as well as dust and clouds, affect the way heat from the sun is held within the earth's atmosphere, and the way the sun's rays are transformed into energy on the earth's surface.

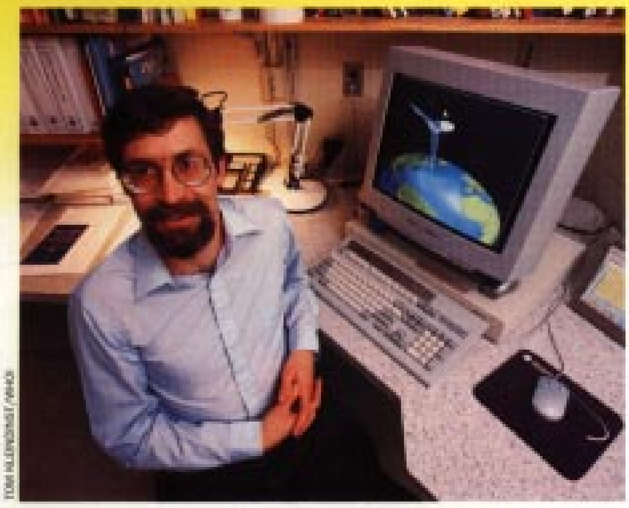
Over the last century, human activities such as the burning of fossil fuels, factory output, and wide-scale farming may have caused these gases to build up in our atmosphere. It's been predicted that if this buildup continues, temperatures on earth could rise as much during the next century as during the 18,000 years since the last Ice Age.

This could cause familiar weather patterns on earth to change dramatically. What might happen? Now-dry areas could see great increases in rainfall. Areas that now have plenty of water could experience droughts. Global warming could also raise the temperature of the ocean, and lead to melting of polar ice caps. This could result in a rise in sea levels, threatening coastal areas.

Scientists around the world are working together on large-scale studies they hope will help explain how the earth's climate works. Not enough is known yet about how the earth as a system operates. The ocean's role in the process is especially mysterious. Covering 70% of our planet, the ocean, the sun that beats down on it, and and the winds that blow over it regulate the earth's climate in ways that are not yet well understood.

To make their studies, scientists are collecting measurements from buoys, research ships, and satellites. They use the information they collect to create computer models they hope will begin to explain and predict large-scale climactic events. The models may help us all make good choices for the future of our planet.

Big Eyes in the



TOM KLEINDINST/WHOI

Above: Mike Caruso's computer provides a window on the activities of the world's ocean.

Right: This is a drawing of the path that TOPEX/Poseidon takes as it travels around the world. Like yarn wound in a ball, the satellite winds around the globe. Each circuit of the globe takes 112 minutes. The satellite views 90 percent of the world's ice-free oceans once every ten days.

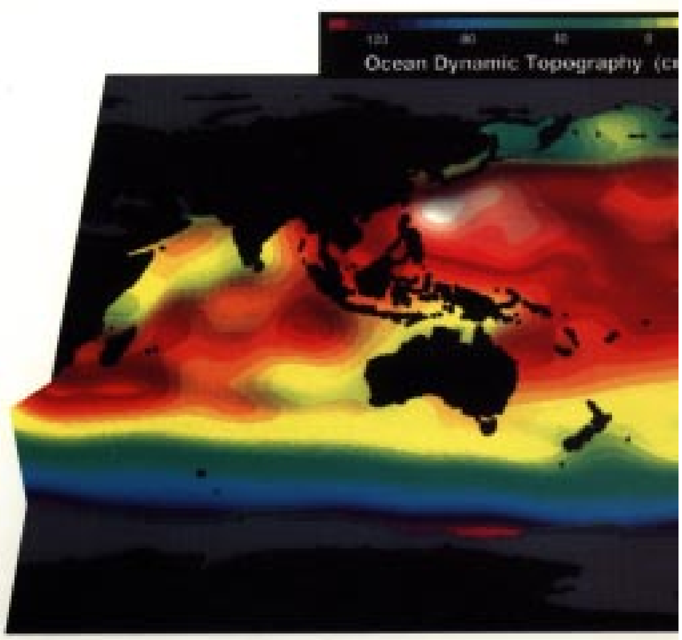
Below, right: This is an image of the topography of the sea surface, thanks to TOPEX/Poseidon. Oceanographers use images like these to figure out the speed and the direction of ocean currents.

Below: Oceanographers can use TOPEX/Poseidon information about the sea surface to make computer images of the sea floor. By the way, the vertical scales in this computer-generated image are very exaggerated.

In August, 1992, a rocket shot into the sky from a launch pad in Kourou, French Guiana. Called the Ariane Expendable Launch Vehicle, provided by France and built by the European Space Agency, it flew up to the altitude of 1,336 km (which is a little more than the distance between Chicago and New York City). There, Ariane deployed a satellite, built by the United States and France, that's changed the way we look at the ocean.

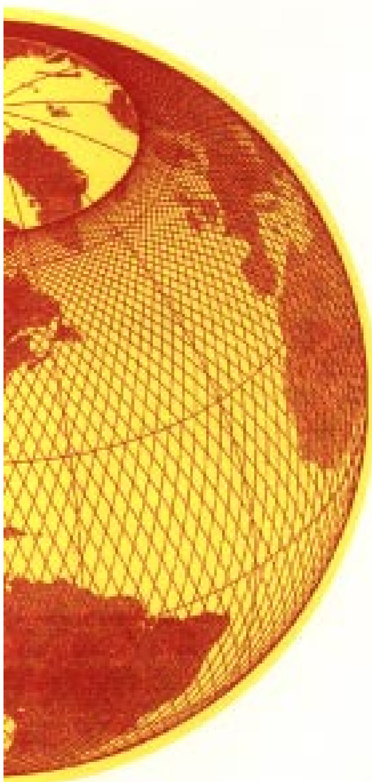
Called TOPEX/Poseidon, it has sent back millions of measurements of the height of the sea surface, and faithfully continues to supply new information at a fantastic rate as it circles the Earth every 112 minutes. The satellite completes its circuit of the world's ocean every ten days. For the first time ever, it's possible to have a continuous world-wide overview of the ocean's surface.

DATA CALCULATED BY NASA/GSFC, IMAGE PRODUCED BY JPL OCEANOGRAPHY GROUP



NASA

Skies Watch Sea Levels Rise



Knowing how the ocean circulates is important to understanding the interaction between the atmosphere and the ocean. Understanding that interaction is important to studying changes in the earth's climate.

TOPEX/POSEIDON'S TOOL

The satellite uses a device called a radar altimeter to beam a signal down to the sea surface. The altimeter measures the amount of time the beam takes to reach the surface and return back to the satellite. It can then calculate the distance between itself and the sea. The altimeter is amazingly accurate. Its measurements are within three centimeters (that's about the same size as the first joint on your thumb).

By knowing the height of the sea surface at different points, it's possible to figure out the paths of ocean currents. Studying these paths makes it possible to understand, better than ever before, how the ocean circulates.

TOPEX/ Poseidon also keeps a very accurate record of the rate of sea level rise, which is another critical piece of information to those studying global warming. As water grows warmer, it expands. Warmer water also melts glaciers and icebergs.

EVERY PICTURE TELLS A STORY

WHOI physical oceanographer Mike Caruso starts his day by scanning the latest images sent back by TOPEX/Poseidon and other satellites.

"We've recently completed a study of how heat is transported in the ocean, and how it moves from the surface to the air in the Gulf Stream region," says Mike, speaking of work completed with colleagues Kathryn Ann Kelly and Sandipa Singh. "That's really important for understanding climate change."

Scientists don't yet understand the interaction of the atmosphere and the ocean. Mike creates computer programs, called models, to study these relationships.

Before TOPEX/Poseidon, most of the data Mike and others worked with were collected by researchers on ships. "There were a lot of bulk estimates made," says Mike. "Until recently, we haven't had the vast amount of data we needed to do this. We're starting to build that up. And there are future satellites that are going to be used, so we will have a long continuous time sequence of this data." *(See page 6.)*

Collecting data over a long period of time is a necessary part of this process. "In the two years TOPEX/Poseidon has been up, we've seen about a millimeter per year of sea level rise," says Mike. "That's nothing to get worried about, because it could be a natural fluctuation." That's the kind of information satellites will help deliver, because they send back data on a global scale. With this type of world-wide information, scientists can make predictions with more certainty.

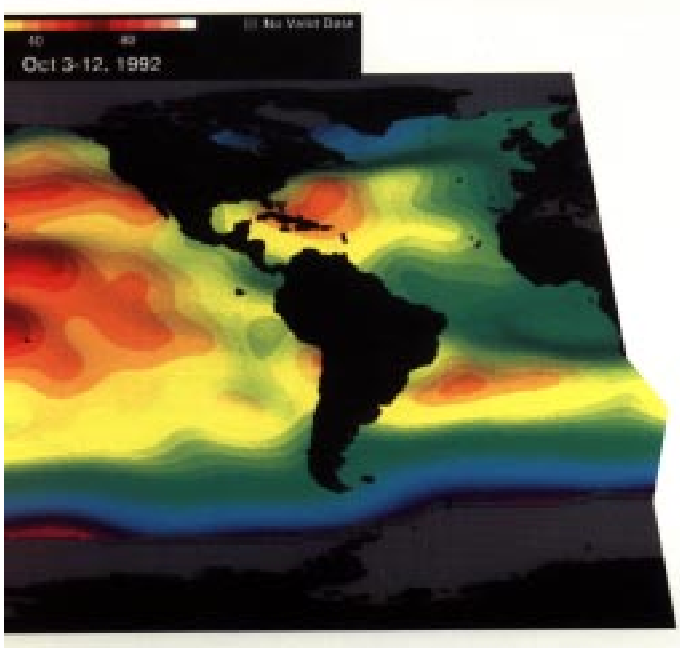
"You can look at things like this millimeter sea level rise and start to analyze what's really happening," says Mike. "We can make measurements on scales we've never been able to work with before."

INSTANT DATA

What has really challenged Mike and other scientists is the experience of trying to lasso this vast amount of information, and to use it to make pictures that people can easily understand. The computer images on these pages were the result of enormous efforts on the parts of many people.

Mike looks forward to the day when computer models will be powerful enough to create usable images on their own. Then, the scientists' focus will be able to shift to trying to understand what the pictures mean. "All we'll have to do is sit there and come up with ideas about how global change is occurring," says Mike.

He makes it sound simple, but it's not. Even so, being freed up to use their imaginations to understand complex processes could lead scientists in the future to many new discoveries.



The Symbionts

Eight-foot tall tube worms. Jumbo clams, with shells the size of dinner plates. How did they grow so big? By making a home for bacteria.

BESIDE A HYDROTHERMAL vent, deep down on the ocean floor where the sun never shines, a tall white tube worm, one of a forest of *Vestimentifera*, waves its red head. Is it eating? Yes, and no. This worm doesn't eat like other animals. It has no mouth, not gut, no anus. Says WHOI biologist Holger Jannasch, "It has given up eating altogether." It nourishes itself by taking in hydrogen sulfide gas from the hydrothermal vent fluid that passes up from a crack in the sea floor and mixes with oxygen from the surrounding seawater. Through a series of capillaries (very small blood vessels), both gases travel to the inside of the worm, where a colony of bacteria live. The worm actually eats the bacteria that it feeds.

EMORY KRISTOF © NATIONAL GEOGRAPHIC SOCIETY

Vent clams are very big – about ten times as big as clams we eat.

If the worm has no mouth, how do the bacteria get inside? Nobody knew the answer to this question for a long time. Then, in 1985 a zoologist named Meredith Jones from the Smithsonian Institution found a microscopic opening in a baby tube worm, which was itself no bigger than the white at the tip of your fingernail. Meredith said that the opening was "a single snout-like structure that appears to sort of snuffle up bacteria." It closes up as the animal gets bigger.

Another vent creature that makes a home for bacteria is the giant clam called *magnifica*. This clam feeds the bacteria that live inside it by taking in hydrothermal fluid through its foot, which it sticks directly into a crack on the sea floor.

J. FREDERICK GRASSLE/WHOI

Tube worms and other creatures living in a cluster near hydrothermal vents.

ENDEAVOUR Carries an Ocean Explorer

Wendy Lawrence, astronaut and oceanographer.

As Space Shuttle astronauts circle the globe, most of them find other things to do than look out the window during long intervals over the ocean. Not Wendy Lawrence, who earned a master's degree in ocean engineering in a program run by WHOI and MIT. She kept her face pressed to the window during ocean fly-overs, in spite of the teasing she sometimes got from her fellow astronauts, whom she points out, "were all astronomers!"

Laughs Wendy, "I'd tell them, 'I've studied oceanography. I kind of like looking at the water.' The others said they'd rather look at the dirt. The dirt is more colorful."

"What you're able to see about the ocean from space is really amazing," says Wendy. By studying the way the sun reflected off the water, Wendy found she was able to observe ocean circulation. "I could see eddies, and internal wave patterns from space."

She also liked looking at alongshore currents and sediment transfer at river deltas. "There are some very impressive river deltas off India," says Wendy. "I looked at the runoff into the sea off Madagascar. I could see so much of the soil being washed out into the sea. You can really see how the current effects its transport into the open ocean."

Looking at the sea from space helped Wendy develop what she now refers to as an "intuitive insight" into how the ocean circulates. "You can really see it happening," she says. She has shared many of her ocean photographs with scientists who are interested by her perspective as an astronaut who has studied the ocean.

UP, UP AND AWAY

Wendy says she'll never forget what it felt like to be shaken by the blast of the solid rocket boosters that shot her into space. "The ride up was spectacular. You definitely know you're going someplace and going fast," she says. "The vibration is incredible. You don't hear anything, you feel the acceleration. It's like nothing I've been through before. Eight million pounds of thrust is an amazing ride uphill!"

The only problem with that phase of the flight was "it's not long enough. It's only 8.5 minutes from take-off to orbit."

Wendy also likes to think back on being in orbit, weightless, "looking out the window to see how beautiful this earth is."

Perhaps strongest of all are her memories are of coming back to Earth: "Looking out the window over the Pacific at Mach 20, 250,000 feet up, realizing how incredibly fast we were travelling. I will never forget that. The clouds were going by faster than I could focus on them."

Does Wendy feel like the experience in space changed her as a person? "People ask if I find myself looking up at the night sky, thinking I've been up above the earth, closer to the stars. I do, particularly when I watch the news now. I hear about countries in Africa or South America or Indonesia, I find myself stopping and thinking, 'I've seen that country from space. I've never been there, but I've seen it.' It's a really great feeling."

Sediment moved by wind and water creates a colorful scene at Disappointment Reach, Australia (top). Sun-glint reflects on surface oils to show a current in the Andaman Islands (bottom).