A CURRENT AFFAIR

BY ROBERT MONROE

Approaching Mexico's Coronado Islands, SCCOOS researchers (from left to right) Edwin Beckenbach, Eric Terrill, and Axel Pierson traverse some of the coast's most closely watched ocean currents.

BEFORE THERE WAS such a thing as extreme sports, swimming in the waters off Imperial Beach counted among the riskier forms of recreation.

For years, high bacteria counts in the stretch of ocean north of the mouth of the Tijuana River forced entire sections of the city's beaches to be closed for months on end. To swim even when the beach was open meant exposure to a host of maladies ranging from earaches to pink eye to skin infections, remembers Imperial Beach City Councilwoman Mayda Winter.

In 1999, the situation improved with the opening of a new international wastewater treatment plant on the U.S.–Mexico border. The plant relieved an overtaxed sewage system in Tijuana, channeling treated sewage six kilometers (3.5 miles) out to sea through an outfall pipe.

But questions continued to nag Winter: Was the outfall pipe far enough out to sea? What if the sewage treated by the plant wasn't really the problem? What proof could Imperial Beach have that it was really safer?

"Monitoring was only done every month and it was not being done at every station every time," Winter said. "I felt very uncomfortable about that because most of our recreation took place between the monitoring at the outfall and where the shore monitoring took place, which is foot deep in the surf."

In 2001, Winter led a group from Imperial Beach that visited Scripps Institution of Oceanography

From left, *SCCOOS researchers drop anchor in an island cove to service one of the newest radar stations in the network.* **Bottom left,** *A hillside radar antenna helps convert surface wave speed readings into measurements of current movement at the border.* **Bottom right,** *Axel Pierson gains clearance from Mexican sailors before reaching the station.*

looking for a way to track ocean currents and the sewage that could be transported in them. "I asked two basic things, if they could show what's in our water and where is it moving," Winter said.

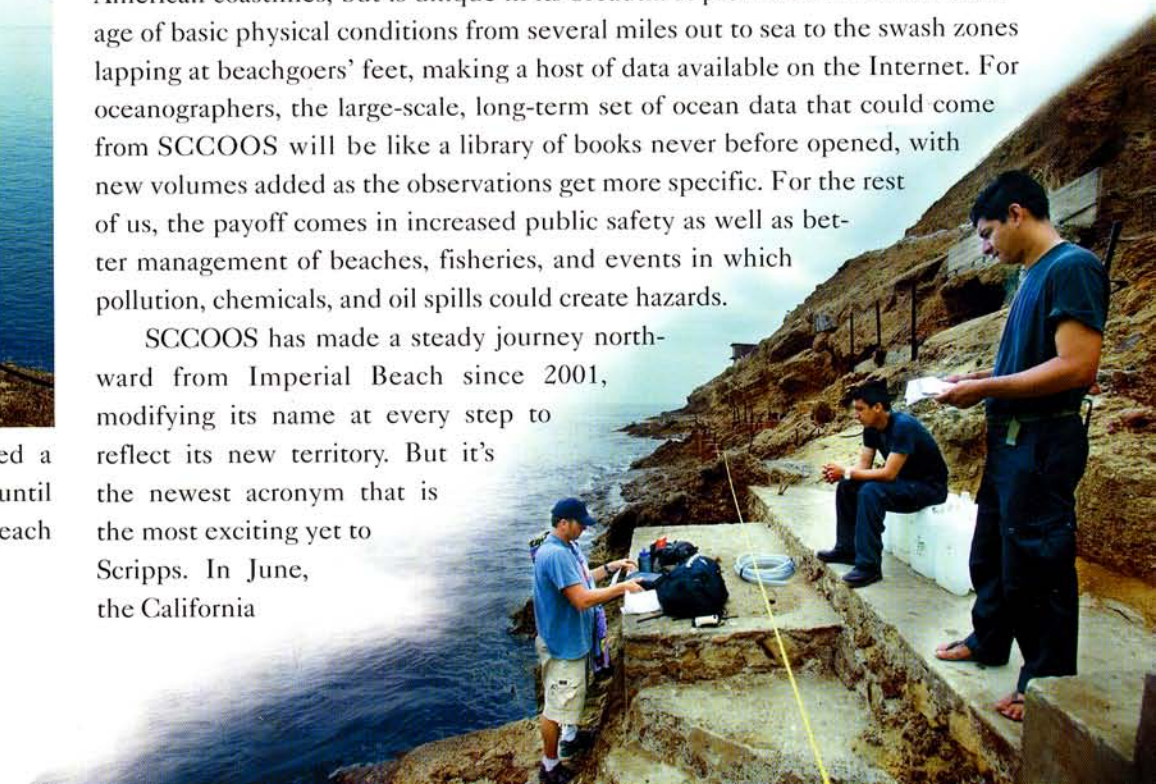
It was Imperial Beach's desire for such basic information and the fortunate timing of the Clean Beaches Initiative that helped create one of the country's most advanced coastal observation systems. The request gave the Southern California Coastal Ocean Observing System (SCCOOS) a different character from typical research ventures. It made cities, counties, and state users partners in the creation of beneficial science-based products instead of indirect recipients.

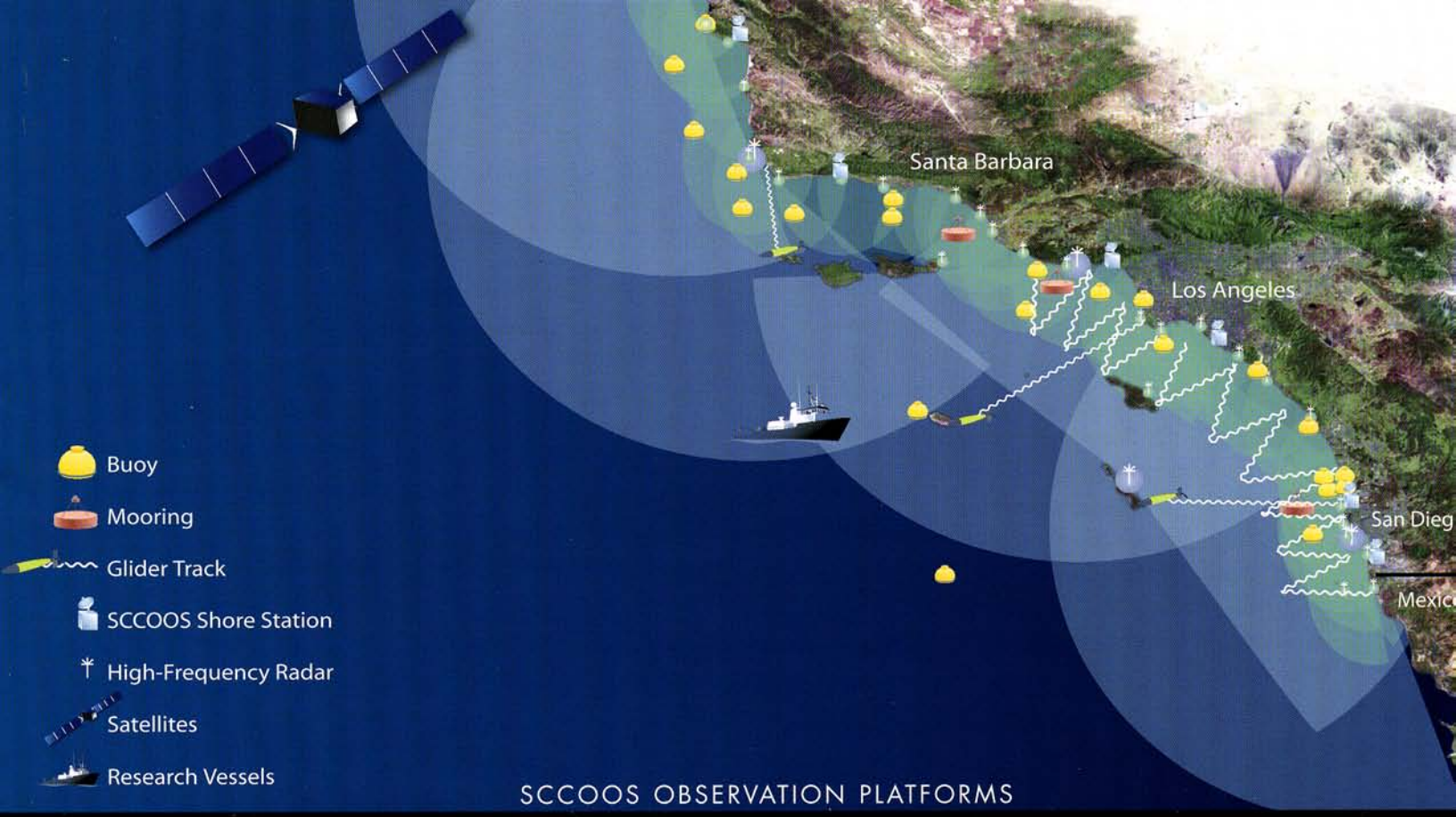
The network of current-mapping instrumentation that SCCOOS Principal Investigator Eric Terrill had been working on lacked a direct user beyond scientists until the concerned Imperial Beach community came along. Now lifeguards, U.S. Coast Guard officials, and water-quality officials are excited about the plans to have this capacity throughout southern California.

"Imperial Beach was necessary," Terrill recalled, "as it placed what we're doing on the radar screens of several of the state agencies that are involved with coastal management issues that do not typically sponsor ocean science."

SCCOOS is one among many networks providing observations along American coastlines, but is unique in its breadth. It provides unmatched coverage of basic physical conditions from several miles out to sea to the swash zones lapping at beachgoers' feet, making a host of data available on the Internet. For oceanographers, the large-scale, long-term set of ocean data that could come from SCCOOS will be like a library of books never before opened, with new volumes added as the observations get more specific. For the rest of us, the payoff comes in increased public safety as well as better management of beaches, fisheries, and events in which pollution, chemicals, and oil spills could create hazards.

SCCOOS has made a steady journey northward from Imperial Beach since 2001, modifying its name at every step to reflect its new territory. But it's the newest acronym that is the most exciting yet to Scripps. In June, the California





SCCOOS OBSERVATION PLATFORMS

Buoys: *Nearshore surface coverage comes from CDIP, National Data Buoy Center, municipal agencies.* Moorings: *Measure physical, chemical, and biological data at and below surface.* Gliders: *Record current, temperature, and salinity from surface to 400 meters (1,300 ft.) deep.* SCCOOS shore stations: *Record ocean temperature, salinity, and water quality.* High-frequency radar: *25 planned short- and long-range radars to track coastal currents.* Satellites: *Image sea-surface temperature, offshore winds, and chlorophyll levels.* Research vessels: *Monitor coastal ecosystem through water sampling and deployment of instruments.*

Coastal Conservancy awarded the SCCOOS consortium and one in northern California based out of San Francisco State University $21 million to launch the Coastal Ocean Current Monitoring Program (COCMP), a network of radars, drifters, underwater vehicles, and moorings that will observe the entire state coastline.

"No other state has made an investment of that scale," said John Orcutt, Scripps deputy director for research. "It's a tremendous opportunity for us to build a system leveraging on work that we have a reputation for."

ONWARD AND UPWARD

The SCCOOS portion of the new coastal-monitoring program runs up the coast from Baja California, where a pair of Mexican research institutions operate a high-frequency radar near Rosarito Beach. In early 2003, Scripps boosted its international component and gained key cross-border radar coverage when it installed another station on Mexico's South Coronado Island. There an antenna situated as close to the edge of the cliffs as possible overlooks the coastlines of two countries and the large pens of a tuna farm to the east. The island hosts the only fully autonomous high-frequency radar station, one that gets its power from solar panels and a wind-powered generator. Also on the island are a lighthouse keeper, a small garrison of Mexican sailors, and the occasional lobster fisherman who seeks shelter in the island's horseshoe-shaped cove nearby.

Left, *A onetime lighthouse is now a SCCOOS nerve center.* **Above,** *Eric Terrill (left) and Axel Pierson reinforce wire casings.*

At the north end of the system, California Polytechnic State University, San Luis Obispo maintains a new marine research pier at Morro Bay and will be operating the northern end of the high-frequency radar network. There already exist several other current-mapping radars in

nearby waters maintained by SCCOOS oceanographer Libe Washburn from UC Santa Barbara.

But the system's growth pattern hasn't just run along geographic lines. Data from nearshore and surf zones, where most human activity takes place, have been made available thanks to a linkage with the Coastal Data Information Program (CDIP), a Scripps network that provides real-time wave data and forecasts. For nearly 30 years, CDIP's fan base has grown to include surfers, harbormasters, and ship captains who rely on data beamed from CDIP buoys to the Internet, where the program's website is now one of the most popular pages run by a scientific institution.

In addition, 10 other universities and government agencies participate in SCCOOS to monitor and forecast the gamut of coastal processes in southern California.

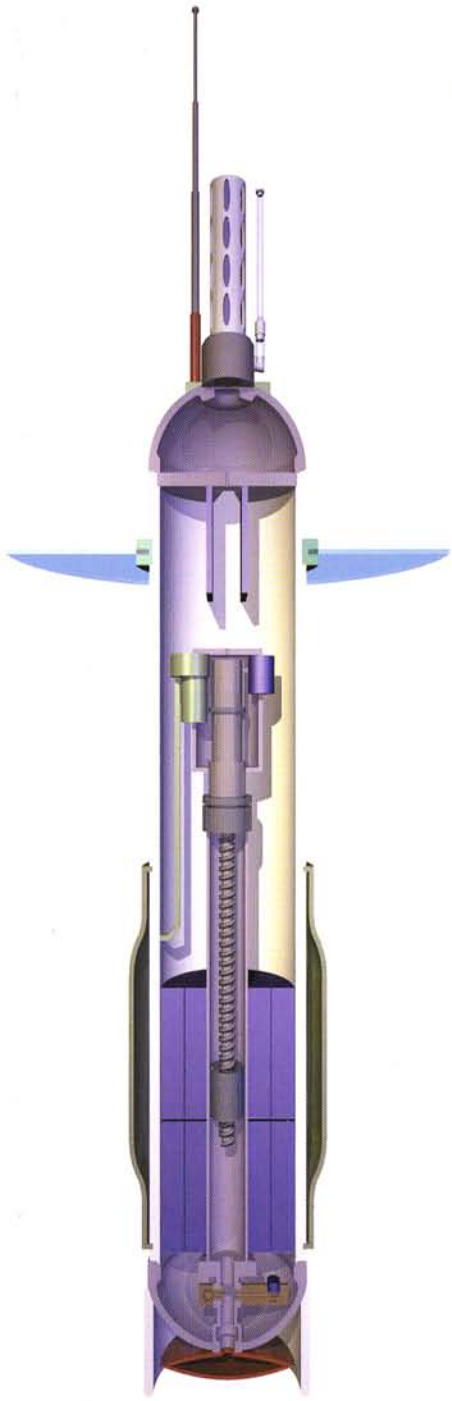
• Cal Poly, San Luis Obispo researcher Mark Moline operates the remote environmental monitoring unit, an autonomous underwater vehicle that measures a variety of biological conditions such as phytoplankton growth and the spread of algal blooms along preselected routes.

• Los Angeles County operates a network of meteorological instruments and web cameras to monitor nearshore activity in its Coastal Monitoring Network. Los Angeles and Orange Counties also operate moorings that record surface-current movements.

• Besides operating radar to measure currents, UC Santa Barbara researchers deploy drifters closer to shore. The floating buoys record their positions as they are carried by currents, following the paths of polluted waters as they near beaches.

• Several Scripps researchers are joining colleagues at the Jet Propulsion Laboratory (JPL) and UCLA to produce regional ocean current models that will draw on SCCOOS in-water measurements from ships, moorings, and gliders to improve their forecasting skill. The accuracy of the models

Pioneered by physical oceanographer Richard Seymour (middle and bottom) and associates like Julie Thomas (top), CDIP is an important new SCCOOS partner. The program's buoy network, including ones being swapped out off La Jolla (below) provide wind and wave data for the West Coast, Hawaii, and Guam.



A cutaway of the Scripps-built Sounding Oceanographic Lagrangian Observer (SOLO) float, one of three types used in the international Argo program. The instruments sink to depths up to 1,800 meters (6,000 feet), then return to the ocean surface to transmit physical data about every 10 days.

ARGO

AS A NUMBER OF GLOBAL OBSERVATION initiatives are launched next year, the autonomous float network considered their role model will be reaching its full potential.

The Argo array of instruments measuring temperature and salinity in the upper ocean is scheduled to reach 3,000 units by early 2007, but researchers at ocean and climate forecast centers are already using data from the 1,300 units in the ocean. As Argo's first encounter with an El Niño winter approaches, officials hope the existing network will prove its value to government officials bracing for natural disasters.

"This is not esoteric science," said Scripps Institution of Oceanography's John Gould, international director of the Argo project. "These are very real issues with big price tags attached that make the price of Argo seem minuscule."

Argo's data are available on the Internet and program leaders have been anticipating multiple uses of these data. Many projects are starting to use Argo data, said Gould.

For instance, one Canadian group recently uncovered an unusual stratification of water in the Gulf of Alaska with help from the array. The find is significant because the normal mixing of deeper and shallower water determines how phytoplankton obtain nutrients. The lack of mixing could spell trouble for creatures ranging from microorganisms to sea lions. The study was carried out only four years after deployment of the first Argo floats and shows the program's potential. The floats make measurements of temperature and salinity, descending to depths up to 1,800 meters (6,000 feet), drifting for 10 days, then returning to the surface to beam results to passing satellites. The information they relay is then processed and posted.

Argo is a direct descendant of earlier programs that made basic readings of ocean conditions over wide areas. While those initiatives were a one-time effort, Argo seeks to be a permanent presence in the oceans, on hand to witness climatic changes that are difficult to identify until they are observed over the course of decades.

Approximately 20 countries, as well as the European Union, take part in the program. Permeating Argo, however, is the special imprint of Scripps. Like Gould, Scripps researcher Dean Roemmich is an Argo leader. The technology that made the program possible in the first place was developed by Scripps scientist Russ Davis and his colleagues.

Davis modeled the units that Scripps has contributed to Argo on the Autonomous Lagrangian Circulations Explorer floats he created for the ambitious World Ocean Circulation Experiment (WOCE), conducted from 1990 to 2002. Thirty countries took part in that endeavor, in which satellites, ships, and floats like Davis's measured temperature, salinity, and currents throughout the world's oceans to create a snapshot of ocean circulation to assess its influence on climate.

WOCE served as the catalyst for Argo as well as for other larger observation programs now in operation such as the Climate Variability and Predictability program and the Global Ocean Data Assimilation Experiment, both of which incorporate Argo data.

Once the array is fully deployed, the next challenge for Argo will be maintaining it at this level. Growing along with the network is the number of countries desiring to participate. Recently Spain, Chile, and the island nation of Mauritius signed on. Still others are considering joining.

Gould hopes that international support remains as deep as it is broad. He notes that funding from the United States, which provides nearly half the floats, covers only the cost of developing the array, not the ongoing research that will come from it. A track record of real-world value could sustain the revenue needed to keep Argo operating.

"It's very much seen as a model of how observation systems ought to develop," Gould said. "Ultimately all countries will benefit."

will improve over time through updates that will rectify model predictions with actual daily observations. The final products will be maps predicting ocean properties and currents that could prove invaluable to water-quality monitors, search-and-rescue personnel, marine-life resource managers, and other users.

PUTTING SCIENCE TO WORK

Recording data is only half the challenge for SCCOOS. Assembling the data into information that scientists and nonscientist clients can use is just as daunting. Several of the agencies involved in SCCOOS, like the Southern California Coastal Water Research Project, already have a direct mission to conduct research and transition science to the water agencies. Part of JPL's mission is to coordinate the reams of data submitted by SCCOOS's various contributors in concert with technology developed by Scripps's Real-time Observatories, Applications, and Data management Network (ROADNet) and the San Diego Supercomputer Center.

Art Allen is among those closely watching the effort. An oceanographer with the U.S. Coast Guard Office of Search and Rescue, Allen says the current maps and water temperature readings that he could get from programs like SCCOOS would save lives if a way is found to integrate them.

"Everyone is struggling with how you get operational products to the operational community," he said. "We have direct and critical needs for the kind of data that would come out of these kinds of systems."

SCCOOS leaders anticipate that the program will soon be participating on a national stage when it becomes part of the Integrated Ocean Observing System, a federal effort to link observation systems to eventually cover all American coastlines. The National Science Foundation's upcoming Ocean Research Interactive Observatory Networks (ORION) program promises to become a key sponsor of future SCCOOS science.

ORION Program Director Alexandra Isern credits Scripps for leading the charge to create useable products that could someday help create the most effective marine reserve boundaries or accurately predict the course of offshore oil spills.

The Coronado station is the only one in the system that is fully autonomous, relying on solar energy to power telecommunications and computer equipment.

Good for another month, the batteries that power the island station get a final check from Axel Pierson. The Coronado station and another radar at Point Loma (bottom) overlap coverage in one of the country's most advanced coastal observatories.

"If you can't do that, you lose a lot of the benefit of having observing systems," she said.

For Terrill, receiving the Coastal Conservancy's financial support of SCCOOS is cause for optimism.

"This is what I've been working toward for the past couple of years," he said. "It's a program that will allow us to conduct observations in support of basic science, but will also provide necessary information for a wide range of socially relevant coastal issues."

IMPROVED INSTRUMENTS, IMPROVED OBSERVATIONS

The explosion in earth observation initiatives has been spurred by advances in the development of a suite of instruments built for long-duration observations.

One example is the Spray glider codeveloped at Scripps Institution of Oceanography by physical oceanographer Russ Davis. The rocket-shaped remote-controlled glider is scheduled to begin running along preprogrammed routes off the West Coast by the end of the year.

"We're getting started by proving the principle, showing that the information from Spray is useful for the models that are trying to create forecasts," Davis said.

Researchers at Woods Hole Oceanographic Institution and Scripps began developing Spray jointly in the 1990s while in search of an instrument that could autonomously measure stretches of ocean over several months before being recharged. The winged craft can sink to depths up to 1,500 meters (4,900 feet) and rise in the water column through the filling and draining of an internal bladder.

The principle is similar to that behind the Sounding Oceanographic Lagrangian Observer floats developed by Davis for the international Argo program, which provide data while drifting throughout the world's oceans. The difference is that Spray will not stay still but chug along at half a knot on tracks from the California coast to the Channel Islands and other paths of interest.

The constant improvement of such instruments is what has enabled the launch of national and international ocean observation programs recently, said officials like Alexandra Isern, program director of the new Ocean Research Interactive Observatory Networks program.

"We probably couldn't even have contemplated this 10 or 15 years ago because we didn't have the technology," she said.