

# AGAINST THE TIDE



Rip Currents,  
Confounding Physics  
Confront Nearshore  
Oceanographers

BY ROBERT MONROE

*Installing surfzone gauge and sensor packages—sometimes in the middle of rip currents—and keeping them working was the job of NCEX's corps of "surfgoons."*

**Opposite center,** *In deeper waters, algae and other stowaways required similar instrument maintenance.*





**N**EVER MIND THE IMAGINABLE HAZARDS of establishing electrical connections underwater. Think about doing so when the water is rushing past at two feet per second and you can begin to appreciate the production that was the Nearshore Canyon Experiment (NCEX).

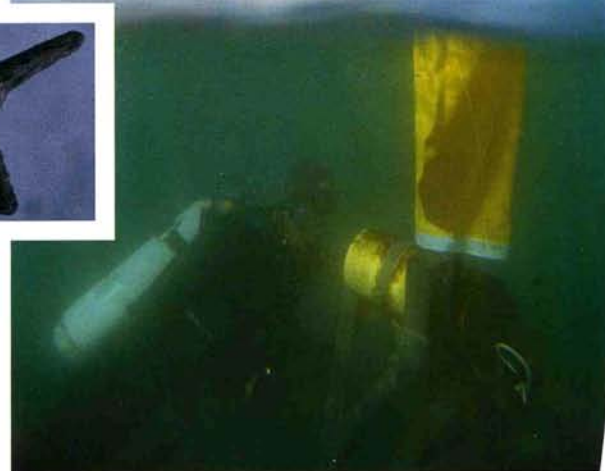
During fall 2003, NCEX scientists studied waves and other dynamics of the La Jolla coastline using instrument-filled buoys, aerial videography, and specialized watercraft to measure changes in the elevation of sand on the seafloor and the height of the water surface.

Few tasks in this project had the danger of Dennis Darnell's. The staff research associate was among the divers responsible for installing and servicing instrument packages mounted on tripods at Black's Beach, a location north of Scripps that has some of the strongest rip currents in the San Diego area. The instruments measured currents and water pressure, and their readings traveled electronically along electric cables buried in the sand that ran up to antenna stations located on the dry beach, then were transmitted back to Scripps. Installing this network meant hooking up cables to sensors and gauges in the midst of breaking waves and strong flows, creating an experience akin to being on the receiving end of a sandblasting.

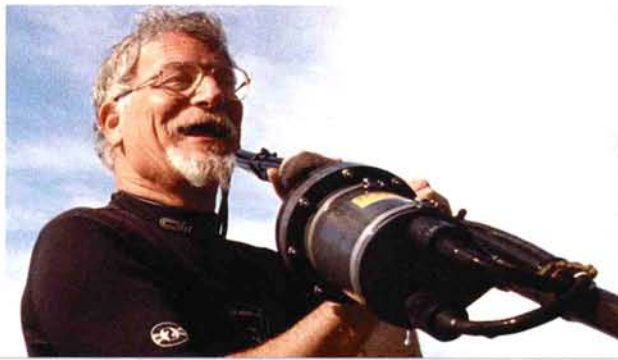
"It's insane," said Darnell, who was a Navy diver before he came to Scripps. "It's sometimes easier to close your eyes and work with your hands because then you're not distracted waiting to see what you're doing."

#### SAND-STARVED SAN DIEGO

Nearly as daunting as the role of "surfgoons" like Darnell is the task of figuring out the forces behind the waves and currents that pummeled him for an eight-week stretch last fall. That will be the job of scientists from 10 research institutions who represent a large fraction of the nearshore dynamics oceanographers in America. NCEX scientists believe that







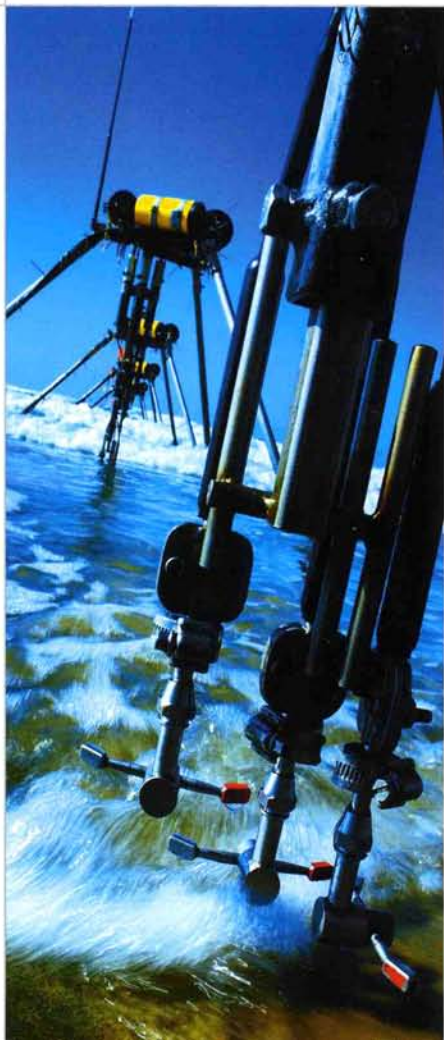
data from the experiment's fieldwork will be of great interest within their community and will provide observations for testing models of waves, currents, and sediment movement for many years.

What's compelling to these scientists—and the reason they are taking on such a large-scale endeavor in such a challenging location—is the fascinating complexity of the wave field and currents. These phenomena are a direct consequence of the La Jolla coastline's elaborate underwater topography, or bathymetry, which is book-ended by a pair of undersea canyons.

At the research site's southern end, La Jolla Canyon terminates near La Jolla Cove. By the time a kayaker has paddled out a few hundred yards from the tranquil spot, the sheer undersea canyon walls have already dropped off several hundred feet. At the north end is Scripps Canyon, which meets with its counterpart just less than two miles out to sea to form a V shape at a depth of 275 meters (900 feet).

In some places, the narrow canyons are three times as deep as the cliffs that tower over Black's Beach. How do those chasms affect the waves overhead? What do those waves do to nearshore currents and sand transport?

The answers to those core NCEX questions have very practical implications. Knowledge gained from NCEX and related nearshore science projects could save millions of dollars through improved beach management, and indirectly through preservation of tourist revenue. NCEX is no small matter, especially to a county that recently spent \$17 million to place 2 million cubic yards of sand onto local beaches.







**Opposite page top,** Scripps researcher Bob Guza. **Opposite page bottom,** A trio of current meters records the rush and retreat of water within the swash zone, the portion of beach alternately covered and uncovered by waves. Investigator Britt Raubenheimer set out a transect of five instrument-bearing platforms stretched out to catch activity in as much of the 20-meter-wide (65-foot-wide) zone as possible.



"We're sand-starved in San Diego County and it's going to get worse, not better," said Bob Guza, co-chair of the Integrative Oceanography Division at Scripps.

#### A SURFER'S PARADISE, A SCIENTIST'S PUZZLE

Surfers know the answer to at least one of NCEX's basic questions

even if no one quite understands the "why" part. Black's Beach is one of California's—and America's—prime surf spots. Its epicenter is a 450-meter (1,475-foot) stretch called "Black's Bowl," where riders from Japan, Australia, and other countries come to surf every year just so they can say they've been there.

The surf that gets them up in the morning is the product of shoreward-moving wave energy interacting with the complicated underwater bathymetry. When the water depth decreases to about twice the wave height, the resulting breaking waves can send currents flowing in several different directions.

### A ROAD MAP TO

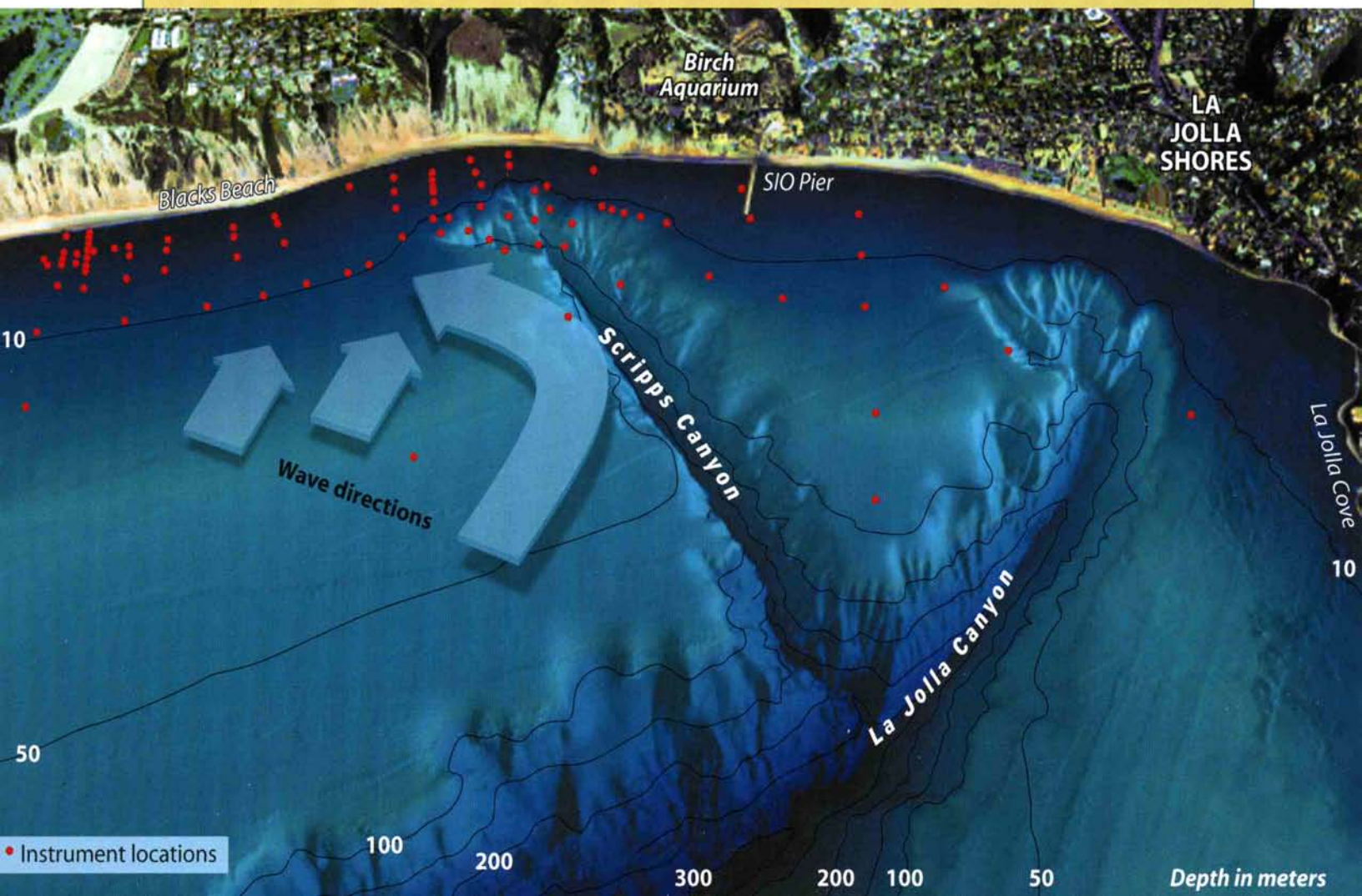
## Tube City

**THE FAMOUS SURF BREAKS** at Black's Beach are caused by the steering of wave energy by underwater bathymetry. Scripps and La Jolla canyons, narrow and several hundred meters deep, extend from offshore to within a few hundred meters of the shoreline.

An extremely rapid drop-off at Scripps Canyon alters the directions of waves originally arriving from the northwest. The waves are redirected (indicated by the curved large arrow)

toward Black's Beach. The exceptionally high waves at Black's occur because wave energy also arrives directly from the northwest (straight arrows). Wave energies in the sheltered region directly onshore of Scripps Canyon are very low.

NCEX wave-measuring instruments were concentrated both near the Scripps Canyon head where strong variations of wave heights were expected and north of Black's Beach where weak alongshore variation was expected.





Along many coasts, there is a clear relationship between wave direction and the resulting currents. On a north-south-oriented shoreline with fairly simple bathymetry, such as that studied in a related project at Duck, North Carolina (see "Sand Wars," Winter 1995 *Explorations*), waves approaching from the north drive surfzone currents to the south, and waves from the south drive currents to the north.

But on this complex coastline dominated by submarine canyons, rules about what's typical go out the window. Through a process known as refraction, the deep waters of La Jolla and Scripps canyons form an effective barrier to waves approaching land. The result is that the energy is diverted away from the canyon head and focused in the locations that make Black's Beach tube city for surfers. The energy creates breaks as high as five meters (15 feet) in autumn's storm season and produces consistently rideable waves with good shape throughout the rest of the year.

Researchers believe that, in places with irregular bathymetry like Scripps Canyon, the surfzone resembles an atmospheric weather system in miniature,



**Top,** NCEX technicians regularly retrieved instrument packages mounted on a variety of platforms, downloaded current and water pressure data, and returned the instruments to sea. Starting



at dawn on a November morning, they netted nearly a dozen packages. **Bottom,** NCEX researcher Tom Herbers supervises instrument retrieval aboard R/V Robert Gordon Sproul.

with areas of varying pressure on the scale of hundreds of yards. Currents around Scripps are a function of wind and waves, but more important, of water moving from high-pressure zones where sea level is relatively high to low-pressure zones around them. The high-pressure zones are created by the highest breaking waves.


"There are areas where the waves are really big, where the surfers are, then you move 100 meters [328 feet] on either side and the waves are really little," said Steve Elgar, a senior scientist at Woods Hole Oceanographic Institution (WHOI).

The energy produces alongshore currents running parallel to the beach. Convergent flows sometimes collide to produce rip currents that rush back out to sea. Other times the flow is divergent and alongshore currents skirt away in opposite directions. Black's, like all other beaches, experiences a transport of sand in the process. It is at the southern end of a littoral cell, a region of sedimentary circulation, that extends north to Orange County's Dana Point.

On most of the coastline, sand lost from one beach might fortify another to the south or north. In the case of Black's, when sand falls into Scripps Canyon, it never comes back.

*continued on page 12*



A woman with blonde hair and glasses, wearing a blue swimsuit and a watch, is crouching in the ocean. She is smiling and adjusting a component of a large, complex scientific instrument. The instrument has a yellow buoy at the top and various sensors and cables. The background shows a clear blue sky and the ocean surface with some white foam from waves.

# CLASS REUNION





**Opposite page,** Former Scripps student Britt Raubenheimer is part of a small community of nearshore researchers that includes fellow Scripps alumni Bob Guza (below left) and Steve Elgar (below right). The "California–Oregon Border" NCEX camp at Black's Beach (left).



**I**F THE COMMUNITY of oceanographers that studies nearshore processes seems particularly chummy, it might be because there's a good chance they all went to the same graduate school.

Of the 20 principal investigators who took part in the Nearshore Canyon Experiment (NCEX), six either received their doctorates at Scripps or are current or former researchers here. Many participants in the fall experiment can trace a lineage of nearshore processes to a study that began with Doug Inman, who founded the Center for Coastal Studies at Scripps in 1973 and continues teaching students today.

"Scripps has been one of the few institutions with several scientists focusing on nearshore research," said Britt Raubenheimer, a researcher at Woods Hole Oceanographic Institution who received her doctorate from Scripps in 1996. "Doug Inman was one of the first to promote beach research and that's a big reason why a lot of people are affiliated with Scripps in one way or another."

Raubenheimer is studying the dynamics of the swash zone, the area in very shallow water where waves alternately cover and uncover the shoreline. Scientific interest in this very specific niche of oceanography has increased greatly during the past 10 years, as it addresses a key feature that makes beaches an accessible attraction for the public.

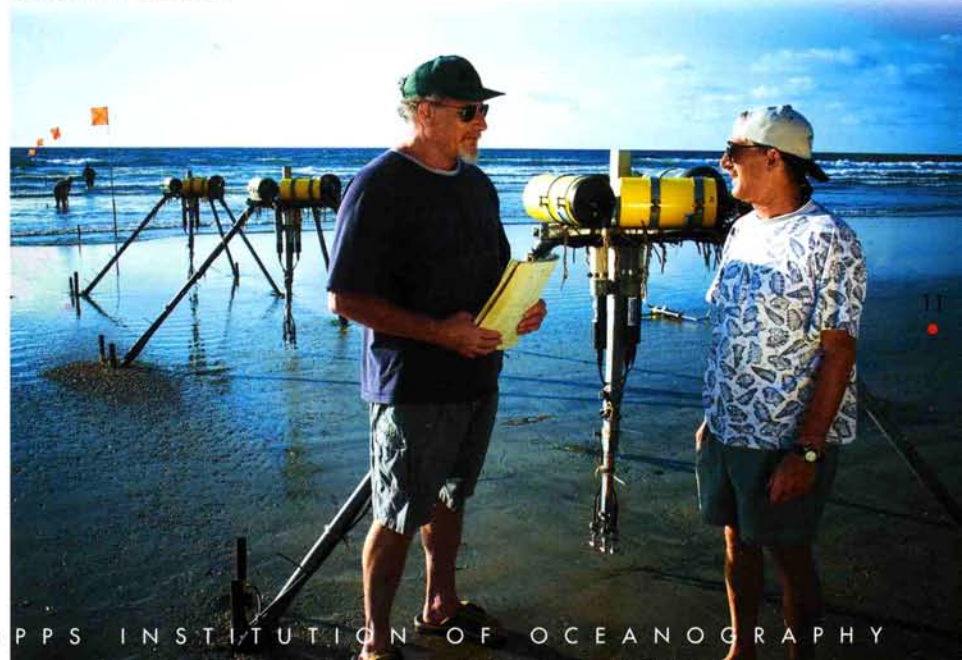
"Most people when they're talking about beach erosion are talking about the part of the beach where they're walking," Raubenheimer said.

As part of NCEX, Raubenheimer participated in a large-scale surfzone study with Scripps's Bob Guza, who received his doctorate here in 1974, and Woods Hole's Steve Elgar, who received his doctorate from Scripps in 1985. Raubenheimer additionally conducted a complementary swash zone study on a stretch of shoreline just north of Scripps. There she installed a transect of tripod platforms equipped with highly accurate pressure sensors and current meters. The row of tripods was laid out to catch as much alongshore flow activity as possible in the 20-meter-wide (66-foot-wide) swash zone.

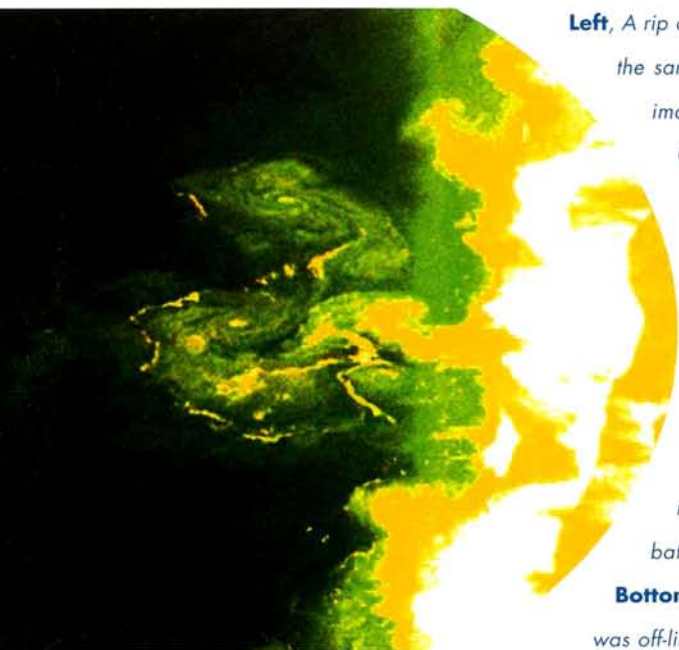
Raubenheimer said her aim is to understand what drives such flows, which follow paths not only perpendicular to the beach but also at a variety of angles, depending on several factors. The project could help determine what combination of water-level changes, wave actions, and other factors is responsible for the characteristics of the ankle-high rushes that lap at the feet of beachgoers.

"Ultimately, a goal of nearshore research is to understand how fluids are driving sediment transport that affects sand levels," she said.

In addition to Raubenheimer, Guza, and Elgar, NCEX researchers Bill O'Reilly of Scripps and Tom Herbers of the Naval Postgraduate School in Monterey, California, received their doctorates at Scripps, as did project coordinator Michele Okhiro. Investigator Tom Lippmann of Ohio State University is a former Scripps researcher.







**Left,** A rip current takes on stark outline thanks to the sand it takes with it in a color-adjusted image taken by the Airborne Remote Optical Spotlight System. The aerial survey portion of NCEX created time-series footage of the La Jolla coast during a 17-day period. Trained on individual locations for several minutes, digital cameras mounted on aircraft recorded movies of wave sets that can help researchers estimate nearshore bathymetry and current characteristics.

**Bottom,** For the sake of surfers, Black's Bowl was off-limits to instrumentation.



## DATA FOR TODAY AND TOMORROW

NCEX principal investigators Elgar, Guza, and WHOI scientist Britt Raubenheimer operated an array of 40 instrument packages distributed from Scripps Pier north to Black's. The tripod packages were placed at varying depths approachable on foot during low tide to as deep as five meters (16.4 feet). In deference to surfers, instruments were not placed in Black's Bowl.

At locations of instrumented tripods, measurements of pressure showed water depth and wave height, and measurements of currents showed the speed and direction of water motion. Free-floating drifters followed the moving water, indicating the locations of rip currents and other flow features.

As Darnell and other scuba divers began dismantling the instrument packages in late November and pulling cable lines out from beneath as much as several feet of sand, other technicians were still servicing instrument platforms

placed in deeper waters where wind and tide, rather than waves, become the main impetus for currents.

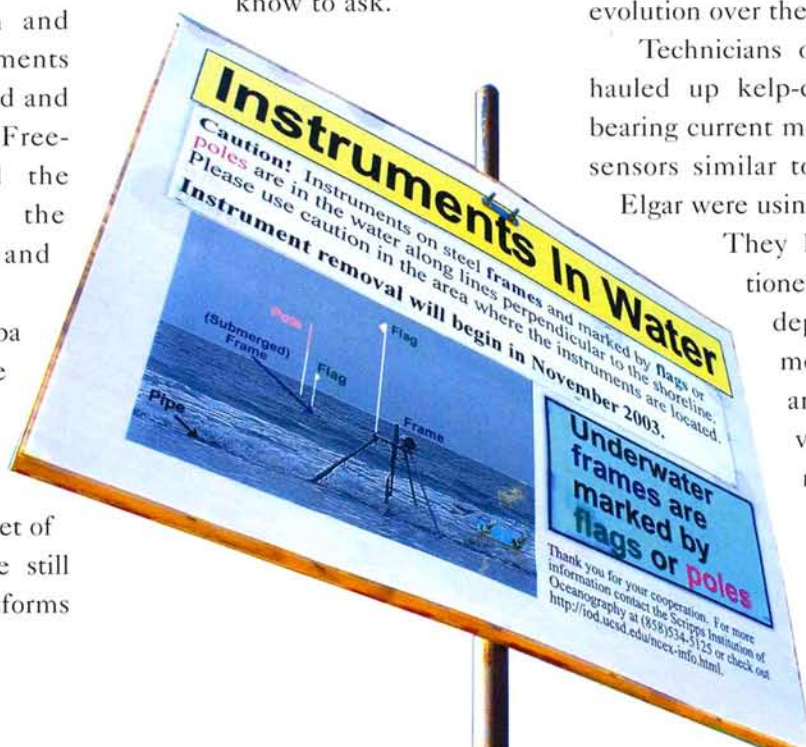
Tom Herbers, another NCEX principal investigator and a former Scripps student who is now at the Naval Postgraduate School in Monterey, California, said some aspects of the experiment will verify the results of numerical models that have predicted what could take place in a complex surfzone like La Jolla's. In other areas, the data will simply be a starting point for questions researchers don't yet know to ask.

"When it comes to circulation aspects of the problem, we really don't have any firm theories," said Herbers, standing on the deck of research vessel *Robert Gordon Sproul* on a November morning. "That's really an area where we don't understand the physics very well."

The combined surfzone and deeper-water NCEX observations provide a complete picture of wave evolution over the canyons.

Technicians on the *Sproul* deck hauled up kelp-covered platforms bearing current meters and pressure sensors similar to what Guza and Elgar were using closer to shore.

They had initially positioned the platforms at depths of about 10 meters (32.8 feet) and had last serviced them a month earlier. A few octopus that had made the platforms home





dropped to the ship's deck and were tossed back to sea as science party members began to download several weeks' worth of data. The next day, the crew reloaded the sensors onto the platforms and returned the packages to their seafloor stations.

In all, a half-dozen types of surveys took place during NCEX that used these new technologies, the absence of which would have made this project impossible even a decade ago. But how successful researchers are in making sense of the La Jolla coastline remains to be seen. Elgar reports that some preliminary conclusions are already in.

"Regardless of what we thought this experiment was going to be when we started, it's turning out to be even more complicated than we thought," Elgar said. 🌐

*Rachel Horwitz, a graduate student at Woods Hole Oceanographic Institution, embarks on her daily measurement of sand elevation using GPS.*