COASTAL HERITAGE

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Keeping Watch
Technologies Track Forces of the Sea

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ON THE COVER: *Boaters flee an approaching storm along Shem Creek in Mt. Pleasant.*

PHOTO / WADE SPEES AND POST AND COURIER

ANCHORS AWAY! *At Pier Romeo on the Cooper River in North Charleston, scientists load an ocean-observing buoy's anchor on a National Research Foundation research vessel.* PHOTO / WADE SPEES

Sea Grant
S.C. Sea Grant Consortium

Coastal Heritage is a quarterly publication of the S.C. Sea Grant Consortium, a university-based network supporting research, education, and outreach to conserve coastal resources and enhance economic opportunity for the people of South Carolina. Comments regarding this or future issues of ***Coastal Heritage*** are welcomed. Subscriptions are free upon request by contacting:

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LOST AND FOUND. *Troy Driscoll, a Charleston-area teenager, recuperates in the Medical University Hospital after being lost at sea with a friend for seven days. Now the U.S. Coast Guard is working with scientists on ways to use a technology that continuously measures currents on the ocean surface, which will lead to an improvement in search-and-rescue operations.* PHOTO/WADE SPEES AND POST AND COURIER

Keeping Watch

Technologies Track Forces of the Sea

By John H. Tibbetts

In April 2005, a rip current spun two Charleston-area teenagers far out to sea in a small open boat after they left Sullivan's Island on a brief fishing trip. Josh Long and Troy Driscoll were lost for seven days.

Ocean currents, according to U.S. Coast Guard's computer models, would likely keep the boat within an area bordered about 30 miles to the north and 50 miles to the south. But when a fishing vessel rescued the boys, they had drifted more than 100 miles north, almost to Cape Fear, far outside the grid where most of the search occurred.

Why did the Coast Guard's computer models miss by so many miles? The problem was that search-and-rescue personnel did not have up-to-date information about coastal-ocean currents. Today's observation tools, which include sensors on moored and tracking buoys, do not provide continuous data on surface current directions.

"There are no sustained measurements of which way the water is flowing," says Harvey Seim, a physical oceanographer at the University of North Carolina at Chapel Hill. He is also lead scientist of a regional university-research group called the Southeast Atlantic Coastal Ocean Observing System (SEACOOS), established to acquire and process data on marine waters of the Carolinas, Georgia, and Florida.

Now, the Coast Guard is working with scientists on ways to use a technology that accurately and continuously measures currents on the ocean's surface. Scientists at Rutgers University, University of Connecticut, and University of Rhode Island have been exploring ways to employ radar signals—essentially AM radio waves—in search-and-rescue operations.

How does this system work? Along the New Jersey coast, a series of whip transmitters installed near the beach's main dune sends radio signals up to 125 miles offshore. Because salt water is highly conductive, radar signals flow over the immediate surface of the sea. But when the signals encounter waves, they scatter.

Another series of 10-foot-tall antennae on shore receives the "sound" of the scattered data, which are relayed to the Rutgers University Coastal Ocean Observation Lab in New Brunswick, New Jersey. A computer program analyzes which direction currents are moving based on the sounds of signals reflecting off waves.

The Rutgers scientists are using a computer-based tool called a geographic information system (GIS), which allows them to sort and analyze huge amounts of information and then view statistical analyses in maps and other visual terms. Computer models are increasingly becoming a crucial part of oceanography, helping researchers understand data arriving from sensors and other observing technologies.

"The data come in and we process them and create a map of the currents every hour," says Josh Kohut, director of operations at the Rutgers lab.

The researchers have installed five transmitters, one every 50 miles, along the New Jersey shore. In recent years, the scientists experimented with the system for academic studies, but only now it is becoming available for Coast Guard use in New Jersey.

A recent demonstration project proved to the Coast Guard that using real-time data from radio signals is effective in locating objects transported in coastal currents.

"If someone were lost," says Kohut, "and the Coast Guard got a distress call, we could give the Coast Guard information about the currents, and they would have an idea of where that boat would be moving."

Arthur Allen, an oceanographer with the Coast Guard Office of Search and Rescue in Groton, Connecticut, says that using this tool in search-and-rescue operations will not be simple. The Coast Guard must ensure that relevant data are processed, stored, and made readily available for Coast Guard requirements everywhere that transmitters and antennae are deployed.

"Take a hypothetical case," says Allen. "We get notified at six this morning that someone was overdue at six yesterday evening. So we need reliable hindcasts of currents over the past 12 hours. We need to know who stores and processes that data in accordance with our needs. It's a responsibility issue. Who's going to store it? You can't go back to the database of the past 12 hours and get a big blank."

Moreover, the Coast Guard must be certain that observing technologies are available consistently on every coastline.

Says Seim, "In an emergency situation, this system has to work naturally within the Coast Guard's information-support system, and that's pretty tricky."

Seim is developing a similar system for the Carolinas and Georgia. One transmitter has been installed in the Outer Banks.

Once the technical problems are sorted out, would a series of radar-wave transmitters and antennae help the Coast Guard find a small boat like the one lost for a week at sea off the Carolinas? "Absolutely," says Seim. "It provides just what you need to know during a search-and-rescue."

This is just one example of a revolution in ocean science that allows researchers to study the marine environment in a more detailed, timely fashion than ever before.

Ocean data are flowing to computer networks from instruments, sensors, and other technologies on shore, in the water, and in the atmosphere.

In some cases, researchers are finding innovative uses for older

SO MANY ACRONYMS!

Even experts in ocean observations have difficulty keeping up with new acronyms in this field: IOOS, GOOS, IEOS, GEOSS, SEACOOS, SECOORA, and on and on. "I think there is a new acronym almost every month," says J. Michael Hemsley, deputy director for coastal operations at Ocean.US. "This has become progressively more complicated."

Here's an overview of some acronyms of ocean-observing systems.

The Integrated Ocean Observing System (IOOS) is the U.S. effort to build a network of comprehensive observations for U.S. waters.

IOOS is the U.S. contribution to the Global Ocean Observation System (GOOS), an international effort to observe the oceans.

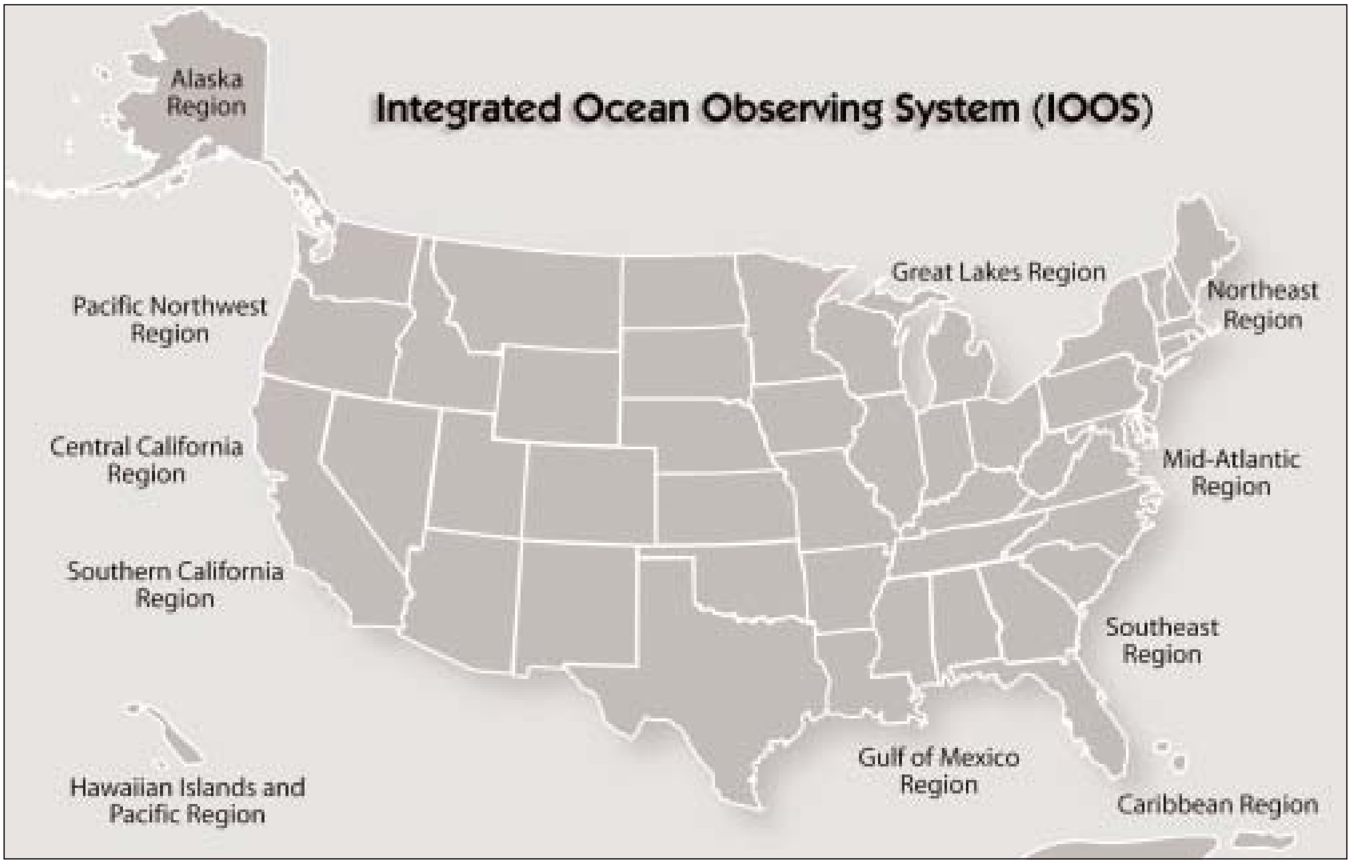
IOOS is also the ocean component of Integrated Earth Observing System (IEOS), a U.S. program to coordinate ocean and terrestrial observations.

IEOS, in turn, is the U.S. contribution to an international program called the Global Earth Observation System of Systems (GEOSS). In April 2004, representatives from 54 nations agreed on a 10-year implementation plan for GEOSS, which would link and provide a compatible standard for environmental antennae around the planet.

The United States and other nations would develop and maintain the system, collect the information, enhance data distribution, and provide practical working models to all of the world.

The Southeast Atlantic Coastal Ocean Observing System (SEACOOS) is a regional university research program created to acquire and process data from observing tools in the coastal ocean waters stretching from Florida to North Carolina.

The Southeast Coastal Ocean Observing Regional Association (SECOORA) coordinates observations activity from North Carolina to Florida. SECOORA is one of 11 regional associations established to coordinate and integrate ocean-observing activities along the region's coasts of the nation's ocean-observing system.



FULL COVERAGE. *The ocean-science community is collaborating on a national initiative called the Integrated Ocean Observing System (IOOS), which comprises 11 regional programs in U.S. waters (shown above). Each program would be responsive to the particular needs of various regional and local users.*

technologies such as radar waves. In other instances, sophisticated observing sensors depend on the most advanced electronics, miniaturization, and highly efficient circuitry. Such instruments produce the same or better quality information with a fraction of the cost of using research vessels.

In the old days, scientists went to sea, bringing back weeks-old data. But "for some purposes data are like fish," says Margaret A. Davidson, director of NOAA Coastal Services Center. "They're of no use after a few days."

Recent advances, however, have made "real-time" observations of the ocean possible—that is, scientists can download data from sensors every few hours or even sooner in some cases.

Some advances in oceanography are due to dramatic leaps in computer power, which roughly doubles every two years. Researchers are creating powerful computer programs that can crunch streams of oceanographic and meteorological data into more realistic forecasts for search-and-rescue operations, disasters, and other needs.

This is important because growing numbers of people are moving to the coast, particularly in the U.S. Southeast. In states from Virginia to Florida, shoreline counties expanded 22.5 percent in population from 1990 to 2002. Coastal development is altering beaches, estuaries, and watersheds, and more people every year are vulnerable to hurricanes, storm surges, and other ocean-related disasters.

Yet the nation's ocean-observing system is fragmented and disorganized. "There is still no coherent observing system for the ocean," says Seim. "There are elements of it all over, but they're not integrated."

The federal government wants to bring together disparate parts of the nation's ocean-observing system and make it function as one. The ocean-science community is working on a national initiative called the Integrated Ocean Observing System (IOOS), which includes:

- Observing platforms such as ships, airplanes, satellites, buoys, shore stations, and drifters for mounting or deploying instruments and sensors;
- Computer models that can be used to create useful information products such as disaster-response or search-and-rescue maps;

- Data-management and communications systems that receive, store, and integrate data from the instruments and sensors;
- Outreach efforts to help people better use and develop information products.

The IOOS will form the U.S. portion of a global system to observe the world's oceans. Finally, the global ocean-observing system will be part of an international effort to study the entire planet, land and sea.

About 150 years ago, the United States set out to create a comprehensive weather forecasting and warning network. Today, NOAA's National Weather Service is the most successful Earth-observing program in the nation. Nearly every American depends to some degree on this service. Millions of people check weather reports each day in newspapers and on television and the Internet.

NOAA, moreover, is one of the driving forces behind advancing the ocean-observing system, and it provides much of the publicly available data from the sea.

It's time to invest in a comprehensive observational and forecasting network for the oceans, according to the U.S. Commission on Ocean Policy, established to make recommendations to the president and Congress for a national ocean policy.

The commission's final report, released in September 2004, strongly urged the further building of an Integrated Ocean Observing System, which would help better track marine resources, ocean-related disasters, and climate.

The commission endorsed the principle of "observing and understanding the ocean in the same way we observe the atmosphere," says commissioner Marc J. Hershman, an ocean-policy professor at the University of Washington.

Some have compared today's effort to improve ocean observations to the building of the U.S. space program, which helped alter how many people perceive the planet. When astronauts sent back the pictures of Earth, showing a bright blue globe against the blackness of space, many Americans said these images made them more sensitive to its beauty and fragility.

HOLES IN COVERAGE

Despite progress in observing the ocean, the U.S. system remains patchy and under-funded, with many holes in coverage, according to the U.S. Commission on Ocean Policy.

Additional observing sensors would help improve storm forecasting, says Doug Marcy, a physical scientist at NOAA Coastal Services Center. In many cases, forecasters must extrapolate the intensity, track, and radius of maximum winds of a particular storm from measurements taken by an airplane flying through one quadrant of the hurricane.

If forecasters can also draw data from an ocean buoy or a wind sensor bobbing in the storm, it would help computer models forecast where the storm is going, how strong it's going to be, and how high the surge will be when the storm hits land.

Madilyn Fletcher, director of the University of South Carolina Belle W. Baruch Institute, and colleagues at North Carolina State University and the University of North Carolina-Wilmington, are drawing ocean data from four offshore moorings and three coastal water-level stations along the South Carolina coast.

The researchers have created a three-dimensional computer model that analyzes various storm-surge scenarios for hurricanes in the Charleston region. This model takes into account ocean currents below the surface during a storm, not just at the surface, says Fletcher. This information could help forecasters predict wave action and wave effects on flooding along the coastline.

WHO USES OCEAN OBSERVATIONS?

The nation's marine industry already relies on forecasts of the marine environment. Oil-and-gas companies, for example, purchase forecasts of ocean currents and waves, which they use to protect offshore infrastructure in case of a storm or other unusual conditions.

Many commercial fishermen and charter-boat captains buy forecasts of ocean currents and temperatures, enabling them to locate and catch more fish without burning up valuable time and fuel.

Who sells these forecasting products? "There are hundreds and hundreds of consultant firms," says Mitchell Roffer, founder and president of Roffer's Ocean Fishing Forecasting Service, Inc., based in Miami. His firm provides services to commercial and recreational fishermen, among other marine sectors.

Environmental consultants download data from ocean-observation Internet portals, most of which are operated by federal agencies or academic programs. They use computer programs to create forecasting maps and other analytical tools, which they sell to the marine industry.

"A lot of these (forecasting) products are created by the private sector and sold to the private sector," says Worth Nowlin, an oceanographer at Texas A&M University.

Shipping companies purchase forecasts of ocean currents so they can plan routes, allowing vessels to travel more efficiently, saving time and money. These savings affect every American's pocketbook—the overwhelming majority of products we use every day are shipped via sea trade.

In the Gulf of Maine a private-public partnership is helping fishery managers obtain more comprehensive ocean data. "Observation systems can

ALL ABOARD. *Scientists and technicians prepare to strap down an ocean-observing buoy on the research vessel* Cape Hatteras. *Four offshore moorings and three coastal water stations along the South Carolina coast have been deployed by the Carolinas Coastal Ocean Observing and Prediction System (Caro-COOPS), a program of the University of South Carolina, North Carolina State University, and the University of North Carolina-Wilmington.* PHOTO/WADE SPEES provide the environmental background information that helps fishery managers do stock assessments," says Philip Bogden, CEO of the Gulf of Maine Ocean Observing System.

Harbor pilots in six U.S. ports use real-time data about currents and tides to guide ships into berths.

In May 1980, when a violent squall caused high winds and near-zero visibility in Tampa Bay, Florida, an empty phosphate freighter struck the Sunshine Skyway Bridge. The freighter took out one of the bridge piers, breaking off a section of the center span, and 35 people fell to their deaths.

Tampa Bay remains a difficult harbor to navigate—ships must thread a narrow, relatively shallow channel into the bay from the Gulf of Mexico.

Increasingly huge commercial vessels, particularly container ships, continue to push the envelope of keel depth in the Tampa Bay channel. Even a very small change in sea level can determine if a harbor pilot can drive a ship in or out of port. That's why pilots need timely, accurate information about factors that affect water depth.

To help ships navigate more safely, Tampa Bay was designated the first harbor to have a Physical Oceanographic Real-Time System (PORTS), part of the national ocean-observing system. Tampa Bay PORTS was installed in 1992.

Each Tampa Bay pilot has a wireless, portable computer with access to GPS-based navigation systems and timely data from PORTS. Every six minutes in multiple locations, Tampa Bay PORTS collects measurements of currents, tides, water levels, temperatures, waves, visibility, and winds. This information is available with a few clicks of a computer mouse.

Within five years after Tampa Bay PORTS was installed, the number of ship groundings dropped 60 percent.

M. DAVIDSON

"The aim is to link all of the nation's ocean sensors, large and small, into a string of pearls of different sizes along U.S. coastlines."

COMBINING KNOW-HOW

Each observing technology has limitations. Satellites can cover broad reaches of the planet, but they lack fine resolution. Also, satellites can view only the ocean surface; they cannot see far into its depths. Moored and free-floating sensors in the ocean can cover only small geographic areas at one time but with much higher resolution than a satellite.

Researchers frequently must combine data from various kinds of observing tools to gain insight into the marine environment. In many cases, though, these instruments are not linked by common standards of measurement or identification, so it's very difficult to use them in tandem.

In addition, the United States has more than 40 coastal-ocean observing systems deployed and maintained by government agencies, university partnerships, private companies, and other organizations. In many cases, data from these observing systems are incompatible.

Academic scientists, for instance, deploy sensors in coastal waters, but their efforts frequently are not coordinated with other university projects. University scientists have a reputation for prickly individualism, building careers by differentiating their efforts from those of colleagues.

"There are hundreds of institutions and scientists all distinguishing themselves from the other guys down the coast," says Davidson.

Many government agencies have also failed to collaborate across bureaucratic boundaries. It's not unusual for a scientist in one government agency to be unable to view data from sensors managed by another agency. Turf battles have inhibited cooperation. And many private companies are skeptical of working with the federal government.

Until recently, the research community spent scant time and resources creating a common "language"—or compatible standard for all—to express numbers from various kinds of ocean-observation tools.

Many ocean scientists are not using the same standards, says Worth Nowlin of Texas A&M. Scientists frequently fail to supply enough "metadata," or the information that explains the location where the data was collected, at which time it was collected, and by what kind of instrument.

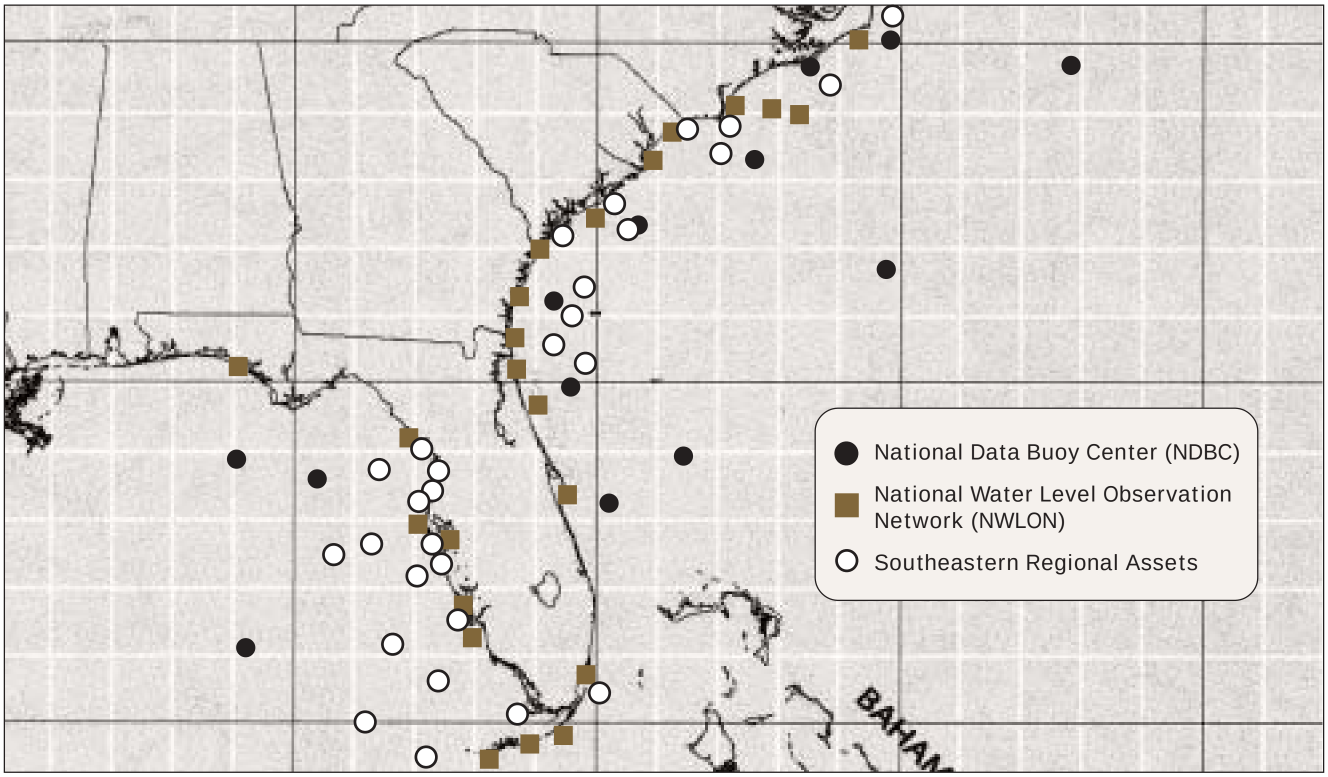
"All this stuff has to be in there," says Nowlin, "but a lot of people don't put enough (labeling information) to make it useful for anyone but themselves."

REGIONAL SYSTEMS SOLVE PROBLEMS

Much of the ocean-science community is broken up into fiefdoms ruled by researchers wary of outsiders and jealous of interference. As a result, there has been scant trading of information.

But now academia, government, and industry are hoping to break down barriers by creating common standards of measurement and identification for various sensors and instruments as well as from various locations along coastlines. This is a crucial step in the nation's capacity to combine data from various sources.

SEACOOS, a regional ocean-observations research program, "is attempting to bring together various



TOOLS OF THE TRADE. *This map illustrates the real-time ocean-observing tools from North Carolina to the eastern Gulf of Mexico. The problem is that these tools have not been integrated into a single operational system. Now, the S.C. Sea Grant Consortium is coordinating efforts of a new regional association called the Southeast Coastal Ocean Observing Regional Association (SECOORA), which aims to establish a system to supply consistent, reliable data for users throughout the region.*

ocean data," says Seim, "so that you can get them all in one place in a consistent fashion."

On the SEACOOS Web site (www.seacoos.org), an interactive mapping application allows anyone to access near real-time oceanographic data in a customized fashion. Ocean-forecasting products are available in formats prepared for visualization tools such as GIS software.

The S.C. Sea Grant Consortium, moreover, is coordinating efforts of a new regional association called the Southeast Coastal Ocean Observing Regional Association (SECOORA). The association will help steer ocean-observing projects of U.S. federal programs in the Carolinas, Georgia, and Florida. "One of SECOORA's key functions is to bring all stakeholders to the table to ensure that ocean observations are meeting their needs," says M. Richard DeVoe, executive director of the S.C. Sea Grant Consortium. SECOORA is one of the 11 regional associations in the National Federation of Regional Associations (www.usnfra.org), the collection of programs augmenting the national backbone of observations gathered by the federal agencies.

In the next few years, a much greater wealth of ocean data could routinely flow from sensors and instruments to computer systems that will acquire, refine, and disseminate information to people who can use it.

Emergency planners, for example, already use GIS software to assimilate complex layers of information into products such as hazard maps for hurricanes and tsunamis. Over the next decade, further advances in computer technology will allow for more sophisticated forecasting capacity.

This next stage of the revolution in data sharing and processing would help any business relying on forecasts of ocean conditions.

Advances in Internet technologies should also make it easier for anyone to visualize forecasts of the marine environment. It seems likely that someday an emergency manager could log directly onto a computer network and click on an interactive map showing an approaching hurricane's projected impacts on a town or neighborhood. Or perhaps coastal homeowners could log onto an Internet network to view interactive maps of storm-surge impacts on their property.

Still, there are many steps to go before an integrated system becomes a reality. One of the first steps—and one of the hardest—is to tie together existing sensors and instruments. Then the nation needs to build and maintain many new ones.

Says Davidson, "The aim is to link all of the nation's ocean sensors, large and small, into a string of pearls of different sizes along U.S. coastlines."

Tracking El Niño/La Niña

A Model for Ocean Observation

In the mid-1990s, South Carolinians were told to watch out for particularly nasty hurricane seasons because El Niño wouldn't be around to protect us. It was the first time many South Carolinians had ever heard of El Niño.

How did researchers know about a connection between hurricanes in the Atlantic and El Niño? They had studied the Pacific Ocean, of all places, over decades.

Between 1975 and 1985, a buoy network was first deployed across the central Pacific Ocean as part of the Tropical Ocean Atmosphere experiment.

This project is unique in marine science, allowing researchers to gather data from real-time, continuous observations in a large open-ocean region.

By the mid-1980s researchers had realized the international importance of the El Niño-Southern Oscillation (ENSO), an intricate interplay between the ocean and atmosphere. When central Pacific waters are cooler, the change is called La Niña, or little girl. When central Pacific waters are hotter, it's called El Niño. Because it arrived at Christmas time, the warming was known as "the little boy" or "the Christ child."

ENSO's sea-temperature oscillations strongly affect the speed of high-altitude, cold winds blowing eastward across the Atlantic Ocean. The speed of these winds helps determine how many large hurricanes form to strike the Caribbean and the United States.

When El Niño arrives every few years to warm the central Pacific Ocean, the resulting heat energy pushes huge amounts of moisture from the sea into the atmosphere. In turn, this heat energy speeds up high-altitude winds racing across the roof of the world, chilling the growth of hurricanes in the Atlantic Ocean. During El Niño years, fewer large hurricanes form off the west coast of Africa. La Niña, by contrast, slows down this jet stream and allows more giant hurricanes to build there.

For some of the tropics and subtropics, particularly in the developing world, El Niño and La Niña's arrival can mean life or death. For example, ENSO can cause dramatic changes in rainfall—bringing the blessings of monsoons or the disaster of drought—in India and Southeast Asia. It can determine whether crops will fail in Australia, the

HOT AND COLD. *During La Niña (top), ocean waters in the central Pacific are significantly cooler than normal, illustrated by the pale, finger-shaped image stretching west from South America. During El Niño (below), however, central Pacific waters are much warmer than usual, represented by the dark image stretching across the equator. The study of these temperature oscillations is providing a model for future ocean observations around the world.*
COURTESY NASA/JPL-CALTECH

WATER TAXI. *Temperature extremes of El Niño and La Niña in the central Pacific Ocean can bring dramatic changes in precipitation across the tropics and subtropics. During El Niño, South Carolina is more prone to heavy rainfall and flooding, as shown here. During La Niña, South Carolina is likelier to face drought. Researchers are observing other marine systems worldwide to learn about their impacts on weather.*
PHOTO/POST AND COURIER

African Sahel, and Peru. ENSO is also an important driver of disease outbreaks, including those of cholera, malaria, and dengue.

By the mid-1990s, to reduce its impacts on agriculture and water supplies, many wealthy countries established detailed forecasts of ENSO. The forecasts, of course, relied on ocean observations.

Today, the economic benefits of ENSO forecasts to U.S. agriculture alone are considerable—about $300 million per year. When all economic sectors are considered, the estimated value of improved ENSO forecasts reaches $1 billion a year for the United States.

The network of ocean-observing buoys, now numbering about 50, has been extended beyond the Pacific Ocean to the Atlantic Ocean. And there are plans to expand the network to the Indian Ocean, too.

Now, the international community hopes to employ the ENSO-observation model in oceans throughout the world.

"What we're trying to do for the rest of the planet is what we have already done with ENSO forecasts," says Margaret A. Davidson, director of the NOAA Coastal Services Center.

Reading and Web sites

NOAA Coastal Services Center www.csc.noaa.gov/

Southeast Atlantic Coastal Ocean Observing System (SEACOOS) www.seacoos.org/

Southeast Coastal Ocean Observing Regional Association (SECOORA) www.secoora.org/

Ocean.US www.ocean.us/

Rutgers University Coastal Ocean Observation Lab marine.rutgers.edu/cool/

U.S. Commission on Ocean Policy final report www.oceancommission.gov/

U.S. Ocean Action Plan ocean.ceq.gov/

Pacific Import

Deploying Tsunami-Detection Technology in the U.S. Southeast

How did so many get trapped without warning? Last Christmas season, an Indian Ocean earthquake spawned one of the worst natural disasters in modern history. On December 26, 2004, a tsunami drove huge waves across coastlines in South Asia and East Africa, killing more than 280,000 people and injuring millions.

A global seismic network quickly located the earthquake (9.3 Richter scale) 155 miles off the west coast of Northern Sumatra. The earthquake displaced massive amounts of seawater, which shot to the surface and spread in waves traveling at speeds of 450 miles per hour or more. Waves were 30 feet high on coastlines near the epicenter of the earthquake.

This catastrophe underscored the principle that the international community must do more to observe the ocean and share vital information about marine ecosystems across regions and national boundaries. Today, there is a concerted global effort to deploy additional ocean sensors and exchange knowledge around the world.

What was tragically lacking in the Indian Ocean was a basin-wide effort to monitor tsunamis.

"If there had been a system in the Indian Ocean like the one the Pacific Ocean has, many of those lives could have been saved," said Waverly Person, director of the U.S. Geological Survey National Earthquake Information Center in Golden, Colorado.

The Tsunami Warning System in the Pacific, coordinated by the International Oceanographic Commission, is the only one of its kind in the world, helping protect the coastlines of 26 nations, including the U.S. West Coast. Several nations in the Pacific, including the United States, supplement the regional system with their own warning systems.

The Pacific Ocean system relies on data from tidal gauges, seismic sensors, and satellites. In 2003, moreover, six new high-tech water-pressure sensors were deployed in the north and east Pacific.

Each Deep-ocean Assessment and Reporting of Tsunamis (DART) buoy is attached to a sensor anchored on the ocean bottom. The sensor detects subtle changes in water pressure whenever a tsunami wave passes overhead, and sends an electronic message to the surface buoy. From there, a transmitter sends a warning via satellite to communications sites on shore.

DART buoys have become the gold standard of tsunami-warning technologies. Tidal gauges near coastlines are also critical, because they pick up a tsunami's first wave making landfall and report it to the entire network.

TESTING THE WATERS. *The federal government is planning to deploy high-tech buoys along the East Coast, the Gulf Coast, and the Caribbean. This Deep-ocean Assessment and Reporting of Tsunami (DART) buoy, shown here, is the gold standard of tsunami-warning devices.*
PHOTO COURTESY OF NOAA

Indian Ocean countries, however, did not deploy deep-ocean pressure sensors or maintain enough tidal sensors throughout the region because basin-wide tsunamis are so uncommon there.

Basic communications failures compounded the disaster. Not long after the earthquake off Northern Sumatra, U.S. scientists understood from computer models that giant waves were racing toward the South Asian mainland and East Africa. Yet U.S. researchers couldn't reach leaders and emergency managers in those countries by phone to warn them.

Emergency officials in Indian Ocean nations who realized that a tsunami was approaching couldn't reach coastal communities in time.

"Even the places with communications systems for disasters didn't succeed in getting the word out in time to people on the shoreline," says Margaret A. Davidson, director of the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center, in Charleston.

Many residents and tourists also didn't know that they must flee from shore when they felt an earthquake tremor or when the sea suddenly receded, an indicator of an impending tsunami.

"You have to have education about tsunamis," says Person. "The most important thing is education, education, education."

Now, the United Nations is preparing a tsunami-warning system for the Indian Ocean, which should be available by 2007. Other regional warning systems will be installed in the Caribbean, the Mediterranean, the Gulf of Mexico, and the Atlantic.

Tsunamis are rare in the Atlantic Ocean, but not unheard of. Forty tsunami and tsunami-like events have struck the U.S. East Coast in the past 400 years, says George Maul, an oceanographer at Florida Institute of Technology.

Most tsunami-like events on the U.S. East Coast are probably rogue waves, which are wind-generated, occurring when several waves traveling similar speeds combine to form a massive one. Tsunamis, by contrast, are caused by earthquakes, landslides, volcanic eruptions, and asteroids.

A rogue wave struck Daytona Beach, Florida, just before midnight on July 3, 1992. Injuring 20 people and damaging 10 cars, the wave, estimated to be 18 feet tall, was linked to thunderstorms along the Georgia coast.

In May 2005, a 70-foot rogue wave struck a cruise ship in the Caribbean, and the ship had to limp into the Charleston port for repairs.

In 1755, a huge earthquake in Lisbon, Portugal, drove a tsunami across the Atlantic Ocean into the Caribbean, where it killed people in Barbados, Martinique, and other islands. There were no reported deaths on the North American mainland, however, perhaps because immediate shorelines were sparsely populated at the time.

W. PERSON

"If there had been a system in the Indian Ocean like the one the Pacific Ocean has, many of those lives could have been saved."

If a similar earthquake occurred in Lisbon today, it could drive a 15-foot high wave into the southeastern U.S. Atlantic beaches, says Maul.

A major earthquake in the Canary Islands off the west coast of Africa or one in the Caribbean could send tsunamis toward the U.S. East Coast.

Seismic events in coastal South Carolina can spawn dangerous waves, as well. The 1886 earthquake in Charleston caused a tsunami that struck Mayport, Florida, near Jacksonville, says Maul.

Since the Indian Ocean tsunami, the federal government and Congress have stepped up efforts to enhance ocean observations in U.S. waters, especially those that help provide tsunami data.

In January 2005, the federal government announced an expansion of the nation's tsunami-warning system for all U.S. ocean basins at a cost of $37 million over two years. This protection would include coverage of the East Coast, the Gulf Coast, and the Caribbean. NOAA will deploy new DART buoys in the oceans, and seismic monitoring and communications will be enhanced.

Deploying additional tsunami-warning buoys around U.S. coastal waters is a good idea, says Maul. However, he points to one of the lessons learned from the December 2004 tragedy. Because major Indian Ocean tsunamis are rare, policymakers in that region had faced more urgent concerns than deploying and maintaining expensive sensors for a single threat.

It seems likely that a single-purpose tsunami-warning system on the East Coast would also eventually lose funding to other spending priorities, says Maul.

Now, Maul and his colleagues are collaborating on a research plan to create a comprehensive Tsunami and Coastal Hazards Warning and Mitigation System. They plan to work on a new DART buoy prototype, which would integrate surface-mounted technologies that can warn of several hazards, including rogue waves, storm surge, rip currents, and sea level changes. "A DART buoy can do just one thing: monitor for tsunamis. Instead, it should have many purposes," says Maul.

In June 2005, the U.S. Senate included language in the FY06 NOAA appropriation bill, requiring that tsunami-warning buoys become part of the broader Integrated Ocean Observing System. NOAA was given direction to reengineer tsunami buoys so that these tools can do more than one task, therefore contributing to the broader observing system goals.

That's one of the main principles of the Integrated Ocean Observing System—to integrate technologies and data so that more industries, agencies, and universities can make use of them. "We need to systematically deploy additional sensor capabilities," says Davidson, "on top of existing or new platforms."

EBBS & FLOWS

3rd International Symposium on Deep-Sea Corals

Miami, Florida
Nov. 28–Dec. 2, 2005

Understanding the ecosystem role, function, and value of deep-sea corals and associated fauna has become a priority topic for many national governments and international regional resource management bodies. This international symposium will facilitate global exchange of current scientific knowledge on deep-sea corals and associated fauna, and will discuss possible statutory means available to conserve and protect deep-sea habitat. For more information, visit conference.ifas.ufl.edu/coral

National Council on Science, Policy, and the Environment National Conference

Washington, D.C.
Jan. 26–27, 2006

The National Council for Science and the Environment (NCSE) will host a conference, "Energy for a Sustainable and Secure Future," bringing together education, business, civil society, and government leaders. NCSE will later produce a detailed report of the recommendations developed by conference participants. Contact Craig Shiffries at conference2006@NCSEonline.org or view www.ncseonline.org/NCSEconference/

American Meteorological Society 86th Annual Meeting

Atlanta, Georgia
Jan. 29–Feb. 3, 2006

This meeting covers all aspects of the atmospheric and related sciences including climate change, weather forecasting advances and technology, space weather, drought, weather modification, environmental policy, climate variability, wildfires, El Niño, and weather-related health issues. More than 1,500 presentations will be made and more than 2,000 weather and climate experts will attend. For more information contact Stephanie Kenitzer, kenitzer@dc.ametsoc.org, or visit www.ametsoc.org

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