NOAA

Celebrating 200 Years of Science, Service, and Stewardship

CELEBRATING

1807 U.S. Coast and Geodetic Survey 2007

200 YEARS

of Science, Service, & Stewardship

http://celebrating200years.noaa.gov/

UNITED STATES DEPARTMENT OF COMMERCE
The Under Secretary of Commerce
for Oceans and Atmosphere
Washington, D.C. 20230

Dear Readers:

In a country as young as America, we do not have many opportunities to celebrate 200-year anniversaries. When we do, it is obviously special. The National Oceanic and Atmospheric Administration (NOAA) is very proud of its history – a history now rooted in 200 years of science serving the American people.

President Thomas Jefferson created the Coast and Geodetic Survey in 1807 to survey and map the country's coastline. The survey's vital role in providing safer travel on the seas and promoting commerce was worthy of its status as the young Nation's first physical science agency.

To accomplish this important mission Congress authorized President Jefferson "to cause proper and intelligent persons to be employed, and also such of the public vessels in actual service, as he may judge expedient, and to give such instructions for regulating their conduct as to him may appear proper." A Swiss immigrant named Rudolph Hassler brought together mathematicians, cartographers, geodesists, meteorologists, hydrographers, topographers, sailors, laborers, and administrators to build the Coast and Geodetic Survey.

The legacy first started by President Jefferson and Rudolph Hassler lives on today throughout NOAA. The agency has grown into a world-class scientific organization whose employees are highly regarded as leaders in their respective fields. The NOAA legacy has blossomed for two centuries, and with the agency's critical role in many of today's most pressing issues, NOAA's leadership role is well-secured for generations to come.

NOAA's importance to Americans' everyday lives has grown a great deal over the past 200 years, and this book will give you an idea of the scope and impact of the agency. I am proud to be part of such an important and notable legacy, and I want to extend my sincere thanks to all past and current NOAA employees, Congressional supporters, and all of our friends and partners.

Sincerely,

Conrad C. Lautenbacher, Jr.
Vice Admiral, U.S. Navy (Retired)
Under Secretary of Commerce for
Oceans and Atmosphere

THE ADMINISTRATOR

THE SECRETARY OF COMMERCE
Washington, D.C. 20230

Dear Readers:

Two-hundred years ago, President Jefferson foresaw the tremendous value of ocean-based commerce and trade to our young and fledgling Nation. He created the Survey of the Coast in part to ensure the country's economic foundation could be built upon safe, reliable marine transportation. Two centuries later, that survey has evolved into the National Oceanic and Atmospheric Administration (NOAA). As a division of the Department of Commerce, it remains an integral part of America's economy.

With responsibility for our Nation's fisheries, ports, weather and climate, as well as environmental stewardship, NOAA touches nearly one-third of our country's gross domestic product. NOAA has a clear legacy of contributing to the strong foundation of our Nation's economy. The agency plays a vital role in the Department of Commerce's economic agenda, and serves on the front lines of protecting and preserving our environment.

President Jefferson could not have imagined the tremendous technological revolution of the past few decades, and the way in which our world has progressed and developed. Yet the importance of understanding the environment's intertwined role with the economy remains just as salient today as it was in 1807.

On this occasion of 200 years of superior service to the country, I congratulate NOAA and its predecessor agencies, and thank the men and women who serve as the guardians of our Nation's environmental treasures.

Sincerely,

Carlos M. Gutierrez

Secretary of Commerce

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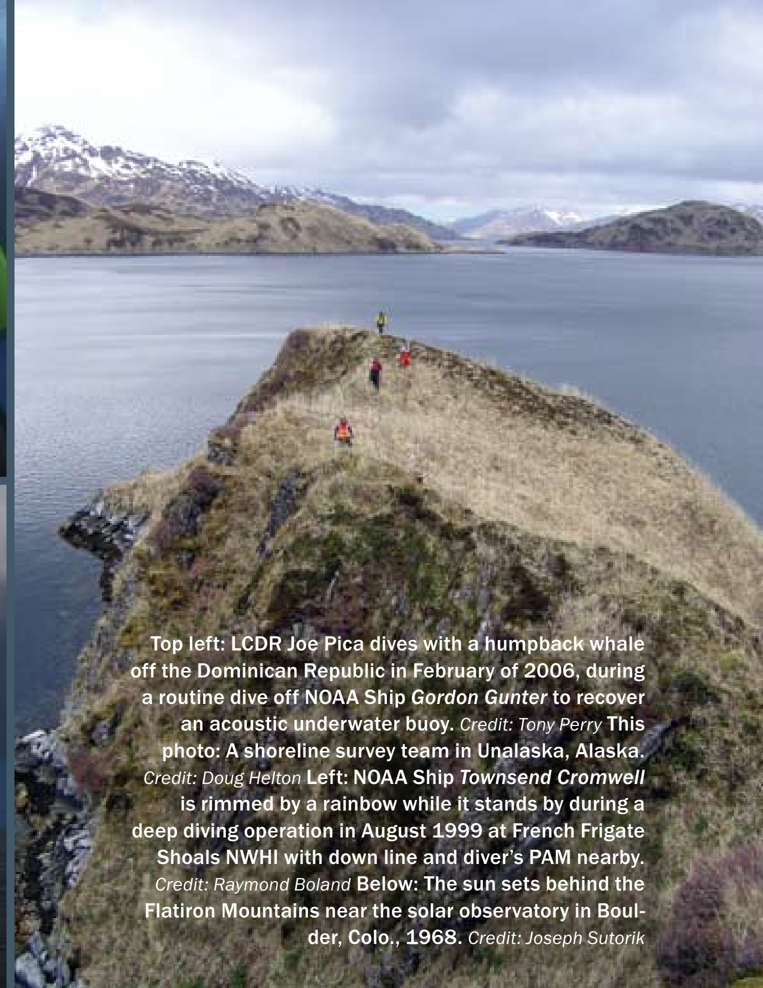


Top left: LCDR Joe Pica dives with a humpback whale off the Dominican Republic in February of 2006, during a routine dive off NOAA Ship *Gordon Gunter* to recover an acoustic underwater buoy. *Credit: Tony Perry* This photo: A shoreline survey team in Unalaska, Alaska. *Credit: Doug Helton* Left: NOAA Ship *Townsend Cromwell* is rimmed by a rainbow while it stands by during a deep diving operation in August 1999 at French Frigate Shoals NWHI with down line and diver's PAM nearby. *Credit: Raymond Boland* Below: The sun sets behind the Flatiron Mountains near the solar observatory in Boulder, Colo., 1968. *Credit: Joseph Sutorik*

Top left: Herring caught during an acoustic trawl survey of Lynn Canal in Southeast Alaska, 2001-2004. *Credit: David Csepp, NMFS – Juneau, AK* This photo: NOAA's last helicopter on its last mission, September 2005, at Eglin Air Force Base, Fla. *Credit: Phil Eastman* Left: Jeremy Potter sips water from a sea ice melt pond with the U.S. Coast Guard icebreaker *Healy* in the background during the summer of 2005. *Credit: Fred Gorell* Below: Hugh Finn looks through the Big Eye binoculars aboard the NOAA Ship *Oscar Elton Sette* on March 21, 2006, during a PISC cetacean research cruise from American Samoa to Honolulu. *Credit: Siri Hakala*

NOAA TOUCHES MILLIONS OF LIVES ... EVERY DAY

Based upon interviews conducted by Michael A. Robinson

Drawing on a 200-year-old legacy, NOAA is an agency in which science gains value. NOAA's footprint is sizable, with science and services saving countless lives, innovations enhancing the lives of millions more, and operations supporting trillions of dollars of U.S. economic activity every year.

"Our ocean and atmosphere are essential to all life on Earth," said NOAA Chief of Staff Scott Rayder. "But we can't manage what we don't know, so it is vital that we learn all we can about how the Earth works, how our planet's processes interact and change, and how all this affects our lives now and in the future. I can't think of more important work than what NOAA employees do each day."

Rayder also is proud of the benefits to every taxpayer. "For about the cost of a cup of coffee, taxpayers benefit from a month's worth of daily weather forecasts, updated coastal maps and charts to support safe navigation, fisheries management, around-the-clock satellite observation, world-class scientific ocean and atmospheric research, and much more."

At the forefront of crucial 21st-century issues, NOAA's importance will only continue to grow. "We have the human talent and technical capabilities to benefit not only all Americans, but the global community," Rayder said.

NOAA's 12,500 employees and many national and international partners play key roles in initiatives that range from the deep ocean to the surface of the sun. The aim is to apply a comprehensive understanding of the role of our oceans, coasts, and atmosphere in the global ecosystem to make the best social and economic decisions.

NOAA work has paid off on multiple levels. NOAA Weather/All-Hazards Radio now reaches about 95 percent of the nation. A new supercomputer capable of conducting over 450 billion calculations per second helps predict extreme weather days in advance. NOAA is helping to spearhead a 66-nation effort to develop a Global Earth Observing System of Systems (GEOSS) that, over the next decade, is expected to yield outstanding benefits in just about every sector, including health, energy, agriculture, weather, climate, and transportation. "The outcomes will be enormously positive," Rayder said. "We will be able to connect many more scientific dots. Decision-makers and many others will have the solid science on which good policy must be built."

Formed in 1970, NOAA drew together a number of agencies that are among the oldest in the nation, including the Office of Coast Survey that dates to 1807. As NOAA celebrates its 200th anniversary, senior officials look ahead to fostering a "One NOAA" concept, building on the expertise and accomplishments of individual NOAA components so that the identity of NOAA is as recognizable as many of its parts. NOAA, for example, is not just the National Weather Service and the National Hurricane Center, but the National Fisheries Service, the National Ocean Service, the National Satellite and Information Service, the Office of Atmospheric and Oceanic Research, and Marine and Aviation Operations. "Operationally," said Rayder, "the goal over the past several years has been to get sometimes distant field offices, centers, line offices, and operations working as one smooth enterprise."

As set forth in NOAA's Strategic Plan, significant headway has already been achieved, and Rayder credits retired Navy Vice Adm. Conrad C. Lautenbacher, Jr., who serves as both Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator, and NOAA staff at all levels for these advances. "Rather than having staff in different line offices focused on an issue such as climate, we now have program managers and goal leads sitting around one table who have knowledge of all NOAA assets that can

NOAA Ground-based Scanning Radiometer in Barrow in March 2004. *Credit: Al Gasiewski*

be brought to bear on a problem. Our planet works in an integrated fashion, and we must too," Rayder said. "We have adopted an ecosystem approach to management, which means moving from the species-by-species approach into a holistic approach that looks at entire ecosystems, including the role we play in many of these ecosystems."

Rayder likes to underscore this point with an example tied to the Washington, D.C., area. "Crabs are popular in this area. The crabs feed on oysters, and rockfish feed on crabs. People eat all three, but with about 7.5 million people living within easy driving distance of the Chesapeake Bay, their activities will have a profound effect on local ocean and river food groups. And all three creatures, along with humans, depend on the environmental balance of the land, sea, and air. To achieve long-term environmental solutions, we need to think at broader levels," Rayder said.

Today, NOAA has a program manager for climate who pulls together critical data from disparate sources. The same is true in many other areas, including ecosystems, weather, water, commerce, and transportation. NOAA's response to Hurricane Katrina is an excellent example of how various parts of the agency work together to protect the American public.

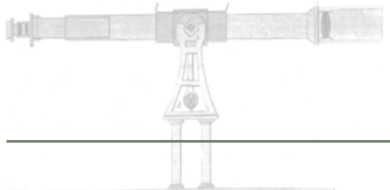
As National Hurricane Center meteorologists were tracking the storm and warning officials about its destructive impact, NOAA's National Weather Service was providing dependable five-day forecasts. NOAA's Satellite and Information Service was delivering overhead images of the killer storm, and NOAA's National Ocean Service was using tide guides to track and predict powerful storm surges. NOAA's Marine and Aviation Operations had aircraft flying into the storm itself. In the meantime, NOAA Fisheries Service staff were working with the fishing community, updating them on the storm's progress, and helping them find a safe harbor. Considerable recovery help continues to this day.

Rayder notes that NOAA's strategic vision is derived largely from NOAA's workforce, which engaged in a "bottoms-up approach" to changing the organization's culture. The approach began in 2002, when employees had 90 days to review the agency's operations and make recommendations for future programming. The focus is now on four mission areas and complementary agendas: Coastal Management, Climate Change, Weather and Water, and Commerce and Transportation. NOAA's science-based management approach also incorporates new priorities for environmental literacy, global observation systems, state-of-the-art research, international cooperation, and homeland security.

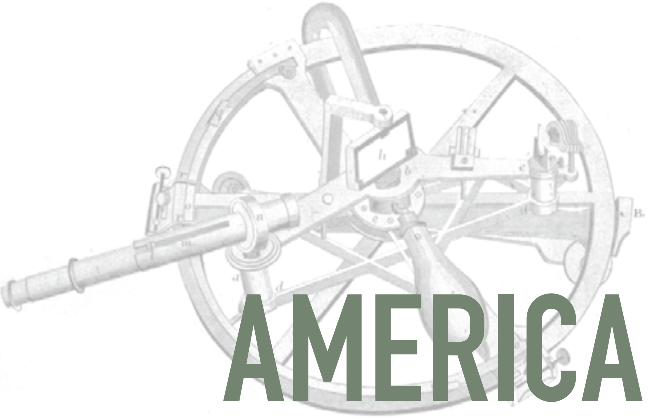
Rayder believes the integrated "One NOAA" approach is the best driver for addressing present and future challenges. "We need to look more to the sea for finding future solutions," he said. "More energy lies in the top 50 feet of the ocean than in Earth's entire atmosphere. The oceans could become greater sources of energy, food, and medicines, and almost certainly will yield clues to global climate shifts and in understanding the role of water vapor on long-term climate change. We still haven't gotten out there and explored the oceans like Lewis and Clark explored the American frontier 200 years ago. The new frontier is the ocean. I think that is as exciting as a trip to Mars.

"Our history goes back 200 years, and in that time NOAA explorers, scientists, researchers, and many others have made remarkable contributions that have made our lives better and safer. The people at NOAA today are no less dedicated. Their dedication, inspiration, and talent will keep NOAA on track to continue shaping our world for the better. I am proud to work at NOAA."

National Oceanic and Atmospheric Administration — www.noaa.gov



THE SURVEY OF THE COAST: PIONEERS OF AMERICAN SCIENCE

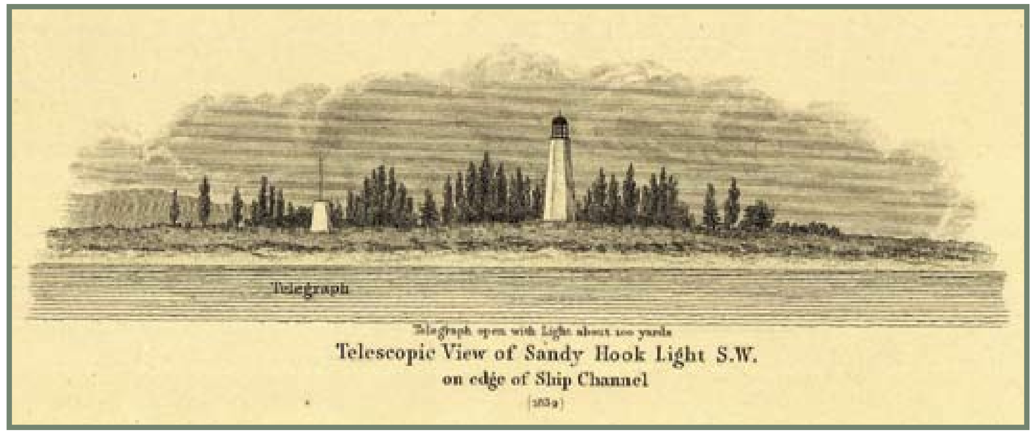


BY ALBERT E. THEBERGE, JR. / COMPILED BY CRAIG COLLINS

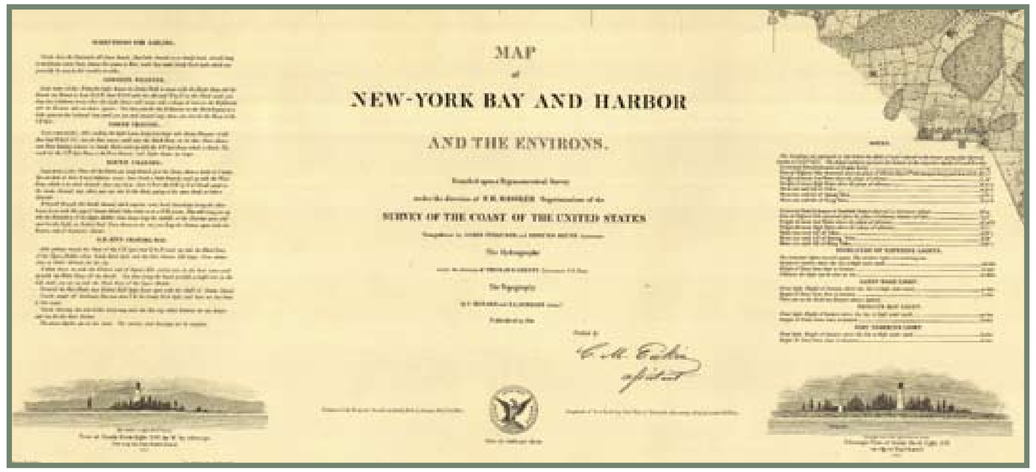
The more you learn about the organization that began as the Survey of the Coast of the United States, the more you might begin to suspect that when President Thomas Jefferson signed the law creating it in 1807, even he – a man certainly among the most scholarly of U.S. presidents – did not completely understand what he was getting into.

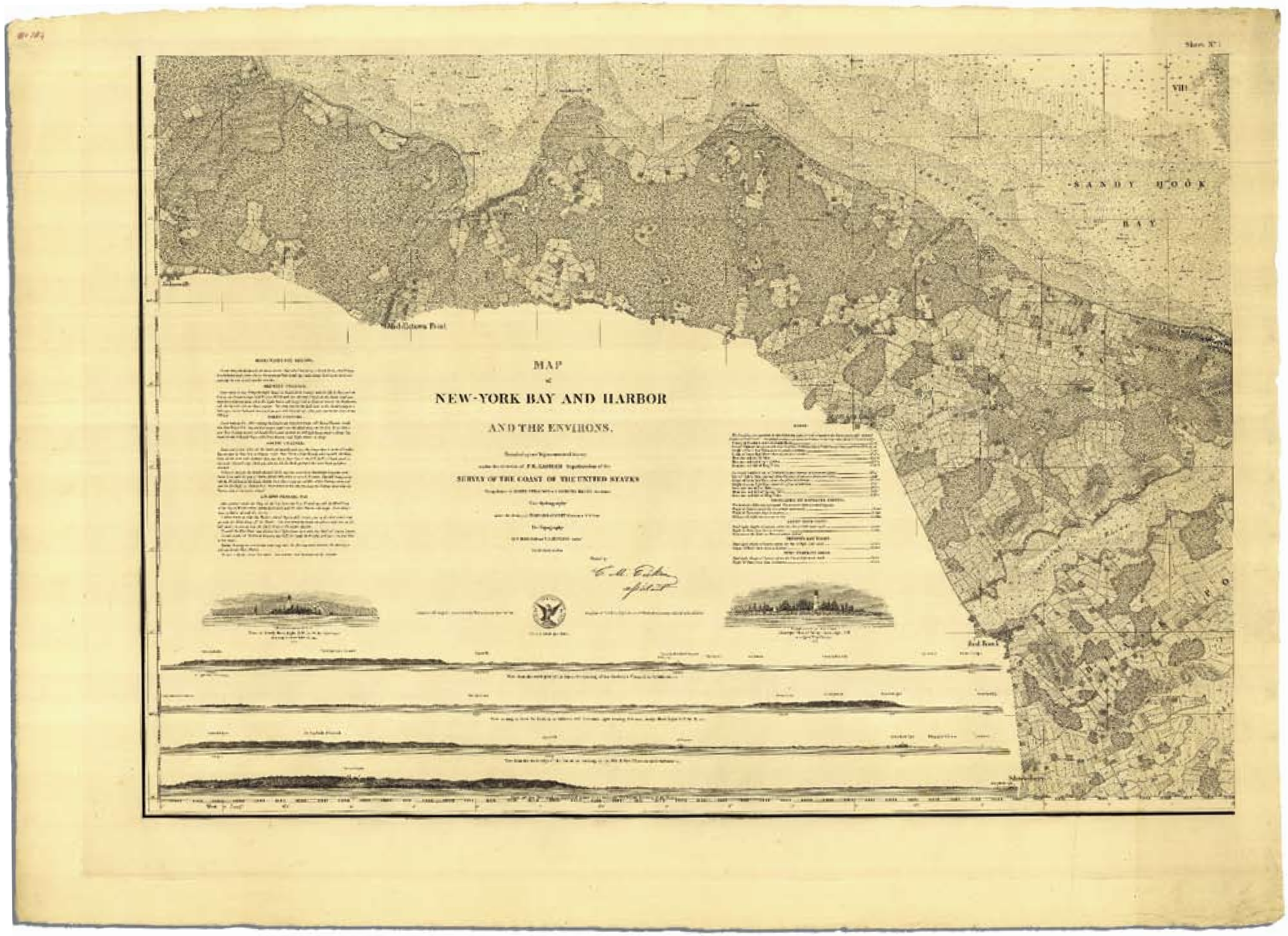
The law, signed less than five months after the conclusion of the Lewis and Clark Expedition into the newly acquired Louisiana Territory, presented the Survey with an apparently simple mandate – to provide charts of the nation's shores and coastlines that would help the young nation safely develop maritime commerce and travel while aiding in the defense of its Atlantic shoreline. Because of its direct relation to the nation's commerce, the Survey was initially placed within the Department of the Treasury.

Strictly speaking, the Survey was an engineering organization, charged with collecting and recording geographic and geophysical facts.



Opposite page: Sheet No. 1 of the New York Harbor Chart, the first classic Coast Survey chart. Above: A cutout of the view of Sandy Hook Lighthouse from the chart. Below: The title block of the chart gives the chart's publication date as 1844.





The tasks of observing, recording, and analyzing these facts, however, was unprecedented in scale, and would require scientific methods that were, at the time, poorly developed in the United States. Without realizing it, Jefferson had opened a Pandora's box of scientific disciplines, including topography, hydrography, bathymetry, tidal physics, astronomy, metrology, geodesy, geology, geophysics, oceanography, meteorology, cartography, and pilotage. By the time of the Civil War, under the leadership of the Survey's first two superintendents, Ferdinand Hassler and Alexander Dallas Bache, these fields would reach a level of discipline and professionalism that would have been difficult to foresee just decades earlier, when Bache and his good friend Joseph Henry — an eminent scientist who would become the first Secretary of the Smithsonian Institution — had privately lamented the state of science in a nation seemingly overrun by quacks, all vying for a chunk of the federal treasury. "At present," Henry wrote to Bache in 1836, " … Charlatanism is much more likely to meet with attention and reward than true unpretending merit."

The work of the Survey of the Coast and its descendant agencies has been, fortunately, a long record of "true unpretending merit," with the regrettable consequence that most American laypersons are unaware of what this organization managed to achieve in its critical first decades: a legacy that resonates today not only because of its scientific discoveries, and not only in the numerous methodologies and processes it pioneered for the scientific community. It can be justly claimed that the men who guided the Survey through its formative years — some of the most eminent scientific minds of the time — were responsible for creating a permanent interface between science and government, ensuring that for future generations of Americans, public policy would be rooted in measurable knowledge.

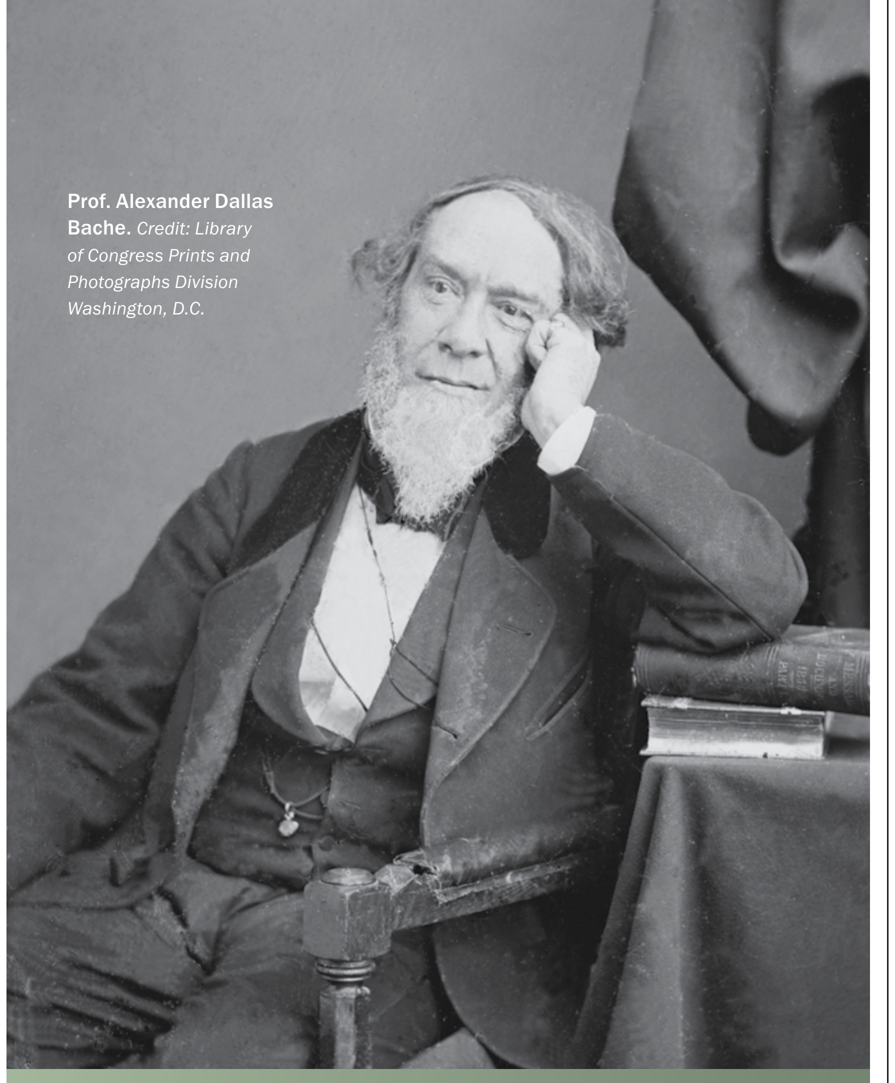
The Foundation: Ferdinand Hassler

Jefferson placed the Survey in the hands of a man who, like himself, was a member of the American Philosophical Society — Ferdinand Hassler, a Swiss émigré schooled in the European methods of surveying and measurement. For various reasons — an embargo that virtually shut down the merchant marine, war with Britain (where Hassler had been sent to procure instruments), and political battles — the Survey did little work in its early years, and in fact suffered a long period of near-dormancy. After the Survey was temporarily transferred to the Navy, Hassler was separated from it for 15 years before being reappointed as superintendent in 1832.

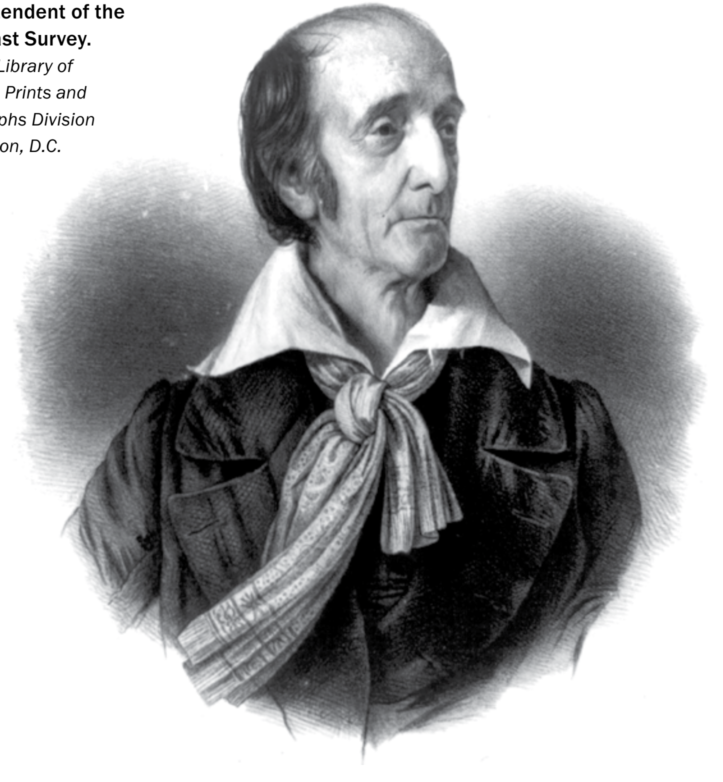
Hassler's political troubles stemmed not only from the fact that he was a scientific idealist who insisted on the most painstaking, accurate methods for obtaining topographic and hydrographic data, but also from the unrealistic expectations of the policy-makers of a young nation who had no experience in managing scientific endeavors and little knowledge of their requirements and procedures. Hydrographic surveys, he maintained, would not be sufficiently accurate unless they were tied to geodetic surveys — that is, points on nautical charts would be referenced to points on land that were "fixed" by the meticulous mathematical process of triangulation.

Because the initial appropriations for the Survey were modest, Hassler drew heavily from the personnel of the Army — which employed most of the government's engineers and cartographers — and the Navy, which owned the ships. While Hassler conducted his first surveys of the land around Long Island Sound, some Naval officers argued that it would be much more efficient to use the Navy's tradition of "detached" surveys, which relied on a sextant and a chronometer.

Time and again, Hassler was proven to be correct in his scientific approach (his survey of New York Harbor Entrance discovered an invaluable deepwater channel that Navy surveyors had never managed to find), while getting the politics all wrong. Triangulation was fine, but the government wanted charts. Hassler, defiant to the end, insisted on verifying his results before publishing, and made no move to appease his



Prof. Alexander Dallas Bache. *Credit: Library of Congress Prints and Photographs Division Washington, D.C.*



Ferdinand Hassler, first superintendent of the U.S. Coast Survey. *Credits: Library of Congress Prints and Photographs Division Washington, D.C.*

critics. By 1843 — the year Hassler died after an injury and illness sustained in the field — the Survey had not produced any charts, and was reorganized by Congress in order to bring other scientific minds from the nation in to broaden the organization's oversight.

It was well that Hassler fought these early political battles and insisted on training and hiring the best surveyors and craftsmen. While he did not have much to show outwardly, he had fended off attacks that might have weakened not only the methods and infrastructure of the nation's first scientific agency, but also the moral principles that guided it — mainly that science, if implemented properly and without political interference, could be a force for social justice and the common good.

The Science

Hassler's successor, Alexander Dallas Bache, shared his insistence on the best science, but also demonstrated an uncanny political shrewdness over the course of his career. A great-grandson of Benjamin Franklin, Bache had close relatives or in-laws scattered throughout the military and Cabinet, and he used his connections to broaden the work of the Survey not only geographically, sending teams to the Gulf Coast and the newly acquired West Coast of the United States, but also scientifically. He directed the nation's first organized studies of tides and tidal currents, began the first systematic oceanographic studies of the vast Gulf Stream that traverses the Atlantic Coast, and instituted the first systematic geophysical studies conducted by the United States with his studies of magnetic forces, particularly magnetic declination and its relationship to both navigation and certain methods of land surveying.

Bache also broadened the intellectual (and, not coincidentally, political) base of the Survey, inviting the most renowned scientists and mathematicians in the nation to either work directly for the Survey as assistants, or to consult on projects while remaining at their academic posts. Among these scientific superstars were Harvard College's Benjamin Peirce, the foremost American mathematician of the mid-19th century; naturalist and paleontologist Louis Agassiz; microscopist Jacob Bailey of West Point (the first to study specimens from the ocean bottom raised by Survey sounding parties); astronomer Maria Mitchell of Nantucket (believed to be the first professional woman ever hired by the federal government); and astronomer Benjamin Apthorp Gould, a pioneer in the Survey's use of telegraphy to determine longitude who in 1866 used the transatlantic cable to establish the difference of longitude between the United States and Europe.

The many fundamental scientific discoveries made by the Survey in the mid-19th century were significant, but more important to the American scientific community were the methods used both to collect and analyze the Survey's enormous amount of field data. Under Bache, the Survey adhered to Hassler's insistence on using organized teams, conducting fieldwork cooperatively under rigorous standards and with the best available instruments — further ensuring that the lone observer, anecdotally jotting down notes while at sea or in the wilderness, would cease to be considered a "scientist" in the American mind. The scientists and mathematicians of the Survey also refined numerical methods for analyzing and verifying static data, such as latitude and other geodetic measurements, and for modeling dynamic phenomena such as tides, currents, and geomagnetics. By communicating these methods to the American scientific community — often through voluminous annual reports — Superintendent Bache helped push American science into the modern world.

The Product

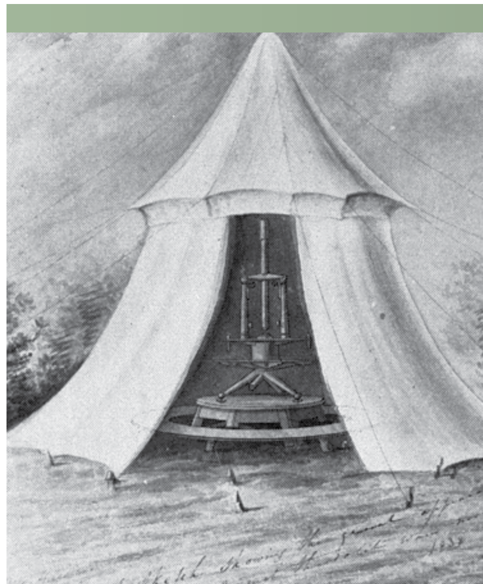
Despite his intense focus on the development of scientific methods, Bache never lost sight of the fact that — in his own words — "The true object of the survey is to furnish charts of the coast for the purposes of commerce." But he initially encountered the same problem as his predecessor on the production side — a lack of skilled engravers who would meet both the Survey's budget and its exacting standards in handcrafting the copper plates used to print maps and charts. Through the ingenious innovations of George Mathiot, chief of electrotyping during the 1850s, this logjam of data was broken elegantly, as Mathiot experimented with and developed means of electrotyping — using electro-chemical processes for producing exact replicas of hand-engraved plates (many of which took up to four years and $6,000 to produce, and would last through only a few hundred printings). By the end of the 1850s, Mathiot had developed a method for electrotyping that would produce exact replicas for about $60 each, and resulted in virtually unlimited printings of map sheets.

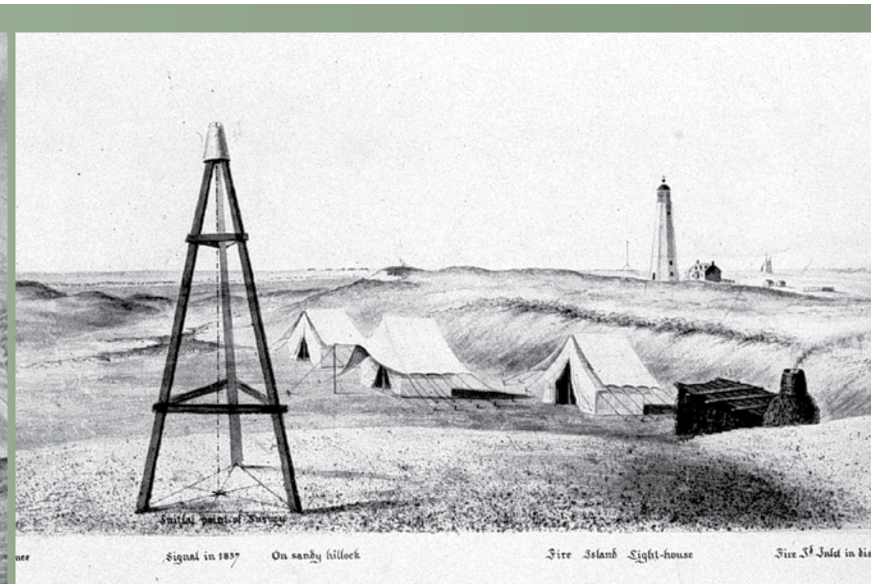
Mathiot also experimented with the use of photoengraving — the use of light-sensitive chemicals to etch original plates — and discovered a way to use photography to reduce original map sheets to a smaller scale. By eliminating the need for draftsmen to reduce or enlarge field sheets by hand prior to engraving scaled-down plates, Mathiot pioneered a first step toward automated cartography.

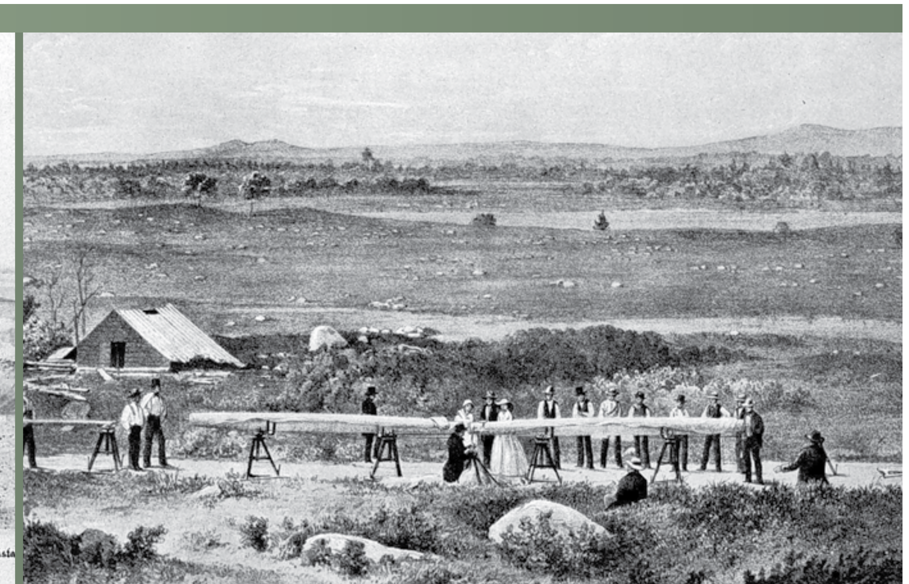
During these years, in addition to its original mandate — the nautical chart — the Survey developed new products, such as tide tables and coast pilots. In tailoring its output to the nation's needs, the Survey signaled a willingness to be led by the unfolding of scientific knowledge, rather than to be hemmed in by a bureaucratic role. Referring to the Survey, Bache once wrote: "The tendency of such works is undoubtedly to adopt a routine and to adhere to it, so that sometimes they fall behind the progress of the science of the day. System is so very desirable that its excess, constituting a blind routine, is always a danger to be avoided." Bache and his colleagues understood as well as anyone that in order to serve the public, the Survey would have to serve science — a recognition that today pervades the work of the Survey and its successors within NOAA, whose datasets and products are used to aid a number of disparate purposes and scientific fields, including climate change, marine geology and geophysics, ecosystem restoration, and construction projects.

American Politics and Society

Bache's meticulously compiled annual reports demonstrated that in addition to his legislative instructions, he charged himself with the broader crusade to use the Coast Survey as a means to raise the







Right: Hassler's observing tent. The original sketch was most likely made by John Farley. Far right: Ferdinand Hassler's camp at the west end of the Great Fire Island Base Line. Opposite page: Coast Survey base line party of Alexander Dallas Bache measuring Epping Plains Base. It was the last base line measured by Bache. *Credits: NOAA Central Library Photo Collection* stature of science, especially within the United States. With his finger on the pulse of all Survey operations, and with a growing network of friends within the growing scientific community, Bache — the undisputed leader of the American physical science community, the nation's first great science administrator — awakened and organized American scientists to assume a more direct role in American policy-making. He had long professed the belief that, "an institution of science, supplementary to existing ones, is much needed in our country, to guide public action in reference to scientific matters," and for several years he assumed a leadership role in the American Association of the Advancement of Science. But Bache remained dissatisfied with the ability of American science to interact with the political decision-making process, and did not forget his dream of a national institution composed of the best American scientists.

It wasn't until midway through the Civil War that Bache and his colleagues would have a clear opportunity to establish their institution, with the help of Rear Adm. Charles Henry Davis, a longtime friend and colleague. In the opening months of the war, Davis saw Joseph Henry's grim prophecies of American charlatanism come to life, as a cavalcade of snake-oil salesmen descended on the capital — some gaining an audience with President Lincoln himself — to peddle revolutionary "inventions" designed to win the war. Davis was keen to install a board of scientists to filter out the nonsense. This initially resulted in the establishment of the Navy Permanent Commission, composed of Davis, Bache, and Joseph Henry and assigned the responsibility of evaluating inventions and proposals brought to the Navy's attention. But Davis persisted in pursuing the establishment of a larger national organization and, with the help of Senator Henry Wilson, an act was passed establishing the National Academy of Sciences on March 3, 1863. The 50 charter members (led by their first president, Bache) were charged, whenever called upon by any department of the federal government, to "investigate, examine, experiment, and report upon any subject of science or art, the actual expense of such investigations, examinations, experiments, and reports to be paid from appropriations which may be made for the purpose." In the interest of maintaining its scientific objectivity, the Academy was to receive no compensation from the government — an arrangement that exists to this day. After the Civil War, American science would expand beyond a point where its pursuits could effectively be controlled or guided by a single individual or group, even one as commanding and charismatic as Bache — who died in 1867. In fact, the postwar years saw the formation of several federal agencies, each whose mission included the pursuit of a distinct branch of science. But the legacy of the Coast Survey, under Alexander Dallas Bache and his predecessor, Ferdinand Hassler, still resonates today in the work of these agencies, and in the work of all American professional scientists. Under Hassler and Bache, American science, along with its practical usefulness, would acquire a social and political significance that it would never surrender.

The Coast and Geodetic Survey: The Beginning — www.history.noaa.gov/legacy/coastsurvey.html

THE COAST SURVEY AND THE CIVIL WAR

As the Civil War broke out between Union and Confederate states in 1861, Superintendent Alexander Dallas Bache was forced to battle against the Union government's plan to conserve resources by disbanding the Coast Survey. Bache, with his allies in the Army and Navy, deftly convinced the Lincoln administration of the Survey's importance to the war effort. He promptly turned the Coast Survey into a powerful tool for Union forces, dispatching personnel to direct or assist in mapping, scouting, and hydrographic surveys. Bache also, as a West Point graduate and member of the Blockade Strategy Board, used his intimate knowledge of the nation's coastlines to help devise the naval choke hold that would prevent key Southern ports from receiving economic or military aid from European allies.

Coast Surveyors played a role in nearly every naval action of the war, from blockade squadrons to key battles such as Farragut's conquest of New Orleans. The "brown-water" clearing of Confederate battlements along the Mississippi River was accomplished with the help of surveyors' reconnaissance sketches and detailed maps.

Coast Surveyors also contributed maps for tactical and strategic use by the Union Army, whose knowledge of battlefield topography tended to give it an advantage even in defeat; when Confederate Gen. Robert E. Lee won his first tactical victory at Cold Harbor as commander of the Army of Northern Virginia, he suffered nearly 2,000 more casualties than Union forces. According to Confederate Brig. Gen. Richard Taylor, who commanded the 9th Regiment of Louisiana Volunteers, ignorance of the surrounding area was a lethal factor: "The Confederates knew no more about the topography of the country than they did about Central Africa ... without maps, sketches, or proper guides, [we were] as helpless as if we had been transferred to the banks of the Lualuba."

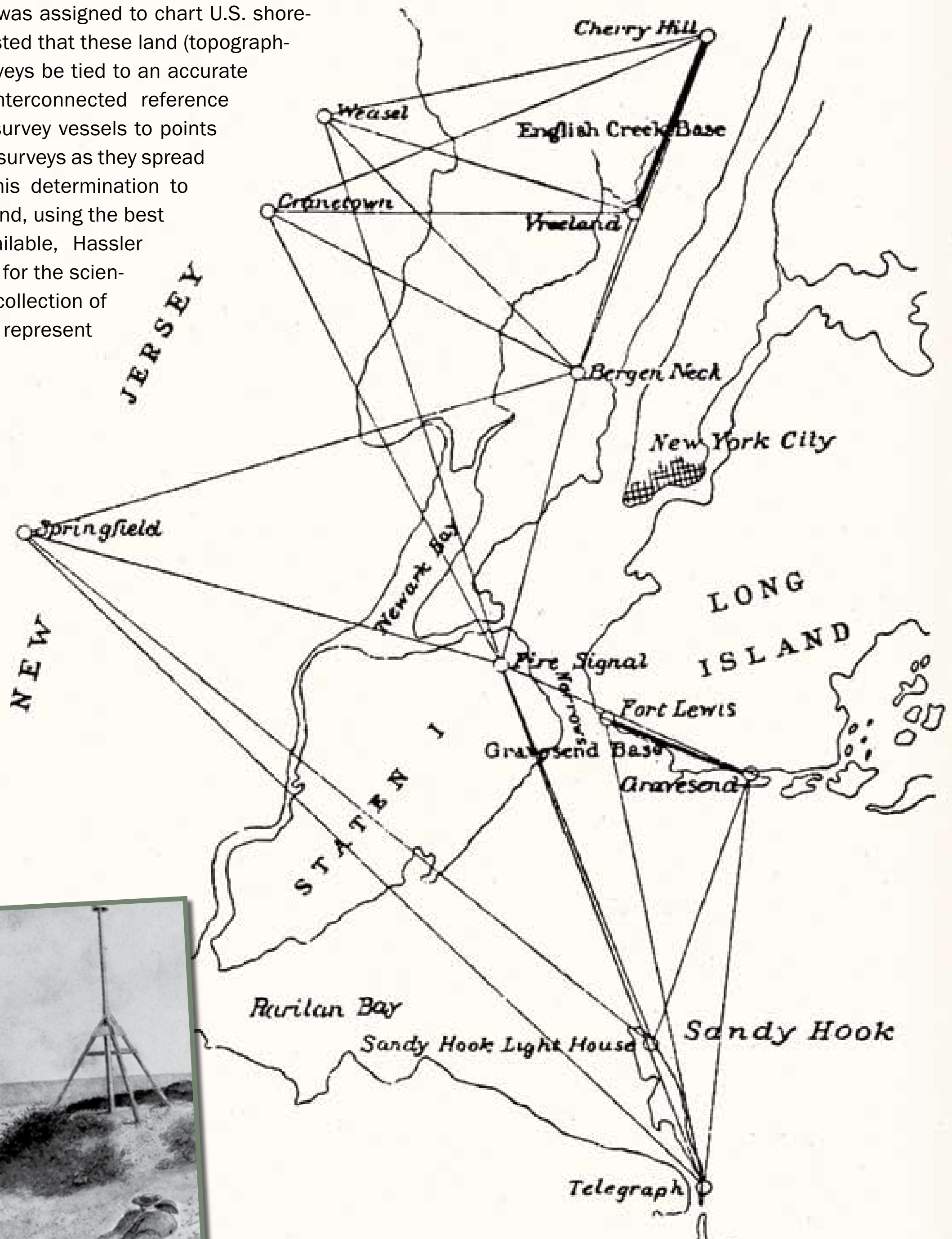
The Coast Survey's Civil War service established two significant legacies beyond its contribution to Union victory. Its surveys of the nation's interior led to the realization that a geodetic framework was needed to link the networks previously established on the coasts. The 1872 launch of the Transcontinental Arc survey (see "Geodesy: An American Odyssey" on page 24) and, in 1878, the re-naming of the agency as the Coast and Geodetic Survey, were a direct result.

The unusual position of civilian surveyors and engineers who were attached to Union military units left them exposed to charges of espionage — a capital offense — if captured by Confederate soldiers. This danger led Bache to request that military commanders grant an "assimilated rank" to civilian Coast Surveyors — a rank that set the Survey on course to develop its own uniformed Commissioned Corps.

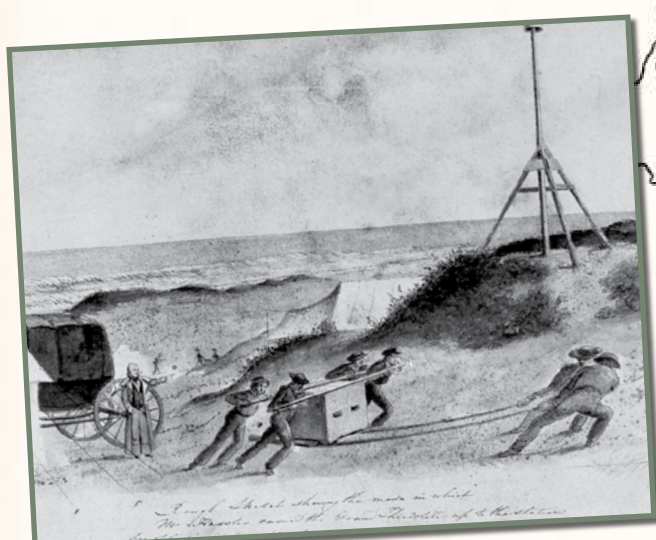
GEODESY: AN AMERICAN ODYSSEY

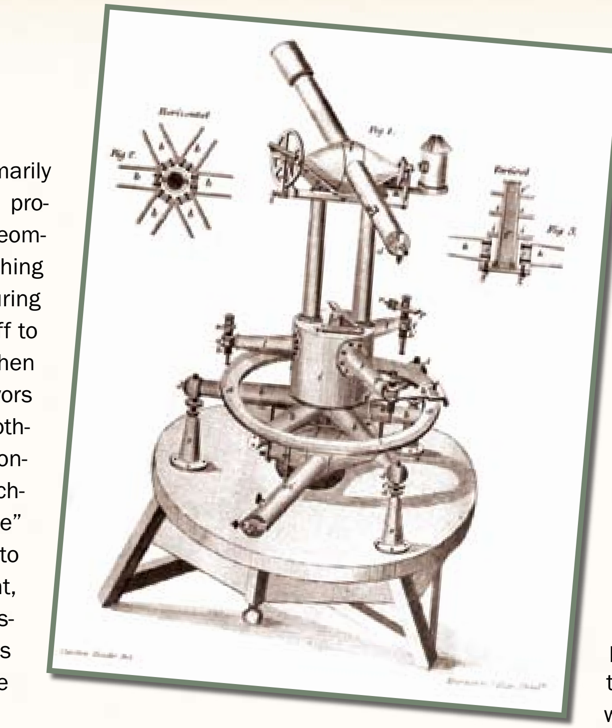
BY CRAIG COLLINS

When Ferdinand Hassler, the first Superintendent of the Survey of the Coast, was assigned to chart U.S. shorelines in 1807, he insisted that these land (topographic) and water (hydrographic) surveys be tied to an accurate survey network: a group of interconnected reference points that would tie seagoing survey vessels to points on land, and later link individual surveys as they spread outward along the coasts. In his determination to link the coastal surveys to the land, using the best methods and instruments available, Hassler was laying America's foundation for the scientific field of geodesy: a complex collection of disciplines used to measure and represent the size and shape of the Earth.



Right: Hassler's first field work, 1816-1817. *Credit: U.S. Coast and Geodetic Survey* **Below: Hassler directing movement of the Great Theodolite on Fire Island to make angle measurements at the end points of the Fire Island base line. The drawing was probably sketched by Assistant John Farley.** *Credit: NOAA Central Library Photo Collection* **Opposite, top: This Troughton 24-inch theodolite drawn by Caroline Hassler appeared in "Papers on various subjects connected with the Survey of the Coast of the United States" by Ferdinand Hassler.** *Credit: NOAA Central Library Photo Collection, photograph by Mr. Sean Linehan, NOS, NGS*





Hassler's first surveys relied primarily on triangulation, a mathematical process rooted in the principles of geometry and trigonometry. By establishing a line between two points, measuring its distance, setting a new point off to the side to form a triangle, and then measuring all three angles, surveyors could calculate the lengths of the other sides of the triangle. An interconnected network of triangles, branching outward from this "baseline" – a straight line cleared, graded to a slope no steeper than 5 percent, and measured as accurately as possible – would allow the new points at the vertices of the triangle to be defined by latitude and longitude.

When Hassler was finally able to conduct his first survey around New York Harbor in 1816-1817, he had procured a fine set of instruments for measuring angles. The theodolite, a telescope mounted on a tripod, and capable of rotating horizontally and vertically in 360-degree circles, could span the entire sky. Hassler's specially designed theodolites included the 300-pound device he affectionately named the "Great Theodolite," which served the Coast Survey for nearly 40 years before being destroyed by a Georgia tornado. The theodolite, an updated version of surveying devices used by the ancient Romans, was the instrument of choice for measuring angles until the advent of GPS technology.

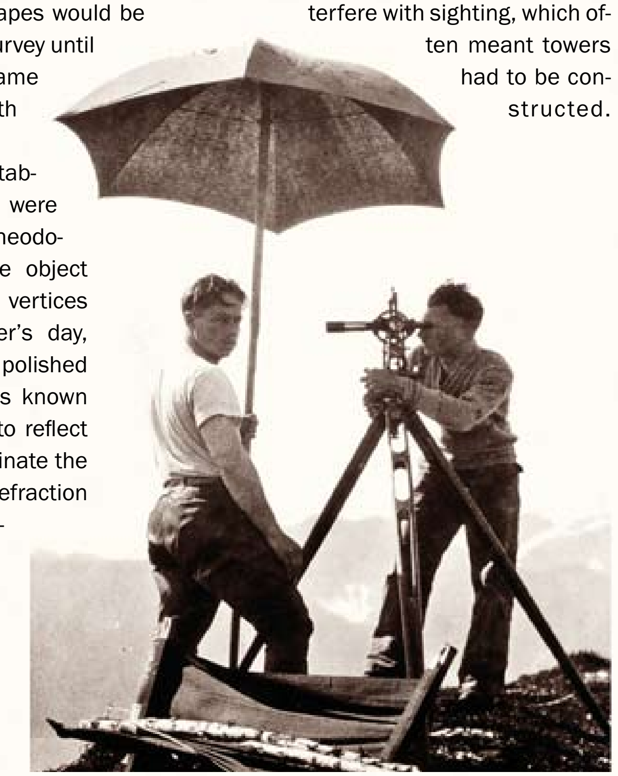
The measurement of distance was more problematic. Hassler's first baselines, Graves and English Creek, in 1817 were measured with chains made of iron links. His most accurate baselines were measured with four standardized iron bars, each carefully cut to a length of two meters. Firmly bracketed together and laid in a wooden trench along the baseline, the position of the leading end was marked with a line (whose fineness was literally established by a microscope and a thread of spider-silk). The bar was moved forward and then laid again from that point, leapfrogging a length of many miles. Obviously, this was a tedious process. A baseline often took weeks to measure, and the bars tended to expand or contract with temperature changes, skewing the measurements. While several ingenious methods were devised for limiting these variations – including the submersion of bars in ice baths during measurement – bars were eventually phased out in favor of steel measuring tapes. These tapes had their own thermal expansion problems, which were later resolved by the discovery of invar, a nickel/steel alloy that had minimal thermal expansion. Invar tapes would be widely used by the Coast Survey until electronic measurement came into usage in the mid-20th century.

Once a baseline was established, horizontal angles were measured by pointing a theodolite directly at a reflective object positioned at the opposite vertices of the triangle. In Hassler's day, these objects were often polished metal cones. Later, mirrors known as heliotropes were used to reflect and focus sunlight. To eliminate the problems of visibility and refraction inherent in daytime measurements, many later surveys were conducted at night, with the use of selenotropes to reflect moonlight, gas lamps, and, later, electric lamps.

Tying the Networks

Even with these sophisticated instruments, triangulation was a long and painstaking process for the nation's pioneer surveyors – not to mention hazardous. The American continent of the mid-19th century had very little infrastructure, and survey crews frequently blazed trails into the nation's unknown wildernesses, their instruments and supplies hauled by horses or pack mules. When the West Coast territories of Oregon and California were added to the United States after the Mexican War in 1849, the triangulation crews measured their baselines and control points from scratch, traversing mountain ranges and rocky coasts – and within eight years had established survey networks in and around San Diego, San Francisco, the Columbia Gorge, and the area around Cape Flattery in what is now Washington State.

The work of triangulation required clear lines of sight, which necessitated placing control points (the corners of the triangles) at the highest elevation possible. Even in flat country, vegetation and the curvature of the Earth tended to interfere with sighting, which often meant towers had to be constructed.



Crewmembers of the *Surveyor* perform a 3rd order triangulation on the west end of Kodiak Island. *Credit: NOAA Central Library Photo Collection, Capt. Harry Garber, C&GS, photographer*

In 1927, the invention of a reusable, portable steel tower by the Survey's Chief Signalman, Jasper Bilby, dramatically reduced the cost and time associated with this process.

In 1871, the Coast Survey undertook the most ambitious geodetic project attempted by any nation in the 19th century: the Transcontinental Arc of Triangulation. Carried out from Maryland to California, the arc would fix points along the 39th parallel of latitude, connect the triangulation networks on the east and west coasts, and serve as the basic framework from which the country's interior could be surveyed. The work, which took 27 years to complete, took surveyors across vast plains and deserts, and over some of the highest peaks of the continental divide, where teams endured lightning strikes and snowstorms that on at least one occasion forced personnel to carve channels out of snowdrifts in order to recover the line of sight, but whose extreme heights also enabled observation of some of the longest lines yet surveyed — some almost 200 miles long.

During the mid- to late-19th century, the Survey — in 1878 reorganized as the Coast and Geodetic Survey to better reflect the organization's activities — began to observe and record other geodetic parameters, such as magnetic variation, gravity, and elevation. Beginning in 1877, and over the next 20 years, a level line was surveyed across the United States, generally following the 39th parallel established by the transcontinental arc. This leveling, undertaken to support the Transcontinental Arc project, helped to create the nation's leveling network.

Opposite page, left: A heliotrope being used in the western United States. Opposite page, right: A lightkeeper orienting lights for distant observers at a tower at Station NORTHOME. Above: A party on mountain triangulation breaks camp at Uncompaghre Peak on the 39th Parallel Transcontinental Arc. *Credits: NOAA Central Library Photo Collection*

Map of the 39th Parallel Arc. *Credit: NOAA Central Library Photo Collection*

Modern Geodesy

Traditional surveying, with its reliance on invar tapes and line-of-sight, had two built-in disadvantages that were resolved by technology in the latter 20th century:

First, distance measurements, while remarkably accurate given the tools at hand, inevitably contained small errors that were magnified over the length of an arc.

THE SEVENTH SERVICE: NOAA CORPS

Throughout much of the U.S. Coast Survey's early history, its technical experts were comprised of a core group of civilian scientists and engineers who worked alongside topographic officers from the Army and hydrographic officers from the Navy. When the Civil War broke out in 1861, all Army officers were withdrawn from the Survey, never to return, along with most of the Navy's officers, who left the Survey permanently to fight in the Spanish-American War of 1898.

In these conflicts, the civilian officers of the Survey were called upon to provide surveying, mapping, and hydrographic expertise for Union and U.S. forces. In the Civil War, Coast Surveyors served in virtually every theater, often on the front lines or scouting in advance of the front lines. This posture exposed them to great risk: If captured by the enemy as civilians, they would not be held as prisoners of war, as would their uniformed comrades-in-arms; they would most likely be tried as spies, with a strong possibility of being executed. At the behest of Superintendent Alexander Dallas Bache, Coast Surveyors who served with Army units were granted an "assimilated rank" and allowed to wear the Army uniform.

To solve this problem, and to more seamlessly accommodate the officers of the Survey into the military when their services were needed, the Coast and Geodetic Survey Commissioned Corps was formed in 1917, upon the U.S. entry into World War I. Then, as today, the officers of this service — the nation's seventh and smallest uniformed service, in addition to the four military branches, the Coast Guard, and the Public Health Service — were a highly trained, deployable Corps that could be assimilated into the military command structure as needed. Ernest Lester Jones, the Superintendent who was instrumental in passing the legislation that created this Commissioned Corps, served with the Army during World War I. More than half of the Survey's commissioned officers likewise served with one of the military branches during the war, and a similar percentage were transferred to either the Army, Navy, or Marine Corps during World War II (see "The Coast and Geodetic Survey in World War II" on page 28).

These commissioned officers became known as the NOAA Commissioned Corps ("NOAA Corps") in 1970, when the Coast and Geodetic Survey combined with several other agencies to form a new scientific bureau within the Commerce Department.

Today's NOAA Corps consists of about 300 officers, who represent an even greater variety of specialties than the hydrographers, surveyors, and engineers who first served during the Civil War. NOAA's officers — trained in earth sciences, meteorology, fisheries science, oceanography, atmospheric science, and other related fields — are as likely to be deployed to work with the Coast Guard, the Department of State, the Department of Transportation, the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration, or other federal agencies as they are to serve one of the defense branches. Most officers spend about a third of their careers at sea, and all are on call 24 hours a day, rotating every two or three years to bring fresh expertise to the operation of NOAA ships and aircraft, the management of research projects, the conduct of diving operations, and other staff positions throughout NOAA. They may be the smallest of the uniformed services, but they remain the most unique — serving on land, in the air, and at and under the sea.

Above, left: A small wooden stand on a ridge in the Mojave Desert is part of a station that was built during observations on Transcontinental Traverse work. Above, right: Signal lamps. *Credits: NOAA Central Library Photo Collection*

It was in the 1950s that the first instruments known generically as EDMI (electronic distance measuring instruments) were developed. An EDMI worked by bouncing a light beam off a reflector. Knowing the speed of light, the distance could be determined. Intent on achieving the highest accuracy and greatest utility possible from this new technology, the C&GS lab in Corbin, Va., modified commercially available instruments and designed and built what was unavailable. Several advancements in EDMI technology were made as the lab replaced earlier light sources with increasingly powerful lasers, producing the most powerful distance measuring instrument of the time, "Big Red," which could measure a line almost 100 miles long. Over the next several years, EDMI were developed that used ordinary light and microwaves, but the most accurate over the longest distances proved to be lasers. The technology irreversibly altered surveying. It was expensive, but quickly paid for itself by eliminating time and labor; there was no longer a need to clear and grade a baseline, no need to lug around bars or tapes and their supporting infrastructure. More important, it was far more accurate than traditional methods — so much so, in fact, that it became the basis of an effort to resolve the problems in scale present throughout the existing network. The High-Precision Transcontinental Traverse, or TCT, began as a small-scale EDMI surveying project conducted for the Air Force in Florida in 1961, then gathered steam and spanned the nation by 1976. The new survey had an astonishing relative accuracy of 1:1,000,000 — in other words, for every 16 miles surveyed, it was off by a little more than an inch.

The second drawback to traditional surveying was its reliance on lines of sight. When the Global Positioning System (GPS), initially developed for military purposes, was first used by the National Geodetic Survey (NGS) in 1983, it virtually eliminated the need for every surveying instrument that had come before it. Almost overnight, the age of Bilby towers, theodolites, and invar tapes — and even of EDMI — was over. GPS had become the standard in speed and accuracy for establishing horizontal coordinates.

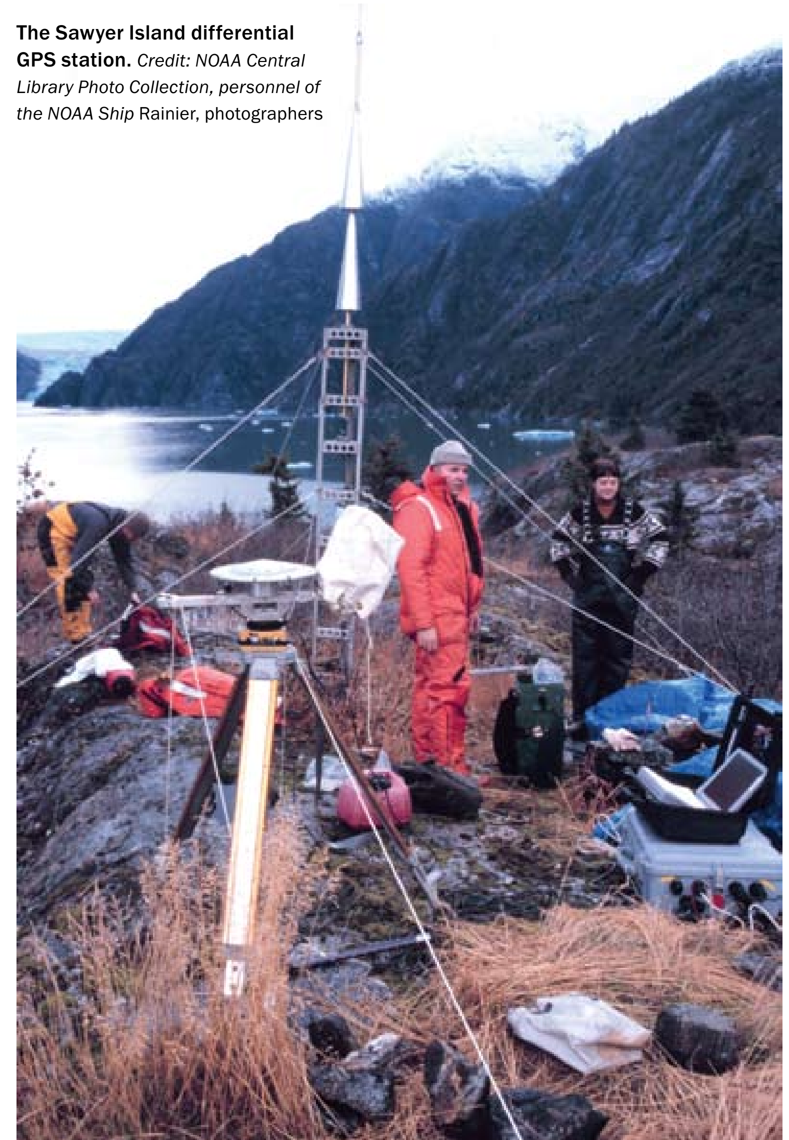
GPS is a network of satellites, currently numbering 29, that orbits in a network designed to ensure that at least four satellites are visible at least 15 degrees above the horizon at any given time anywhere in the world. With GPS, longitude and latitude are computed from the time it takes for a transmitted satellite signal to reach a given receiver: Three satellites are necessary for this determination, while a fourth allows the determination of elevation.

Today the survey network begun by Hassler and his Survey of the Coast is called the National Spatial Reference System (NSRS), a national coordinate system that includes not only horizontal information (latitude, longitude), but information about height, scale, gravity, orientation, and how these values change over time. The NSRS is composed of about 1.5 million surveyed positions; a national shoreline based on long-term water-level observations; a set of models that predict geophysical processes such as crustal movement; and a network of 1,000 Continuously Operating Reference Stations (CORS), where permanently installed GPS receivers, located from Canada to South America, offer surveyors direct online access to GPS data.

The surveyors and engineers of the Coast and Geodetic Survey who once navigated the mountains, plains, and deserts of the American continent possessed an intriguing combination of technical knowledge, stubborn resolve, and courage. They were, in a very real sense, the vanguard of American physical science, and they were probably aware that in performing work too technical and obscure to be understood by most of the population, usually in areas too remote to be noticed, they were nevertheless defining nothing less than the future dimensions and boundaries of the United States — and ultimately, of the planet. The men who erected Bilby towers above the rainforest canopy of the Pacific Northwest, who scaled 14,000-foot peaks with theodolites strapped to their backs, and who traveled with mule trains across the alkali flats of the American West, would no doubt be surprised — and maybe a little disappointed — at how much faster and safer the work of geodesy is today.

National Geodetic Survey — http://geodesy.noaa.gov/

The Sawyer Island differential GPS station. *Credit: NOAA Central Library Photo Collection, personnel of the NOAA Ship* Rainier, *photographers*



THE COAST AND GEODETIC SURVEY IN WORLD WAR II

When the United States entered World War II in December of 1941, the peacetime activities of the Coast and Geodetic Survey (C&GS) came to a virtual standstill. More than half the Survey's civilian work force — about 1,100 commissioned officers and other employees — were immediately transferred to, or volunteered to join, the Army, Navy, or Marine Corps; those who remained on the home front were occupied almost completely with the conduct of surveys at defense facilities in the states and the Caribbean. More maps and charts were produced during World War II than for any other event in human history, and the Survey was at the forefront, distributing more than 100 million maps and nautical and aeronautical charts for the Allies.

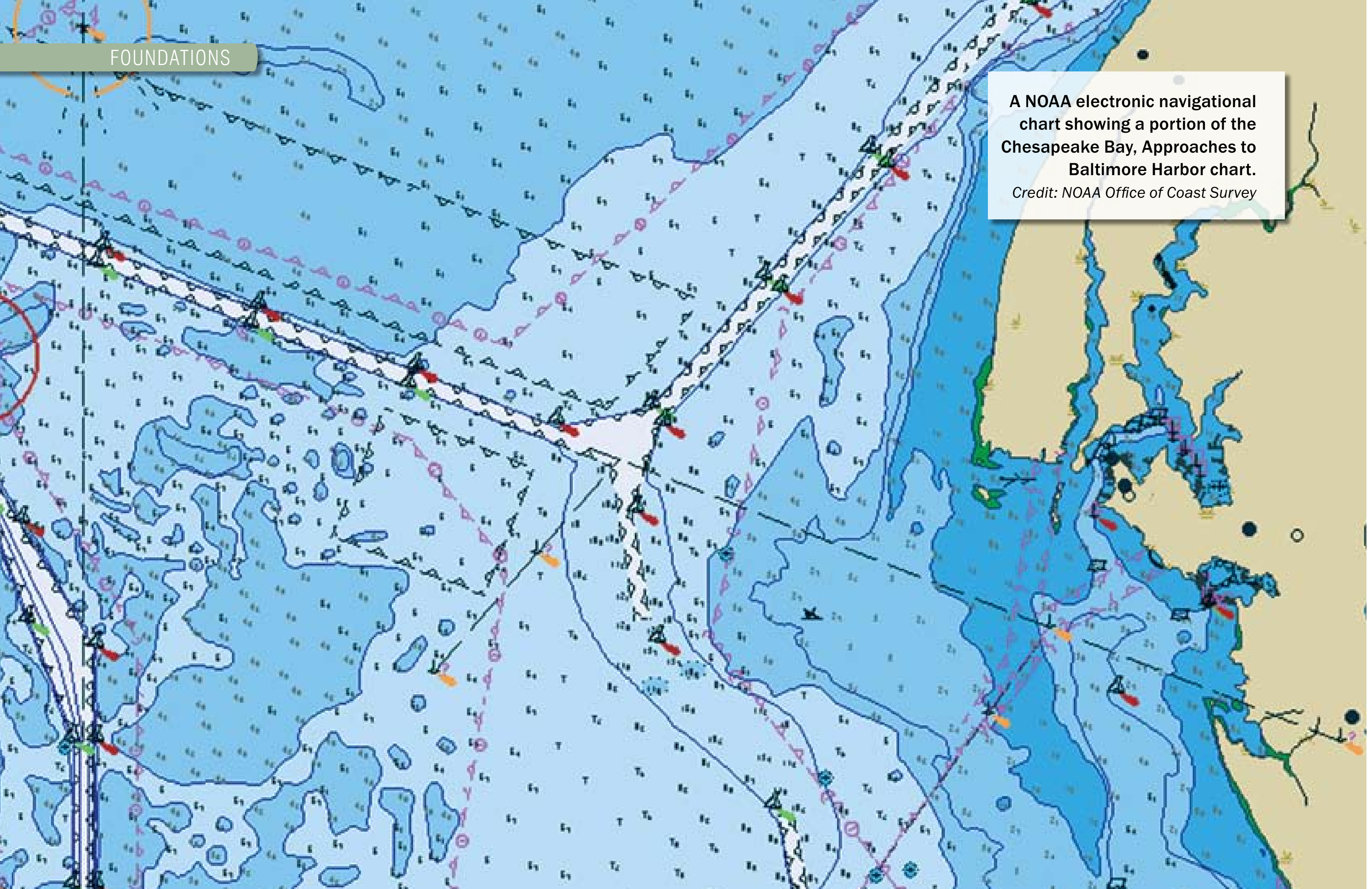
In Europe, North Africa, and throughout the Pacific, Coast Surveyors served as hydrographers, artillery surveyors, cartographers, Army engineers, geophysicists, and intelligence officers. In Europe especially, those who served as artillery surveyors — advance scouts who pinpointed and mapped the locations of batteries and targets — assured the success of the "time on target" method for attacking the enemy. The tactic required that a first round of artillery shells, fired from different positions, would be coordinated to hit a target simultaneously, depriving the enemy of the chance to seek cover. Thereafter, rounds would be fired continuously but at irregular intervals that were impossible to predict. When "time on target" was effective — and with the help of C&GS artillery surveyors, it was often devastating — soldiers, Marines, and other Allied forces who later advanced through these batteries encountered little resistance.

C&GS officers were also integral to the war in the Pacific, where the Survey's amphibious engineers helped the Army and the Marines move men and supplies during Gen. Douglas MacArthur's island-hopping campaign through New Guinea and the Philippines. Three of the Survey's nine major ships were ordered into duty with the Navy during the war; one of these, the USS *Pathfinder*, which took its name from a previous C&GS vessel of similar renown, was commissioned on Jan. 11, 1942, when it began the long and dangerous journey that would take it from Guadalcanal to Tokyo Bay.

For the next three years, the *Pathfinder* and her crew were deployed to conduct hydrographic surveys in advance of Allied fleets and to chart naval approaches to strategic islands, over and around countless hidden reefs — usually alone, to avoid attracting attention, and often many miles distant from other Allied vessels. The *Pathfinder* was attacked and bombed literally dozens of times, including a kamikaze attack in the 1944 Okinawa campaign that killed a crew member. In all, 11 members of the Survey lost their lives during the war.

The *Pathfinder* was uniquely equipped to solve a problem that plagued American cartographers throughout the war: how to get maps and charts into the hands of the people who needed them when presses were mostly stateside. Along with modifications for her defense — two aircraft guns mounted fore and aft — the *Pathfinder* had a huge hole cut in her decks to accommodate the crew's own printing press, which eventually reeled off about 62,000 copies of their hydrographic field sheets for use in Allied campaigns.

After the war, the *Pathfinder* was released by the Navy to serve out her years in the C&GS, quietly conducting hydrographic surveys until 1971. Some years after the war, a C&GS commemorative publication made the rightful claim that "the rocky road to Tokyo was paved with the charts of the *Pathfinder*." The service of her crew — like that of all the men and women of the Coast and Geodetic Survey who served during World War II — streamlined the logistical and tactical performance of Allied forces in many theaters around the globe, and helped to save an inestimable number of lives.



A NOAA electronic navigational chart showing a portion of the Chesapeake Bay, Approaches to Baltimore Harbor chart. *Credit: NOAA Office of Coast Survey*

NAUTICAL CHARTS: LEADING THE WAY

The Coast Survey and Its Successors Revolutionize Nautical Chartmaking

BY CRAIG COLLINS

When Congress and the Jefferson administration authorized the Survey of the Coast of the United States in 1807, their ambitions for the new organization could be boiled down to one thing: the nautical chart. The seas surrounding the nation's shores were still a perilous and dimly understood frontier, littered with submerged shoals and outcrops that had sunk an alarming number of ships, and Jefferson — a surveyor himself — wanted these hazards and other features of interest mapped in order to aid mariners.

The political struggles that plagued the Survey throughout much of its early era stemmed from a disagreement between its first superintendent, Ferdinand Hassler, and rivals in the Navy about the field work these charts would require. Navy surveyors insisted that depth soundings, coupled with astronomic readings using a sextant and a chronometer, were an accurate and efficient means of conducting "hydrographic surveys" — measurements and descriptions of the physical features and conditions of navigable waters and their shorelines. Hassler insisted that the first step was to establish a land-based survey network that would anchor these hydrographic observations to fixed reference points. For many years he was on the losing end of the dispute, and was literally dismissed from the survey for 15 years before being reinstated as Superintendent in 1832. His first hydrographic surveys were not undertaken until 1834, after Hassler had determined that the Survey's land-based surveying was developed sufficiently to support a sounding party in and around New York Harbor.

It didn't take long for Hassler to be vindicated himself. In 1835, Lt. Thomas Gedney, commander of the Survey's first hydrographic survey ship, the *Jersey*, took soundings along the entrance to New York Harbor between Long Island and Sandy Hook, N.J. Gedney discovered a deep-water channel near Long Island that led directly into the harbor and could be used by vessels anytime, regardless of water level. The deepest channel previously known had been far to the south, off the coast of Sandy Hook — where larger ships had been forced to wait for high tide and favorable winds to make the passage. Hassler wasted no time in pointing out that his methods had uncovered this channel, which had enormous implications for both the economy and the naval defense of the harbor.

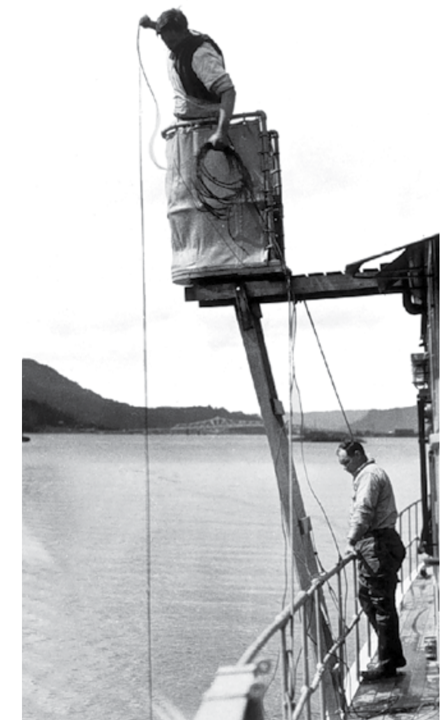
Hydrographic surveys, until well into the 20th century, continued to be conducted much in the same way as Gedney had conducted his: by throwing a line over the side of a sounding boat (in later years, a reel of kink- and snag-resistant piano wire was used in deeper water), determining the position of the boat visually, recording the measured depth, and then taking another measurement a few meters farther along. This laborious process, while surprisingly accurate, still left large areas of the sea-bottom unmapped and unknown.

The First Charts

The process of compiling the Survey's first nautical charts was even more painstaking — a fact that proved to be another political problem for Hassler and his exacting methods. By 1843, he had still not produced a nautical chart for general distribution but had nearly overseen the completion of the New York Harbor series of six charts. Unfortunately, he did not live to see their publication in 1844-1845. These charts stand as monuments to his vision and methods.

Even as hydrographic surveying gathered steam under Alexander Dallas Bache, who became superintendent after Hassler's death in 1843, the Survey was confronted with a backlog of data ready for compilation into nautical charts for publication. The printing of a chart required a hand-engraved copper plate that was often very large — as large as 10 square feet. Even for the most skilled engravers, which were in short supply in the mid-19th century United States, original plates took three to four years to create, and cost from $3,000 to $6,000 each.

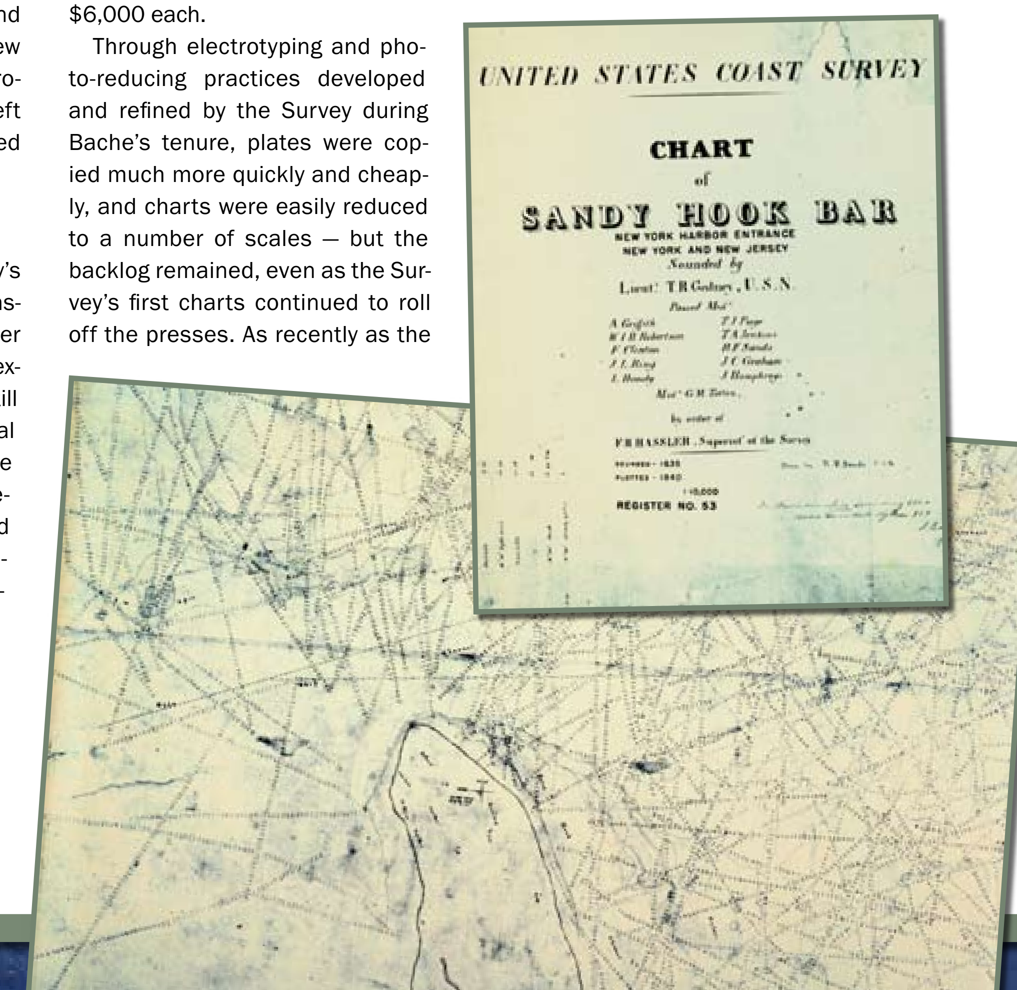
Through electrotyping and photo-reducing practices developed and refined by the Survey during Bache's tenure, plates were copied much more quickly and cheaply, and charts were easily reduced to a number of scales — but the backlog remained, even as the Survey's first charts continued to roll off the presses. As recently as the 1990s, revisions of charts involved thousands of hours of labor: It usually took about 10 months from the time a revision was undertaken to the moment a new chart was printed.



Left: Tossing the leadline off the *Westdahl*. The leadline is vertical for reading. Below: The chart of the Sandy Hook Bar, New York Harbor entrance. Surveyed under the direction of Lt. Thomas R. Gedney, 1835. Hydrographic Survey H-53 helped publicize survey efforts by finding a new channel that made it easier and cheaper to enter and leave New York Harbor. *Credits: NOAA Central Library Photo Collection*

Today's Surveys

It was under Bache's leadership that hydrographic surveyors also came to an important realization: the configuration of the seafloor was not static, but in constant flux, due to a number of natural and human-related changes. The first and most important goal of Coast Survey hydrography — to discover and chart hazards to navigation — was supplemented



by others aimed at defining and describing more completely these underwater configurations and the multitude of factors that influenced their dynamics. The old method of lead-line soundings clearly would not fit the bill. Fortunately, just a few decades after the first primitive echo-sounding devices were used with some success by Coast and Geodetic Survey vessels during the 1920s and 1930s, sonar technologies were developed that would at last provide a complete picture of the sea floor.

Today's hydrographic surveys are conducted with two different types of sonar device. Multibeam sounding arrays, mounted directly on the hull of survey ships, emit a fan-shaped signal that measures a number of precise depths in a swath perpendicular to the course of the vessel. Behind these survey vessels, a specialized "side-scanning" device, towed by cable, sends out a wide sonar swath that carefully maps the shape of the seafloor, including any objects or outcrops that might pose a hazard. Today survey ships use satellite-based Global Positioning System (GPS) to reference their own location to a fixed point on land. This establishes their location to within 3 to 5 meters.

Smart Charts

In little more than a decade, technology has also radically changed the way charts are both produced by NOAA's Office of the Coast Survey and used

CHARTING THE SKIES

In 1917, Secretary of the Navy Josephus Daniels commented prophetically to Ernest Lester Jones, director of the Coast and Geodetic Survey: " … We are on the threshold of a period when the battles of the world will not be fought on the land or sea alone, but in the air, and I look to you … gentlemen to chart the air as you have charted the ocean."

Nine years later, in 1926 — 23 years after *Kitty Hawk* — the U.S. Department of Commerce created an Aeronautical Branch, the direct predecessor of today's Federal Aviation Administration (FAA), to promote interstate air commerce. The department assigned production of the required aeronautical charts to a well-established chart-making organization: the Coast and Geodetic Survey (C&GS).

C&GS published the first of its initial series of Strip Airway Maps, covering the route from Kansas City to Moline, Ill., just a month after Charles Lindbergh completed the world's first transatlantic flight in 1927. Within a few years, the agency was producing Sectional and Regional Charts that covered wider areas.

At the outbreak of World War II, the U.S. Army Air Forces contracted C&GS to produce a Western Hemisphere series of 120 aeronautical charts at the scale of 1:1,000,000. By 1943, the demand for the Survey's aeronautical charts had ballooned from a prewar 464,000 units to 11,775,000 units, which were printed and distributed mostly for the Army and Navy. Additionally, new specialized aeronautical charts were required for the war effort. Some of these included a series of 1,812 target charts and charts for such areas as the Ploesti oil fields, Hiroshima, and Nagasaki.

In the postwar decades, the demand for aeronautical chart products increased significantly. And with the advent of many computerized technologies over the last two decades, many digital aeronautical charts and related information products have been added to support modern aircraft navigation systems. However, the paper aeronautical chart remains the most widely used air navigation reference.

In 2000, Congress directed the transfer of the Survey's Office of Aeronautical Charting and Cartography (AC&C — now the National Aeronautical Charting Group) to the FAA, where it supports the National Airspace System as the nation's civil aeronautical charting organization. Today, NOAA's National Geodetic Survey, a descendant of the C&GS, supports FAA's aeronautical charting program and other FAA aeronautical information programs by conducting aeronautical surveys at public use and general aviation airports throughout the United States.

by mariners. While it still does offer printed paper charts and makes digital images of these charts available online, perhaps the most promising chart format released today is the on-board electronic navigational chart (NOAA ENC®), a "smart" chart whose applications have only begun to be explored. The NOAA ENC® is a data set displayed in a real-time information system that may show a ship's position, speed, course, and draft, along with nearby soundings, way points, and warning systems. Such a system may use color-coded lines to differentiate between a ship's planned route and the actual course taken, and may display a vessel's projected course. Electronic charts can integrate NOAA ENCs® with GPS satellite data and other sensor information (such as radar, tide levels, winds, and weather) to enhance awareness of the immediate environment. An electronic chart, using a NOAA ENC® and GPS, automatically updates a vessel's location every one to two seconds, and indicates floating aids to navigation, other vessels in the area, and points of land. Electronic chart systems, with their ability to display NOAA ENCs® on a shipboard computer, may be able to instantaneously detect hazards, estimate how long it would take to run into them, and automatically sound an alarm. The electronic chart with GPS has been hailed as the most significant advance in navigation since the advent of radar. Within a mere decade, it has been brought on board by an increasing number of vessels operating within U.S. waters. The days when navigators stooped over tables with parallel plotters in their hands, below-decks, or in chart houses, are rapidly becoming a thing of the past.

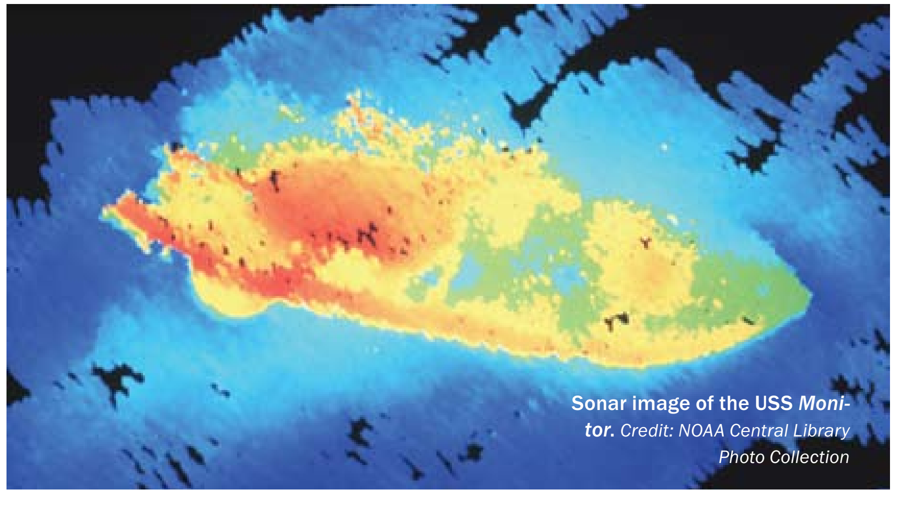
The Race to Modernize

Now that the technology provides accurate, up-to-date nautical charts, the Office of the Coast Survey's work is far from finished — in fact, in many ways, it has only recently begun. Despite the fact that NOAA is the only organization authorized to create navigational charts of U.S. waters, its fleet of hydrographic survey vessels is astonishingly small. NOAA's Office of the Coast Survey is charged with exploring and charting 95,000 miles of coastline, as well as 3.4 million square nautical miles within the U.S. exclusive economic zone (EEZ), an area extending 200 miles beyond the nation's shores.

There is still — as there was in the days of Alexander Dallas Bache — a significant backlog of requests for hydrographic surveys and updated charts. As recently as 1995, the Office of the Coast Survey estimated that 60 percent of NOAA's nautical charts were based on data collected with a lead-line or primitive echo sounders.

The trend in commercial shipping (which carries 95 percent of U.S. international trade and is projected to double or even triple in volume by the year 2020) has been toward fewer but larger vessels, some with drafts greater than 60 feet — the height of a six-story building submerged beneath the water's surface. In U.S. ports and harbors, clearances are in some cases down to a matter of two feet or less between cargo ship hulls and dredged channel bottoms. Given estimates that range between $38,000 and $288,000 in profit added for each additional foot of draft carried by large bulk and container ships, it's likely that commercial shippers will continue to push against subsurface limits — and rely increasingly on NOAA charts that are accurate and up-to-date NOAA charts.

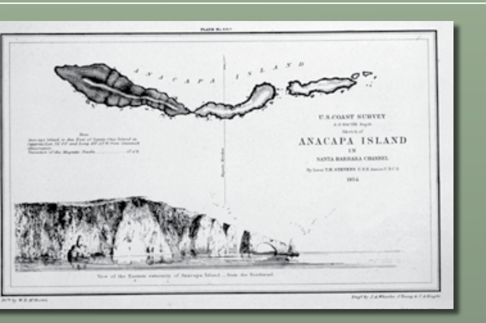
NOAA Charting and Navigation — www.noaa.gov/charts.html



Sonar image of the USS *Monitor.* *Credit: NOAA Central Library Photo Collection*

WHISTLER: A COAST & GEODETIC SURVEY EMPLOYEE

CONTRIBUTED BY DORIA B. GRIMES



Whistler's Anacapa Island engraving from a William B. McMurtrie sketch. *Credit: NOAA Central Library Photo Collection*

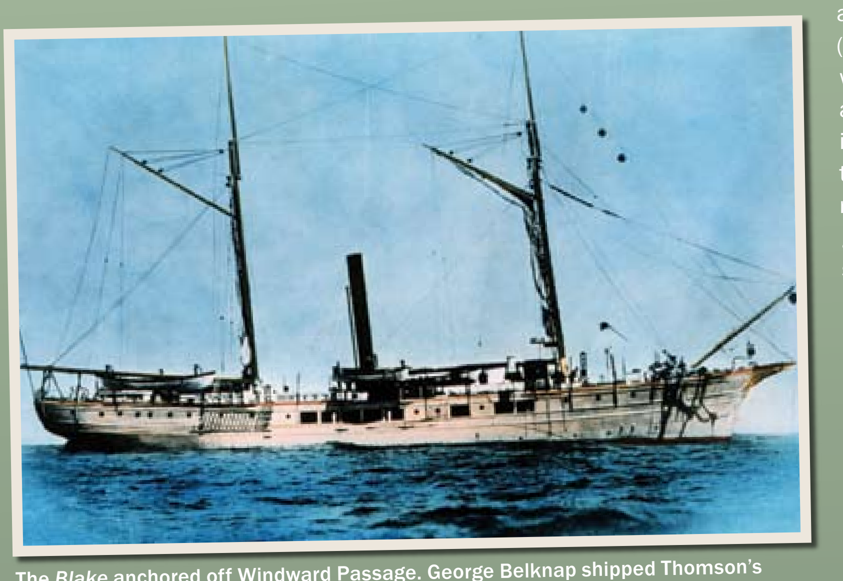
From Nov. 7, 1854, to February 1855, James McNeill Whistler was assigned as a draftsman to the Coast & Geodetic Survey's Engraving Department at the salary of $1.50 per day. Early clues of his creativity and artistic expression can be seen in the practice sketches and engravings on plates 414A and 414B. For example, he arbitrarily inserted two flocks of gulls on copper plate 414A – Anacapa Island. This and his tardiness, in large part, contributed to his resignation, to the mutual satisfaction of the employer and employee.

In the same year he left for Paris and London, where he subsequently achieved fame as one of America's greatest artists and expatriates.

http://www.history.noaa.gov/art/whistler.html

THE U.S. COAST AND GEODETIC SURVEY STEAMER *BLAKE*

The U.S. Coast Survey, in studying and surveying the nation's shores, was also a pioneer in the field of oceanography — a broad term used to denote the study of the earth's oceans and seas. Of all the ships in the Survey's fleet, the steamer *Blake*, commissioned in 1874, was unique in the number and significance of its contributions. In the winters of 1874-1877, with the use of a piano-wire sounding machine developed by her skipper, Charles Sigsbee, the *Blake*'s crew meticulously compiled a bathymetric map of the Gulf of Mexico — the first modern and accurate map of any portion of the ocean floor. This work also led to the development of the first three-dimensional model of a portion of the ocean floor.

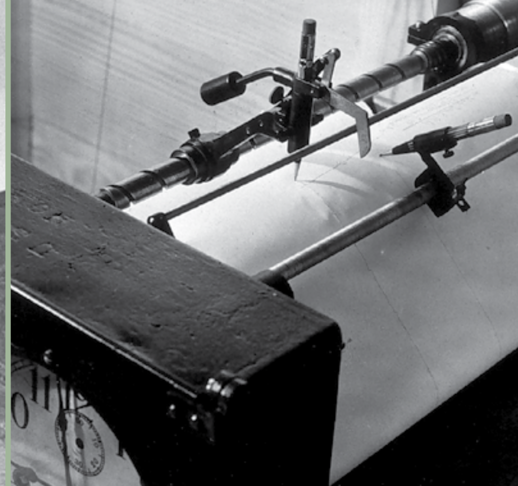


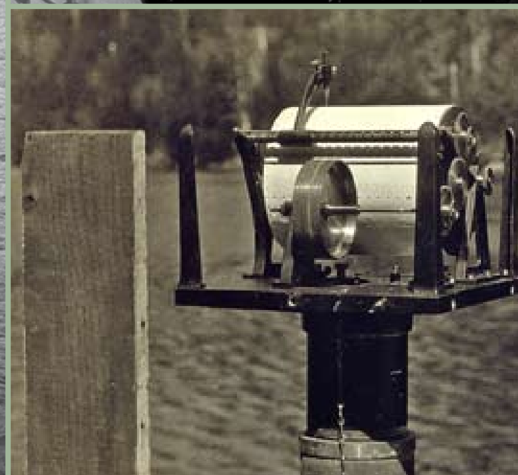
The *Blake* anchored off Windward Passage. George Belknap shipped Thomson's piano wire machine to the *Blake* in 1875. Charles Sigsbee modified Thomson's machine. Sigsbee's sounding machine was the standard for many years. *Credit: NOAA Central Library Photo Collection*

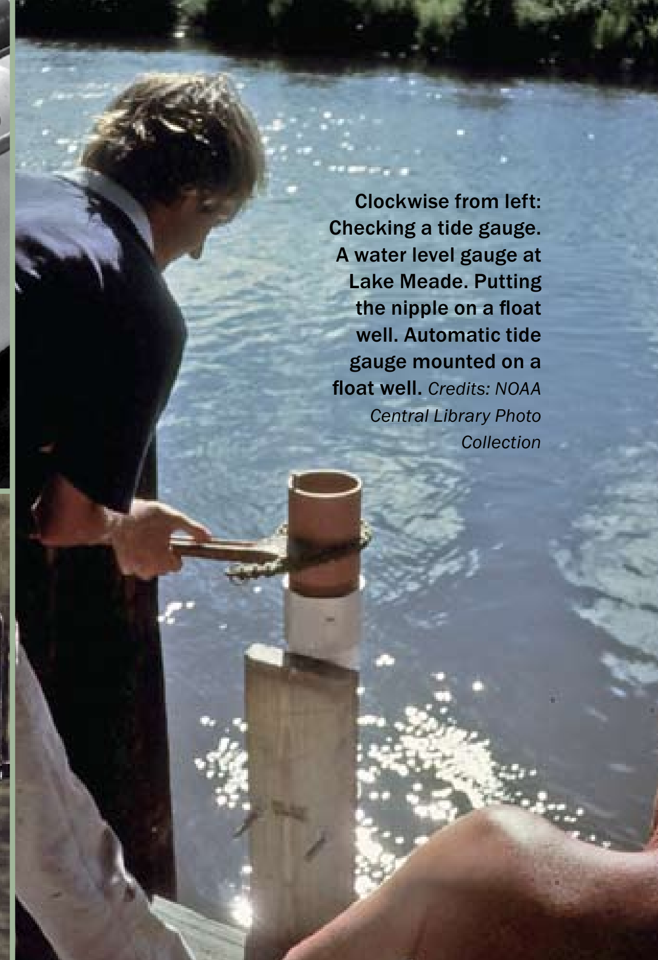
In the winter of 1877-1888, Sigsbee and the American scientist Alexander Agassiz pioneered the use of steel rope for deep-sea dredging operations aboard the *Blake*. With this stronger, more compact, and more durable material, the *Blake* conducted 200 deep-sea dredgings in a single season. In comparison, the British *Challenger* Expedition conducted 362 deep-sea stations with hemp rope over a three-year period.

In 1885 the *Blake*, commanded by John Elliott Pillsbury, pioneered the use of steel rope to accomplish deep-sea anchoring for classic Gulf Stream studies and anchored in depths as great as 2200 fathoms (13,200 feet). This was the forerunner of all deep-sea anchoring systems including those used by meteorological and oceanographic buoys to study the deep-ocean harbingers of global phenomena such as El Niño.

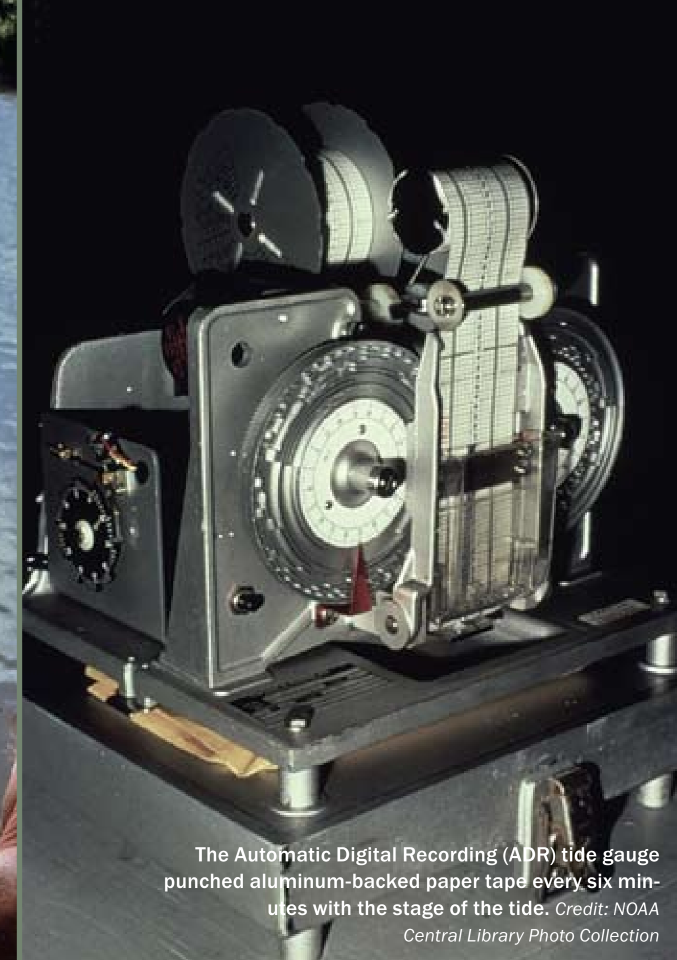
In recognition of its exceptional lifetime of service and innovation, the *Blake* — which was burnt and lost off Frying Pan Shoal, North Carolina, in 1908 — is one of the few oceanographic ships to have its name inscribed on the façade of Monaco's world-famous cliff-top Oceanographic Museum.



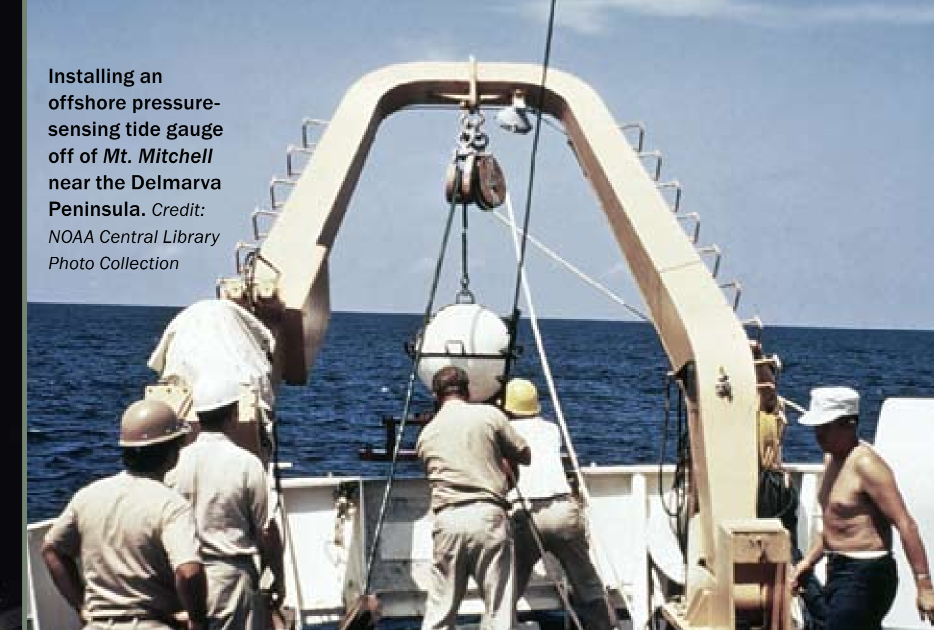




Clockwise from left: Checking a tide gauge. A water level gauge at Lake Meade. Putting the nipple on a float well. Automatic tide gauge mounted on a float well. *Credits: NOAA Central Library Photo Collection*



The Automatic Digital Recording (ADR) tide gauge punched aluminum-backed paper tape every six minutes with the stage of the tide. *Credit: NOAA Central Library Photo Collection*



Installing an offshore pressure-sensing tide gauge off of *Mt. Mitchell* near the Delmarva Peninsula. *Credit: NOAA Central Library Photo Collection*

ABOVE THE BENCHMARK

THE EXPANDING USES OF TIDAL INFORMATION

BY CRAIG COLLINS

Tidal indicator erected at Reedy Island on the Delaware River, Del. This indicator and two others at New York and San Francisco were built by the Coast & Geodetic Survey. The face is 30 feet in diameter.
Credit: NOAA Central Library Photo Collection

In the mid-19th century, the U.S. Coast Survey began to systematically study tides under the leadership of Superintendent Alexander Dallas Bache, who created a "tidal division" within the organization. For Bache, knowledge of the tides would help fulfill two important components of the Survey's mission: enabling safer navigation and clearly defining a national shoreline boundary. Tides had always been of interest in America both to fishermen, who knew that certain species often concentrated in ebb or flood currents, and to mariners, who benefited from knowing the time and height of tides as well as the speed and direction of tidal currents.

Because there was no such thing as a tidal specialist in the early decades of the Survey, the first observations were made by scientific frontiersmen, perhaps more curious than knowledgeable, who were attached to the field parties that marched into unknown regions with the broad mission to conduct topographic and hydrographic surveys. Specialties such as geodesy, geophysics, and tidal physics would develop in the United States as a result of these teams' need to know more about the environments they were attempting to chart. Before the invention of the self-registering tide gauge in the 1850s, tides were recorded by a person with a notebook who watched and recorded as water levels moved up and down a graduated staff planted in the tidal zone. It's likely that many of the first staffs used by these parties were placed in areas that no other American had ever seen, especially when the Survey began to study the newly acquired West Coast in 1849.

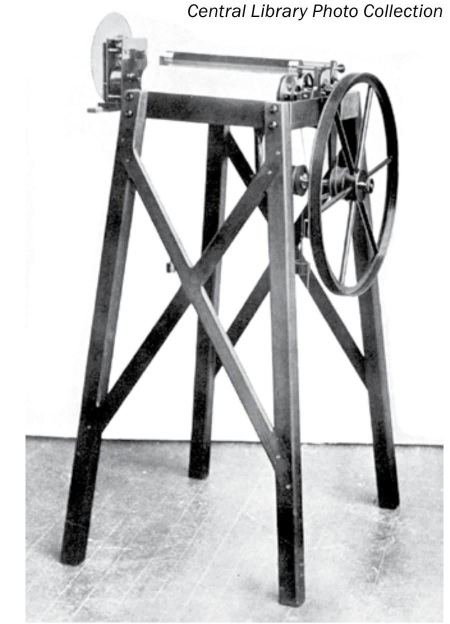
It was one thing to observe the tides, and another to accurately predict them. The Survey's first attempts to model tides, based on a system that related the positions of the sun and the moon to the water level, were riddled with inconsistencies that puzzled Bache, and were not resolved completely until the application of harmonic analysis in the late-19th century. The Survey's early tidal predictions did prove useful enough to warrant their publication as "Tide Tables for the Use of Navigators" beginning in 1853.

Harmonic analysis, a complex mathematical procedure based on the principle that periodic movements or oscillations (such as tides) can be resolved into the sum of a series, proved too labor-intensive for tide predictions to be computed by hand. It was the invention of the Survey's Tide-Predicting Machine No. 2 — an 11-foot-long, 2,500-pound behemoth, powered by a hand crank — that enabled the use of harmonic analysis for predicting tides. The machine, a bewildering array of dials and gears that had to be calibrated in accordance with input data, was a mechanical analog computer, and was used to predict the nation's tides from 1885 to 1911. Similar (but smaller) machines were used until they were superseded in 1966 by electronic digital computers.

For about a century, the Survey recorded tides with gauges designed to reduce the errors associated with staff readings. The gauges consisted of a float that rose and fell with the water level in a "stilling well" — usually, a wide length of pipe that calmed the water around the float, shielding it from the influence of wind and waves. This float was linked to a pen that marked the water level on a continuously running strip chart. The records were collected once a month and sent to headquarters for manual processing. When electronic computing became widely used in the 1960s, the strip chart was replaced by paper tape, automatically punched at six-minute intervals and later fed into a digital computer.

The old system provided to mariners and oceanographers the unprecedented ability to describe and understand tidal phenomena in U.S. coastal regions, but it involved several disadvantages. The gauges, particularly the floats, were subject to biological fouling and had to be cleaned periodically. They were in need of frequent tending and maintenance. The six-minute interval between recordings provided a data set that was not linear, like the ebb and flow of tides, but staggered into isolated points. The most important drawback to the old system was that even after the advent of electronic digital computing, tidal station data could not be provided until weeks after they were collected.

Saxton self-registering tide gauge, model as of 1897. *Credit: NOAA Central Library Photo Collection*



Work on a buoy. *Credit: NOAA Center for Operational Oceanographic Products and Services*

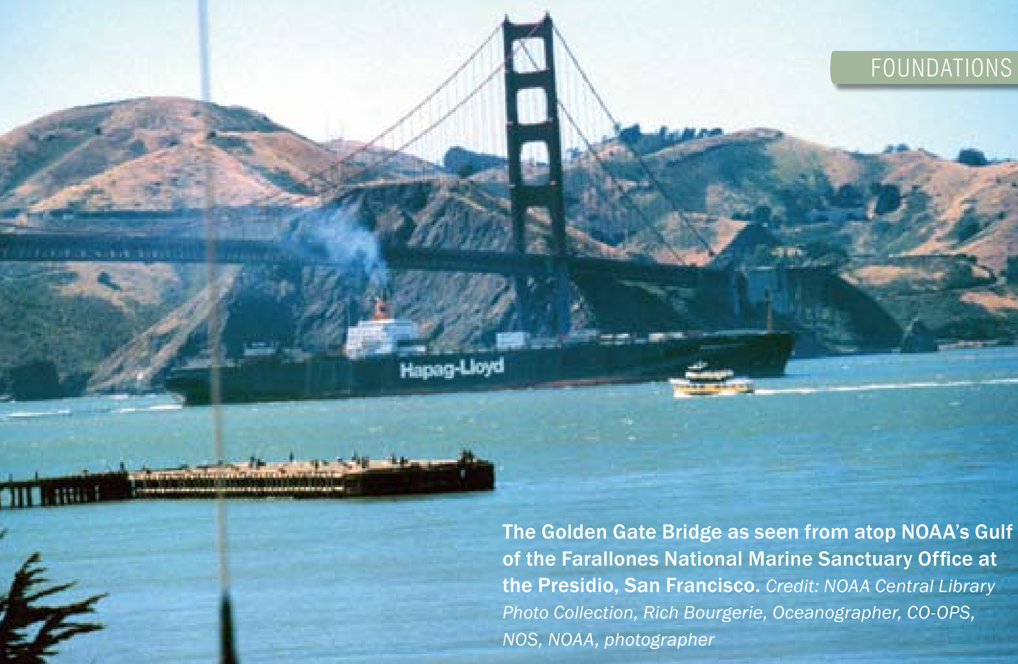
The Next Generation

In 1985, the old system of float-and-wire gauges was replaced by a state-of-the-art water level measurement system, which uses technology to solve these problems. The new system uses a smaller stilling well to allow more of the dynamic environment's influence to be recorded, and the old float is replaced by an acoustic sensor that bounces sound waves off the water surface below. The device is self-calibrating and can be leveled directly to local benchmarks. The data acquired, while still gathered every six minutes, are averaged into a linear reading.

As important as the way data are observed and recorded is the way they are now disseminated: They are immediately uploaded for transmission by satellite, radio, or telephone, and can accommodate input from at least 11 ancillary sensors that record other oceanographic and meteorological data: wind speed and direction; water current speed and direction; air and water temperature; and barometric pressure. The stations transmit data hourly to NOAA headquarters — an interval that can be changed to every six minutes in the case of a storm — and can be accessed at any time by field teams using laptop computers.

Today, these continuously operating "next generation" tidal stations — currently numbering 175 throughout the United States and its territories — form the National Water Level Observation Network (NWLON), the backbone of the National Water Level Program operated by the Center for Operational Oceanographic Products and Services (CO-OPS), a bureau of NOAA's National Ocean Service. By enabling real-time access to a wider range of data from observing stations, CO-OPS is able to provide a customized array of tidal products to users — including Tides Online, a Web-based product that provides users with the latest graphical and tabular water-level observations, predictions, and meteorological data in real-time or near real-time from each of the 175 NWLON stations.

Another important CO-OPS product, the Physical Oceanographic Real-Time System (PORTS), is a decision-support tool designed to improve the safety and efficiency of maritime commerce. By providing NWLON data and other information and forecasts to mariners through a variety of channels, from telephone lines to shipboard computers, PORTS promotes safety and efficiency at 13 major U.S. ports. When 95 percent of U.S. international trade consists of waterborne goods, PORTS is an invaluable tool both for navigation safety as well as economic efficiency. Knowledge of water levels, currents, winds, waves, visibility, and water density can increase the amount of cargo that can be safely moved through a harbor by enabling mariners to use every inch of depth. A



The Golden Gate Bridge as seen from atop NOAA's Gulf of the Farallones National Marine Sanctuary Office at the Presidio, San Francisco. *Credit: NOAA Central Library Photo Collection, Rich Bourgerie, Oceanographer, CO-OPS, NOS, NOAA, photographer*

NOAA-sponsored study completed in late 2005 concluded that the economy of Tampa Bay, Fla., had a savings of more than $7 million a year and direct income from the operation of PORTS since its installation in 1990.

The Wave of the Future

Some of the tidal records of the early Coast Survey span more than a century and a half, making them some of the oldest geophysical records in the United States. The tidal station at the Presidio, in San Francisco, took its first readings in 1854 to assist clipper ships navigate the dynamic and often hazardous waters of the Golden Gate. The station, which has continuously recorded water levels ever since, is now an NWLON station and part of San Francisco's PORTS system, which enables massive ships and crane barges (about 260 deep-draft vessels per month) to safely navigate over channels and beneath the suspension bridges of San Francisco Bay.

Today's real-time availability and the historic record of tidal stations such as the Presidio have enabled tidal data to be used far beyond their traditional applications to navigation and shoreline boundary determinations. In 2003, in recognition of this, CO-OPS established the Coastal Oceanographic Applications and Services of Tides and Lakes (COASTAL) program to focus on non-navigational applications of tidal data, such as marsh monitoring and restoration projects, beneficial use of dredged material, coastal planning and development, long-term sea-level assessment, tsunami and storm surge warnings, and emergency preparedness.

Despite its cutting-edge digital observation network, today's Office of the Coast Survey realizes a hard fact: We are missing far more tidal information than we have. The 175 digital NWLON stations are a good start, but with 95,000 miles of U.S. coastline, they are only a start, as are the already considerable savings enabled by PORTS in 13 port complexes around the nation. Today, about two-thirds of tidal predictions are based on data more than 40 years old; another 10 percent is data more than 60 years old; and a few tidal predictions are based on data from the turn of the 20th century. Moreover, there is still very little concrete information about the bathymetry of the nation's ports and harbors, despite the availability of sonar technologies that could be used to create subsurface maps (see "Nautical Charts: Leading the Way" on page 32). There is still much work remaining to do. Despite more than a century-and-a-half of progress in recording and predicting tides, the experts within the Office of the Coast Survey remain in many ways like their predecessors who, with little more than a wooden staff and a notebook, set out for the unknown: perhaps a little more curious than knowledgeable.

Tides and Currents — www.tidesandcurrents.noaa.gov
Tides Online — www.tidesonline.nos.noaa.gov

NOAA WATCHES WEATHER, WATER, AND CLIMATE

BY BARBARA STAHURA

When Congress created the first national weather service in 1870, the agency was assigned to the Department of War. Only people accustomed to military discipline, Congress believed, would be able to provide the necessary information in a prompt, ongoing, reliable manner. Later that year, "observer sergeants" of the Army Signal Service were the first to take synchronous, systemized weather observations, which were telegraphed to Washington, D.C. In 1890, the renamed Weather Bureau was assigned to the new U.S. Department of Agriculture. Then, in 1970, the National Weather Service (NWS) was reassigned to the new National Oceanic and Atmospheric Administration (NOAA), an agency of the Department of Commerce.

Top: A Weather Bureau office circa 1900. *Credit: NOAA Central Library Photo Collection*
Left: Operations area, National Weather Service Forecast Office in Key West, Fla., as spiral bands from Hurricane Charley spread over the Florida Keys. *Credit: Jim W. Lee*

WEATHER

NOAA's largest component, NWS is the primary source of weather data, forecasts, and warnings for the United States. It is the nation's sole official voice for issuing warnings during life-threatening weather events. These services cost each American only about a cup of premium coffee a year — quite a bargain considering how much the weather affects our daily activities. The "observer sergeants" have long since been replaced by highly skilled employees as well as more than 12,000 volunteer citizen observers, using technology not even dreamed of in 1870, such as satellites, supercomputers, "Hurricane Hunter" aircraft, marine data buoys, Doppler radar, and high-speed communication systems.

NOAA's NWS activities are reflected in the theme of its strategic plan for 2005-2010: "Working Together to Save Lives."

WATER

Annually, floods in the United States and its territories claim more lives than lightning, tornadoes, and hurricanes, and flood damage averages more than $2 billion per year. The Office of Hydrologic Services Division (HSD) oversees plans, policies, and procedures for flood warning and forecast operations. HSD works with the Federal Emergency Management Agency and NOAA's Tropical Prediction Center on hurricane flood emergencies, which often produce the inland flooding responsible for many of the deaths associated with tropical cyclones in the United States. HSD also conducts flood-mapping projects to provide more advanced notices of flooding and produces outreach campaigns to warn people about the dangers, such as the "Turn Around Don't Drown" campaign.

CLIMATE

When viewed over time, weather becomes climate, and climate plays a crucial role in human activity. For instance, if the climate in an area changes dramatically, drought, floods, or blizzards may become common — all events that would disrupt lives and socio-economic patterns. If climate change were long-term and large enough, it would play havoc with the national well-being. Therefore, NOAA maintains several programs and offices devoted to the ongoing study of climate change. Their overall goal is to "understand and describe climate variability and change to enhance society's ability to plan and respond." The Climate Program Office leads NOAA's climate education and outreach activities and coordinates these activities across the agency. NOAA's National Climate Data Center in Asheville, N.C., is the world's largest active archive of weather data. It provides data and related information to everyone – scientists as well as the general public.

MODELING THE WEATHER: NUMERICAL WEATHER PREDICTION

British mathematician Lewis F. Richardson made the first numerical calculations for weather forecasting during World War I. Using a slide rule and logarithmic tables — the most advanced tools of the day — he took six weeks to predict a six-hour change in pressure over a single point. Nevertheless, his work was an important step in the evolution of numerical weather prediction, also known as computer weather modeling. Today, with its supercomputers, NOAA's massive Central Computing System ingests more than 210 million observations daily, most obtained from satellites, and processes them at 1.36 trillion sustained calculations per second. If that number is difficult to grasp, think of someone working with a handheld calculator around the clock — with no coffee breaks! — for 78,000 years to perform the same calculations these supercomputers carry out in one second.

NOAA's National Weather Service (NWS) and the National Centers for Environmental Prediction use these calculations in global and regional models to produce forecasts in many areas: atmospheric, oceanic, hurricane, severe weather, aviation, fire weather, volcanic ash, air quality, and dispersion. NOAA's human forecasters interpret the atmospheric models, adding another layer of accuracy beyond what supercomputers can do.

A dynamic climate forecast system is able to make forecasts out to one year. Models to predict space weather are available. Forecasts now expand beyond weather, water, and climate services to include ecosystems and to serve customers in the transportation, health, and energy communities. Improvements will continue, with the next upgrade to the supercomputer system scheduled for 2009.

NOAA's NWS already operates the most advanced weather and flood warning and forecast system in the world. With each further enhancement to numerical weather prediction, weather forecasting accuracy improves, saving countless lives and much property every year.

National Centers for Environmental Prediction – wwwt.ncep.noaa.gov

Related Web sites:
NOAA – www.noaa.gov
National Weather Service – www.nws.noaa.gov
Office of Hydrologic Services Division – www.weather.gov/om/water
Climate Program Office – www.climate.noaa.gov
National Climate Data Center – www.ncdc.noaa.gov

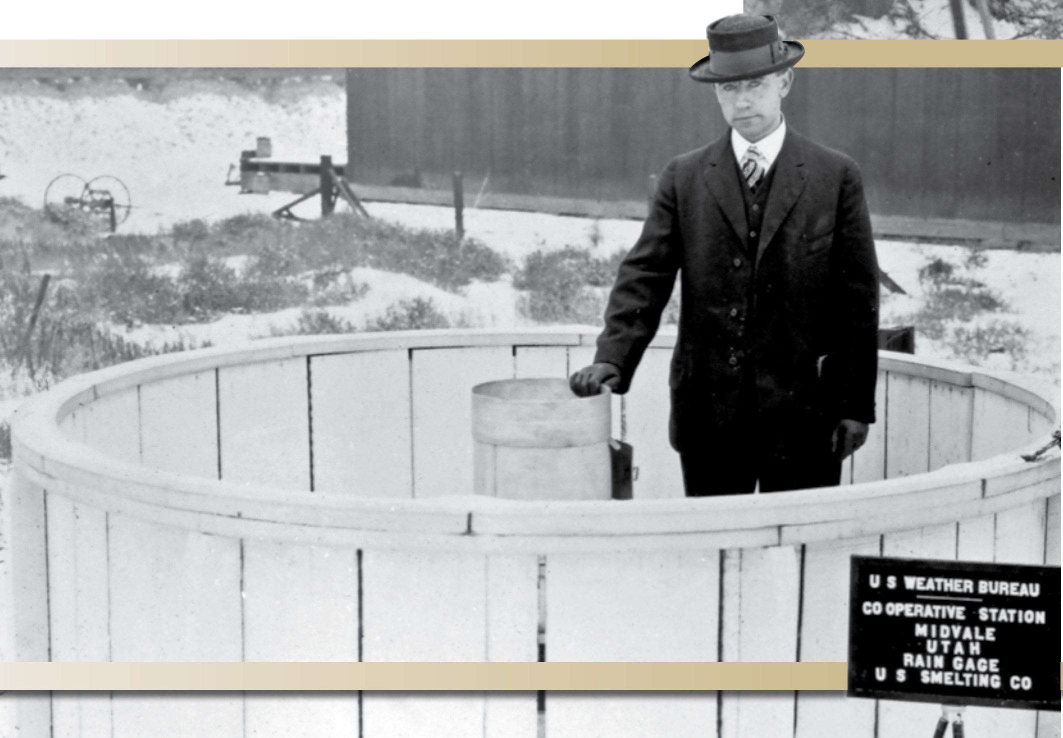
COOPERATIVE WEATHER PROGRAM:

DEDICATED VOLUNTEERS WATCH THE WEATHER

BY BARBARA STAHURA

While NOAA's National Weather Service (NWS) employs highly-skilled scientists and technology specialists, the NWS could not do its job as well as it does without the efforts of more than 12,000 volunteers around the country: the Cooperative Weather Observers, or COOP. COOP observers willingly dedicate time every day to measuring and recording maximum and minimum temperatures, snowfall, evaporation, soil temperatures, and 24-hour precipitation totals — together spending an estimated million hours per year — to contribute to the accuracy of the nation's weather forecasts. From farms and cities, suburbs and seasides, valleys and mountains, observers record their local data and transmit it to the NWS by phone, email, or mail.

COOP observations are a vital link in NOAA's efforts to protect lives and property in case of severe weather. NOAA's NWS has issued severe weather warnings based on information from volunteers. Furthermore, the most definitive source of climate data in the United States comes from the COOP network, given its many years of operation (since 1891), high density across the



Top: The rain gauge at the cooperative weather station at Granger, Utah, circa 1930. Left: The rain gauge at the U.S. Smelting Co. cooperative weather station in Midvale, Utah, circa 1930. *Credits: NOAA Central Library Photo Collection*

country, and large number of rural stations not affected by urban "heat islands." This climate record increases in value with time and is essential to climate-change research. These millions of measurements are used not only for understanding droughts and floods, heat waves and cold

Left: A cooperative weather station at Granger, Utah, circa 1930. Volunteers observed temperature, precipitation, sky conditions, etc. *Credit: NOAA Central Library Photo Collection* **Above: The NOAA weather station at the Shuttle Landing Facility's midfield on NASA's Kennedy Space Center in Florida.** *Credit: NASA Kennedy Space Center (NASA-KSC)*

spells but also for agriculture, engineering and architecture, utilities planning, environmental impact, litigation and insurance purposes.

Weather Observer Stations

When Congress established the Weather Bureau, the predecessor of NOAA's NWS, in 1890, that law included the formation of the weather observer program, which was meant to define the climate of the United States for agricultural assistance. By the next year, 2,000 weather stations staffed by volunteers had been established around the country.

There are different types of cooperative weather observer stations, grouped into networks.

- The "a" network is the most basic, supporting NWS climate records, with the minimum task of observing daily minimum/maximum temperatures and 24-hour precipitation totals.
- The "b" stations primarily support NWS hydrologic programs such as flood forecasting, water planning, and water supply. These stations report 24-hour precipitation, river or lake levels, high and low temperatures, the water equivalent of snow, evaporation, and soil temperature as applicable.

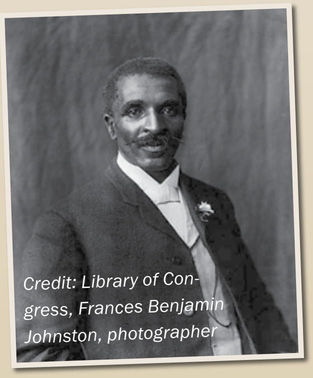
WEATHER WATCHERS HONOR ROLL

Many people — whom today we might call "weather buffs" — were watching the skies, measuring rainfall, and recording temperature long before Congress formally established a weather observation network in 1890. The first known weather observer in the American colonies was the Swedish clergyman John Campanius Holm, who regularly recorded the weather in what is now Delaware in 1644 and 1645. In 1776, Thomas Jefferson began recruiting volunteer weather observers in Virginia, and within four years, observers were also volunteering in five more states (Jefferson's personal weather observations stretched across 40 years). Jefferson contemporaries George Washington and Benjamin Franklin were two more famous weather observers.

Some more recent COOP volunteers have attained very long terms of continuous service. Edward H. Stoll of Elwood, Neb., observed for 76 years; Earl Stewart of Cottage Grove, Ore., 75 years; and Ruby Stufft of Elsmere, Neb., 70 years, the woman with the longest service as a COOP observer. All of them, now deceased, have COOP awards named in their honor. One long-time COOP volunteer is still at his station. When Richard Hendrickson took his first reading for COOP, Herbert Hoover was president. The year was 1930, and twice a day, every day since then, the Bridgehampton, Long Island, farmer has chronicled the nation's climate from his COOP station. (See sidebar on George Washington Carver as a voluntary weather observer on page 51.)

GEORGE WASHINGTON CARVER: VOLUNTEER WEATHER OBSERVER

BY DORIA B. GRIMES



Credit: Library of Congress, Frances Benjamin Johnston, photographer

In addition to creating hundreds of new uses for peanuts, soybeans, sweet potatoes, and cow peas, George Washington Carver served as a voluntary weather observer for the U.S. Weather Bureau. From November 1899 through January 1932, he dutifully completed W.B. Form 1009 in triplicate at Tuskegee University by recording the daily minimum and maximum temperatures, precipitation, wind direction, and day descriptions. He mailed these monthly to the Alabama Section of the Climate and Crop Service of the Weather Bureau, a part of the U.S. Department of Agriculture until 1940.

A review of the correspondence between Carver and the Weather Bureau indicates that his diligence was not accepted without question. For example, in a letter dated Nov. 7, 1905, Alabama Section Director F. P. Chaffee wrote to Carver, "It is thought maximum entry of 44 degrees on the 8th was inadvertently substituted for 74 degrees ... ."

Another example is on Feb. 13, 1920, when Weather Bureau Meteorologist P.H. Smyth wrote to Carver, "... on several dates there are marked discrepancies in hour daily temperature values as compared with surrounding stations. For instance, on January 25th your maximum temperature is recorded 78; at Montgomery it was 48; at Auburn 68 ... ."

Accuracy of weather data is essential, and NOAA's National Weather Service can be depended upon to review and correct all data submitted by voluntary weather observers, now called "cooperative weather observers" — all 12,000 of them.

Scanned images of George Washington Carver's handwritten weather reports including corrections in red by the Weather Bureau can be found at: http://docs.lib.noaa.gov/rescue/gw_carver_tuskegee/data_rescue_tuskegee_observations.html.

• When a station supports both climatic and hydrologic programs, it is considered an "ab" station.

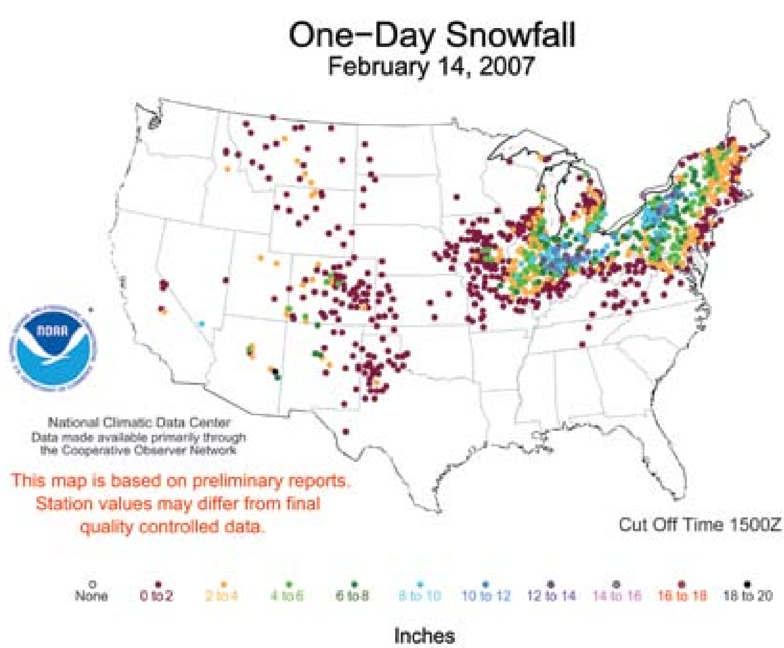
• Finally, a "c" station supports NWS meteorological programs, such as the issuance of warnings, forecasts, and public service, as well as the same observations as the other networks.

All the stations use standardized equipment, approved by NWS. Two types of thermometers can be used, the older Cotton Region Shelter or the newer Maximum/Minimum Temperature Sensor. Both shelter the thermometer but still allow accurate readings. Precipitation is measured with either the Fisher & Porter rain gauge or the 8-inch standard rain gauge.

While there are volunteer observers at most of the stations, about 1,000 stations are Automated Surface Observing System (ASOS) stations located at large airports. ASOS reports are available hourly, as opposed to weekly or monthly, and are used for immediate forecasting. However, because ASOS stations have often been relocated at their airports and since they are often affected by urban "heat island" influences, their long-term data is not as stable as that provided by volunteers.

The NWS has embarked on a plan to modernize the COOP volunteer networks and ASOS in order to meet demand for higher density, real-time weather, and climate data. The modernization will include replacing obsolete equipment and upgrading the network by filling in gaps in reporting coverage to improve data accuracy and availability.

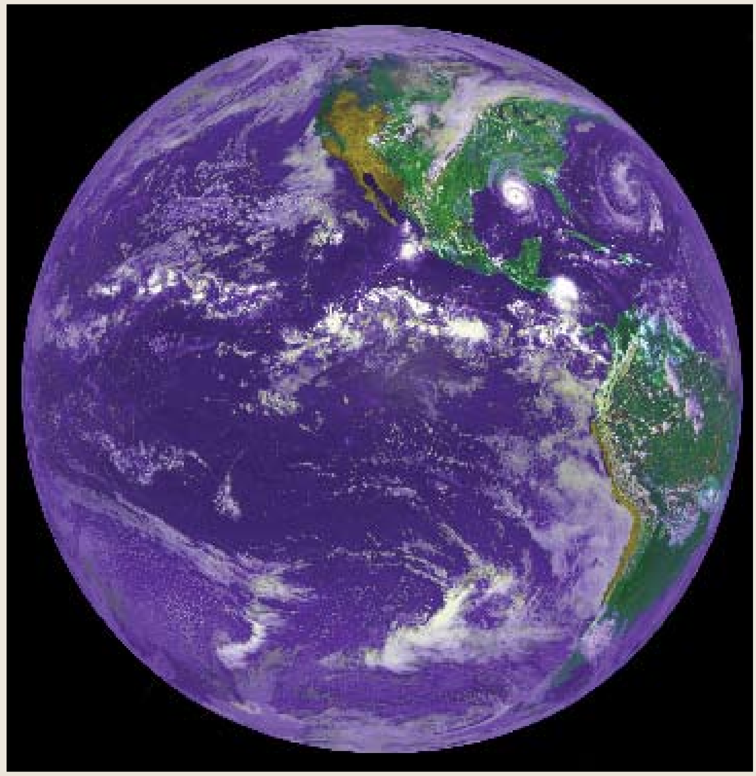
Cooperative Weather Observers — www.weather.gov/om/coop



A map displaying the amounts of snowfall for different U.S. locations on Feb. 14, 2007. The data depicted on this map was primarily gathered by volunteers in the Cooperative Weather Observer Program. *Credit: NOAA's National Climatic Data Center*

WEATHER EYES IN SPACE: NOAA SATELLITES

BY BARBARA STAHURA

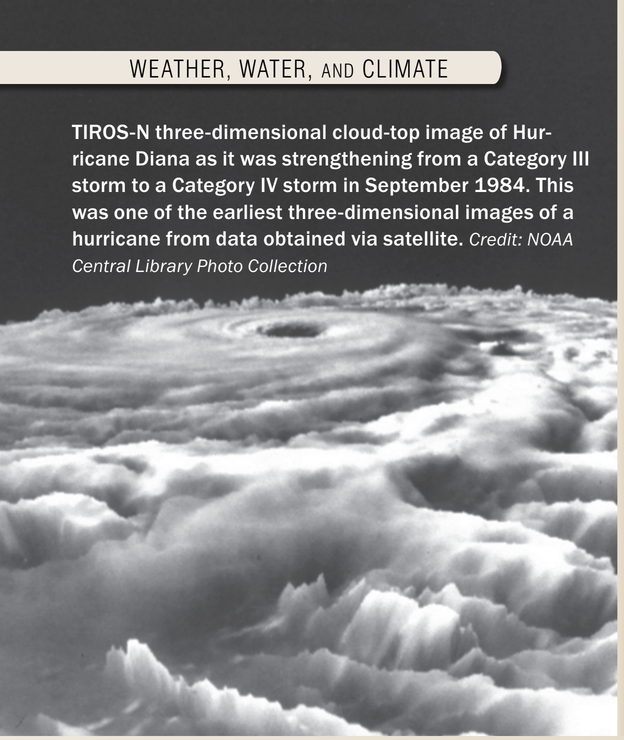


In April 1960, the world's first weather satellite, TIROS I, zoomed into space at the tip of a rocket. Although not much more than a camera that could take photos in black and white during daylight, TIROS I — an acronym for Television Infrared Observation Satellite — revolutionized weather forecasting. In a sense, it freed meteorologists to view our planet from 450 miles high, complete with cloud formation patterns. Meteorologists used this eye in space to examine these patterns, which reveal emerging weather, and improve their forecasting abilities. TIROS I operated for 77 days, sending back 19,389 usable photos. TIROS II was launched in November 1960.

For the next half-century, NOAA, in partnership with NASA, has launched many more weather satellites. Technology has now grown more sophisticated and is able to provide increasingly detailed information on atmospheric conditions. This allows for accurate weather prediction days in advance, as well as long-term climate monitoring. Today, NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) operates the nation's environmental satellites. Two types of satellites — GOES and POES — provide global weather monitoring, producing billions of bits of data and photos daily.

GOES — Geostationary Operational Environmental Satellites — orbit at 22,300 miles above the equator at the same speed as Earth's rotation, which means they provide a full-disc view of Earth as they hover always at the same point. Ever-vigilant, the two GOES presently in orbit provide constant views of the United States that allow meteorologists to spot the atmospheric triggers for severe weather such as hurricanes, tornadoes, Nor'easters, hail storms, and flash floods; and then to track storm development and movement. GOES satellites are the backbone of short-term weather forecasting called "now-casting." NOAA combines the GOES' real-time data with that from Doppler radars and automated surface observing systems to provide severe-weather warnings and monitoring.

Top: An image taken on Aug. 25, 1992, by NOAA GOES-7 weather satellite of the Americas and Hurricane Andrew as it makes landfall on the Louisiana coast. *Credit: NOAA image by F. Hasler, M. Jentoft-Nilsen, H. Pierce, K. Palaniappan and M. Manyin* **Right: An early TIROS satellite is mounted on the nose of a rocket prior to launch. TIROS satellites were 18-sided polygons, 22 1/2 inches high with a 42-inch diameter. They weighed between 270 and 300 pounds.** *Credit: NOAA Central Library Photo Collection*



TIROS-N three-dimensional cloud-top image of Hurricane Diana as it was strengthening from a Category III storm to a Category IV storm in September 1984. This was one of the earliest three-dimensional images of a hurricane from data obtained via satellite. *Credit: NOAA Central Library Photo Collection*

An image of Hurricane Katrina taken by a GOES satellite. *Credit: NOAA Environmental Visualization Program image*

POES — Polar-Orbiting Environmental Satellites — monitor the entire Earth from 500 miles up, making complete north-to-south orbits in about 100 minutes for about 14.1 orbits daily. In addition to data for long-term weather forecasting, their technology — light-years beyond that of TIROS — provides visible and infrared radiometer data for imaging purposes, radiation measurements, temperature, and moisture profiles. POES satellites collect global data for a broad range of environmental-monitoring applications, including climate research, ocean dynamics research, volcanic eruptions, forest fire monitoring, global vegetation analysis, and even search and rescue.

Satellite Information Saves Lives and Property

NOAA weather satellites were essential in saving lives and reducing economic losses from recent severe-weather events. In 1992, NOAA forecasts, resulting from satellite data preceding Hurricane Andrew, allowed the evacuation of thousands of people in Florida and Louisiana. Only 26 people died — far fewer than previous hurricanes of similar strength. NOAA satellite data would prove crucial again in 2005 with Hurricane Katrina. NOAA's hurricane forecasters used the satellite data and imagery to provide watches and warnings with lead times of 44 and 32 hours, respectively — an additional eight hours beyond when alerts are typically issued. In another example of the impact of NOAA satellites, information from POES monitors increasing sea-surface temperatures. This data supported NOAA's prediction of the El Niño of 1997-98 six months in advance. This allowed communities sufficient time to reduce the impact of this climatic phenomenon. (See "Forecasting El Niño and La Niña" on page 59.)

Not as well known is the use of NOAA satellites in the international Search and Rescue Satellite-Aided Tracking System, called COSPAS-SARSAT. This system uses a constellation of satellites from many nations to detect and locate distress signals from emergency beacons onboard aircraft and boats and from handheld personal locator beacons.

Finally, NOAA operates satellites for the Department of Defense through the Defense Meteorological Satellite Program (DMSP). Since the 1960s, DMSP has assisted the U.S. military in planning and conducting operations worldwide.

New GOES and POES Planned

As advanced as GOES and POES already are, NOAA is planning for more sophisticated instruments to improve its weather-forecasting abilities and environmental monitoring in response to climate change.

GOES-R, scheduled for launch in 2014, will scan the Earth five times faster and deliver photos 40 times faster than the satellites now in orbit. It will improve hurricane monitoring with sensors able to analyze the various parts of these monster storms. Even more amazing, GOES-R will continuously detect lightning from space — an essential tool in predicting hurricanes.

NPOESS, or the National Polar-orbiting Operations Environmental Satellite System, is NOAA's next generation of polar satellites. Managed by the Integrated Program Office, NOAA, the Department of Defense, and NASA, NPOESS will gather information about Earth's weather, oceans, land, and atmosphere, and distribute it to civilian, military, and scientific communities.

NOAA Satellites — www.noaa.gov/satellites.html
National Environmental Satellite, Data, and Information Service (NESDIS) — www.nesdis.noaa.gov

SPACE HAS WEATHER, TOO

Weather does not exist only on the Earth; space has weather, too. Instead of high pressure systems or cold fronts, space weather is a consequence of the sun's behavior. Changes in the solar wind interact with the Earth's magnetic field. Instead of rain and wind, space weather produces solar radiation storms, radio blackouts, and geomagnetic storms. These storms can interfere with radio communication, cause electrical blackouts, and create concerns about radiation for people in high-flying aircraft. So, the more we depend on technology, the more we need to understand space weather.

The Space Environment Center (SEC) is jointly operated by NOAA and the U.S. Air Force. It is one of NOAA's nine National Centers for Environmental Prediction and is the first defense against the effects of solar weather as well as the nation's official source of space weather alerts and warnings.

Space weather storms have huge economic impacts. For instance, airline flights at high latitudes are rerouted to avoid increased radiation and communication problems. If not accurately predicted, solar particles can damage the International Space Station's $1 billion arm, satellites, and the GPS system. A geomagnetic storm affecting electric power could result in a $3 billion to $6 billion loss in the gross domestic product.

SEC forecasters are responsible for predicting these storms from hours to weeks in advance. By alerting customers to impending solar storms, the SEC enables them to take protective actions that reduce the threat to lives, property, and the economy.

Space Environment Center – www.sec.noaa.gov

Sgt. David J. Owen, a Defense Meteorological Satellite Program (DMSP) operations maintenance technician with the 2130th Communications Group, U.S. Air Force Communications Command (AFCC), completes an inspection of a DMSP receiver. NOAA also operates such satellites in conjunction with the Department of Defense. *Credit: Department of Defense photo*

NOAA's National Hurricane Center

BY BARBARA STAHURA

Credit: NASA

Left: GOES-12 satellite imagery of Hurricane Katrina over the Gulf of Mexico at peak intensity of 175 mph. *Credit: NOAA Satellite Services Division*

As a hurricane barreled toward Galveston, Texas, in September 1900, local U.S. Weather Bureau forecasters closely monitored the threatening weather using the best tools available — experienced observation of skies and tides, barometers, and anemometers. Despite forecasters' warnings to move to higher ground, many people in the seaside community ignored them. Additionally, given their limited data, the forecasters could not accurately predict the horrific intensity of the storm. Eight thousand people died, making this the worst natural disaster in U.S. history.

Today, three NOAA National Weather Service (NWS) Centers monitor the tropics from Guam to the west coast of Northern Africa employing sophisticated technology far superior to that available a century ago. The National Hurricane Center/Tropical Prediction Center, Central Pacific Hurricane Center, and the NWS Joint Typhoon Warning Center on Guam use satellites, supercomputers, ocean buoys, and hurricane-hunting aircraft (see sidebar) to detect the wispy beginnings of a hurricane in the open ocean. They create accurate models of storms as they develop, and predict direction and landfall. They use data from space, land, and sea to protect people and property.

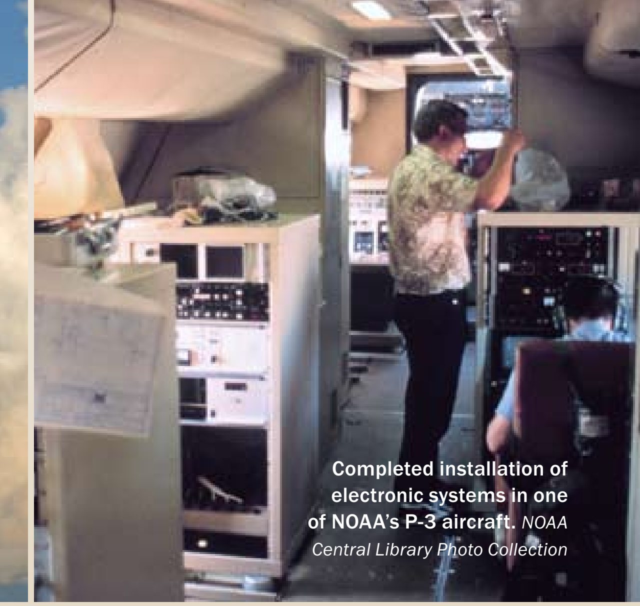
The United States launched its first weather satellite on April 1, 1960. Its descendants have grown increasingly more complex, enabling highly skilled forecasters to analyze weather systems, including hurricanes, in intricate detail and make better forecasts. From the Earth, NOAA's Doppler radars scan the atmosphere around hurricanes and typhoons, reading wind data, precipitation intensity, and movement, giving forecasters a cross-section analysis of the storm. Scattered in the ocean, floats and buoys transmit data from their watery locations to satellites, sending information on air and water temperature, wave height, and wind direction and speed.

Data from all these sources and more are funneled into NOAA's supercomputers, which perform more than 450 billion calculations per second. Using richly-layered mathematical representations, these technological workhorses model a hurricane's interactions with the ocean and the atmosphere, producing more accurate forecasts. In the 1980s, NOAA was able to issue two-day hurricane predictions. Today, thanks to its supercomputers, NOAA makes accurate hurricane predictions five days in advance.

The impacts of hurricanes — the costliest natural disasters in the United States — can be tremendous: billions of dollars in economic and property losses, damage to near-shore ecosystems, and especially human lives disrupted and lost. NOAA's continued investment in research and operations, along with partnerships with other agencies and public education and outreach, help to ensure that a tragedy on the scale of Galveston will not happen again.

National Hurricane Center – www.nhc.noaa.gov

A NOAA P-3 and NOAA's Gulfstream GIV-SP (foreground). *Credit: NOAA Marine and Aviation Operations*



Completed installation of electronic systems in one of NOAA's P-3 aircraft. *NOAA Central Library Photo Collection*

HURRICANE HUNTERS

Thomas Jefferson never heard of Miss Piggy, Kermit, or Gonzo, but all three are aircraft in the NOAA Hurricane Hunter story. NOAA, the National Oceanic and Atmospheric Administration, traces its roots back to President Jefferson. A very curious and scientific man, Jefferson established the Survey of the Coast in 1807, the first time the young nation made a concerted effort to chart its waterways and shorelines. This was the foundation of today's NOAA Corps, the smallest U.S. uniformed service, comprising 300 officers serving throughout NOAA.

Now, 200 years later, Miss Piggy, Kermit, and Gonzo are not only as known as Muppets, but also are mechanical members of NOAA, sturdy aircraft flying into and around the swirling environs of hurricanes to study and monitor these massive atmospheric phenomena.

Civilian and NOAA Corps personnel of the NOAA Aircraft Operations Center (AOC) based at MacDill Air Force Base near Tampa, Fla., fly in conjunction with the Air Force Reserve 53rd Weather Reconnaissance Squadron from Keesler Air Force Base, Miss. While the 53rd, flying the Lockheed Martin WC-130J aircraft, tracks the hurricanes, AOC's aircraft study, monitor, and fly the landfall missions of both East and West Coast hurricanes every year between June 1st and November 30th.

Today, satellites locate and identify hurricanes – so no one actually has to "hunt" them. However, satellites cannot yet gather the data needed to measure hurricane intensity or to forecast their directions. The Hurricane Hunters are heavily instrumented, flying weather laboratories, capable of performing this service that can be accomplished in no other way ... up close and personal. The data gathered by these intrepid aircraft and crew save countless lives, protect property, and advance our knowledge of hurricane structure to improve the forecasting ability of the scientists of the National Hurricane Center.

Although several types of aircraft flew into hurricanes as early as 1947, the first NOAA/NWS Hurricane Hunter aircraft were McDonnell Douglas DC-6B aircraft, which started flying regularly in 1961. The DC-6s were replaced by the Lockheed WP-3D Orion aircraft, which first flew in 1976 through Hurricane Bonny. Thanks to a lot of care and meticulous maintenance, NOAA's Aircraft Operations Center is still operating the venerable WP-3D, even though Lockheed discontinued manufacturing the P-3 in 1990. In 1996, the AOC's Gulfstream GIV-SP was acquired. With high-altitude capability and "long legs," the GIV (Gonzo) flies completely around the outside of the storm dropping GPS dropwindsondes that measure temperature, barometric pressure, relative humidity, wind speed, and wind direction. The WP-3D aircraft (Miss Piggy and Kermit) work through the storm into the eye using the same GPS dropwindsondes and an array of sophisticated instruments, sensors, and radar to gather data and measure the dynamics of these massive weather systems.

Using the combination of the WC-130J tracking the path of the hurricane, the GIV measuring the atmospheric conditions around the circumference of the storm, and the WP-3D aircraft measuring and studying the interior of the weather system, NOAA's National Hurricane Center acquires a cornucopia of data to predict what a hurricane may do. In turn, this saves the lives and property of millions of people living along our beautiful shorelines. We've come a long way in 200 years.

NOAA Aircraft Operations Center – www.aoc.noaa.gov

A gust probe on a NOAA P-3. *Credit: NOAA Central Library Photo Collection*

Wing sensors on a NOAA P-3. *Credit: NOAA Central Library Photo Collection*

IN CASE OF EMERGENCY:
NOAA WEATHER RADIO ALL HAZARDS

BY BARBARA STAHURA

Weather radios like Midland's Model WR-100 weather/All Hazards alert radio provide owners with weather and civil emergency warnings and information. *Credit: Image courtesy of Midland Radio Corporation*

When commercial telegraph lines began crisscrossing the United States in the 1840s, it became possible for the first time in history to alert people at a distance about severe weather bearing down on them. While this system was not very accurate and often not rapid enough, at least it was a start. It was not until the 1970s that an effective nationwide warning system was established: NOAA Weather Radio All Hazards (NWR), created by NOAA's National Weather Service. Before long, NWR became America's single source for comprehensive weather and emergency information, working in conjunction with federal, state, and local emergency managers and other public officials. Today, more than 960 NWR stations are located around the United States, remotely programmed from one of 126 local National Weather Service offices and transmitting over one of seven discrete radio frequencies dedicated to NWR.

As the voice of the National Weather Service that helps to fulfill NOAA's mission to protect lives and property, NWR broadcasts routine weather information around the clock. During an emergency, however, these broadcasts are interrupted to send a special tone that automatically turns on specialized All Hazards receivers to alert listeners to the potentially life-threatening situation. Characterized as "personal storm sirens," these radio receivers, which cost between $30 and $70, have already saved many lives. In one instance in 2005, the National Weather Service office in Binghamton, N.Y., issued a severe thunderstorm warning 22 minutes before the storm struck Charles F. Johnson Elementary School in Endicott. Thanks to being warned by the alarm on the school's All Hazards receiver, school officials had enough time to evacuate 340 students, faculty, and staff to designated storm-safe areas. Although winds up to 70 mph tore part of the roof off the kindergarten wing of the school, no one was killed or injured.

Emergency weather warnings are also delivered via commercial radio and television through the FCC's Emergency Alert System, which issues these alerts in conjunction with the National Weather Service. While the original primary mission of the Emergency Alert System was to warn Americans of a large-scale enemy attack, it is nevertheless an excellent vehicle to deliver various kinds of important warnings via the mass media.

In addition to information about severe weather, NWR has become "All Hazards" by broadcasting warnings and post-event information about many other hazardous events, including natural hazards such as tsunamis and forest fires; technological hazards including chemical releases and nuclear power plant emergencies; and national emergencies such as terrorist attacks. Also added to the list were Amber Alerts, which are issued in the most serious cases of child abduction. Like all other non-weather emergency messages sent over NWR, Amber Alerts are initiated by local, state, or federal emergency management officials, not the National Weather Service.

In many emergencies, minutes can make a difference between life and death. So the voices that issue the NWR emergency warnings are computer-generated in order to send out multiple independent warnings over many transmitters simultaneously. New automated voicing technology automatically converts text to speech, a much faster process than having humans read the messages aloud for broadcast after they have been composed. When NWR began using a computerized voice for emergency warnings in 1997, the voice, known as "Paul," was obviously not human and was sometimes difficult to understand. New voices — "Donna," "Tom," and in a few areas "Javier" (en español) — have been implemented and sound much more human.

NOAA Weather Radio – www.weather.gov/nwr

FORECASTING EL NIÑO AND LA NIÑA

BY BARBARA STAHURA

So what if there is a temporary rise in the surface temperature of the tropical Pacific Ocean, leading to a shift in the Pacific trade winds? What could possibly happen?

In a word, *disaster*.

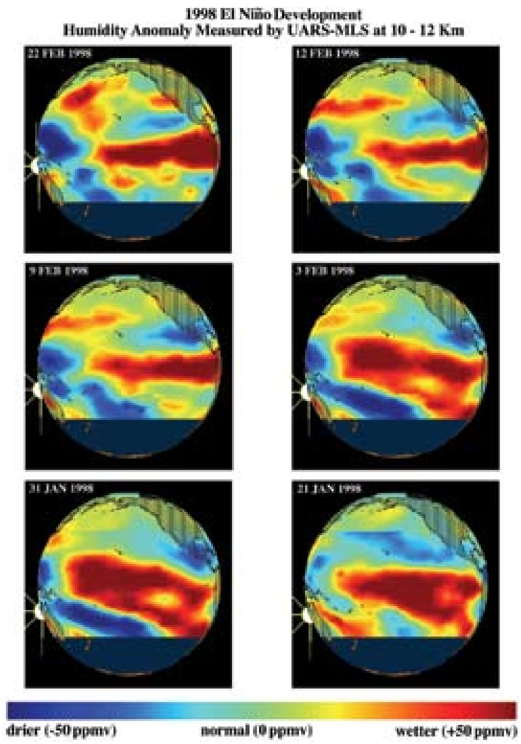
When this climate pattern occurred in the winter of 1982-83, famine struck Indonesia, drought-caused bushfires blasted Australia, rainstorms battered California to the tune of $2.2 billion, and the warm ocean devastated Peru's anchovy fishing industry. It is said that, worldwide, 2,000 people died and economic losses exceeded $8 billion.

Nine El Niño events have occurred in the last 40 years, with the 1982-83 and 1997-98 events being the strongest. The term "El Niño" originally referred to a warming of coastal waters in the tropical Pacific that occurs annually beginning in mid- to late-December (near Christmas, hence the term El Niño or "the Child" in Spanish). We now know that the warmer waters quite often result from a weakening and reversal of the region's normal ocean currents.

The term "El Niño" is now used for unusual coastal warmings that are longer and more intense than the annual warming. Research studies in the 1960s revealed that the coastal warming was part of a large-scale warming across much of the equatorial Pacific, associated with large-scale atmospheric circulation (pressure and wind) changes that are related to a phenomenon called the Southern Oscillation. This gave birth to the acronym ENSO, or El Niño/Southern Oscillation, and the concept of the ENSO cycle, which has cold (La Niña) and warm (El Niño) phases.

NOAA is the global leader in forecasting and monitoring this climate pattern. Thanks to decades of research, NOAA's Climate Prediction Center (CPC) can monitor and predict the ENSO cycle. By making its findings available to private organizations and government agencies worldwide, CPC helps them avert or reduce negative impacts and take advantage of positive effects.

CPC was able to predict the 1997-98 El Niño, one of the strongest events of the last century. Its accurate predictions, six months in advance, of heavy winter rains over the southern United States and a mild Midwest winter meant that the most harmful effects were alleviated, while the benefits were used to advantage. For instance, while California still suffered heavy flooding, the advance warning meant that economic losses totaled only half those of 1982-83.



These six images, compiled with data obtained by the Microwave Limb Sounder (MLS) on NASA's Upper Atmosphere Research Satellite (UARS) during January and February 1998, show the evolution of atmospheric water vapor over the Pacific Ocean during the 1998 El Niño condition. *Credit: NASA Jet Propulsion Laboratory (NASA-JPL)*

After the unpredicted 1982-83 event, NOAA became a major partner in the international Tropical Ocean Global Atmosphere program designed to improve tropical-ocean monitoring. The ENSO Observing System, which NOAA helped design and continues to maintain, was established then. Its major components: the Voluntary Observing Ship program measures ocean temperatures; the tide gauge network monitors sea-level changes; the drifting buoy network captures ocean currents and surface temperatures; and moored buoys (TAO array) monitor surface winds, relative humidity, air temperature, surface and subsurface ocean temperatures, and ocean currents. Satellites collect data transmitted from the TAO array several times daily.

NOAA's National Centers for Environmental Prediction use computer models and statistical models to help predict ENSO activity. The CPC produces a monthly ENSO discussion and weekly updates (available via the Internet) used by farmers, the media, power utilities, water resource and transportation agencies, insurance companies, various government agencies, and others.

NOAA continues to build upon its leadership and legacy in the detection, prediction, and understanding of ENSO and is improving the ENSO Observing System. Among the new components is the research ship *Ka'imimoana*, dedicated to servicing the TAO array. Further improvements in technology, predictive techniques, and global hazard and benefit assessments will provide the world with a more thorough understanding of ENSO evolution and its impacts. While an El Niño on the scale of 1982-83 and 1997-98 may occur again, thanks to NOAA, the world is better prepared.

NOAA Climate Prediction Center – www.cpc.ncep.noaa.gov

LIGHTNING: DANGERS AND SAFETY

BY BARBARA STAHURA

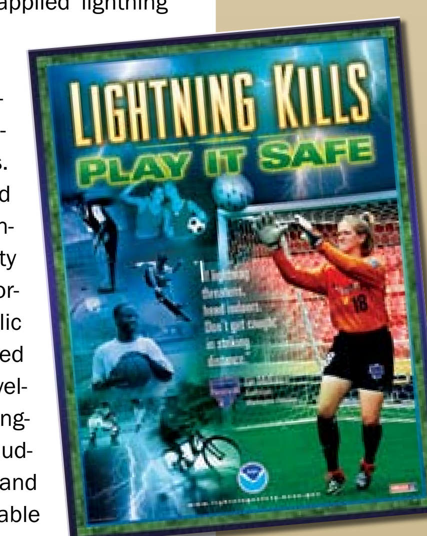
Lightning in the night. *Credit: Ståle Edstrøm*

Damage caused by a lightning strike. *Credit: Photo courtesy National Lightning Safety Institute*

Lightning has fascinated and frightened humans for millennia. Ancient cultures from the Greeks and Romans to the Mayans and Norse had lightning stories: Their gods hurled it from the heavens. Sacred plants sprang from lightning-struck soil. Today, even though we understand the science of lightning, it is no less fascinating — or dangerous. Lightning is an underrated killer, causing more storm-related deaths in the United States than either tornadoes or hurricanes; only flooding causes more fatalities.

Lightning results from the buildup and discharge of electrical energy. Collisions between various forms of precipitation within the thunderstorm cloud and air movements in the cloud cause positive and negative charges to build up. These charges in the clouds also cause charges to build up on the ground under and near the thunderstorm. When the difference between opposite charges becomes too great, a conductive path forms between the charges and a giant spark of electrical current that we call lightning. Lightning can reach a temperature of 50,000 degrees Fahrenheit. Packing several hundred million volts and up to 100,000 amps, lightning is extremely powerful. (In comparison, typical household current is only about 115 volts and 10 to 20 amps). Because lightning can reach outward 10 miles from the thunderstorm cloud, it can strike from a clear sky both before and after the storm. While NOAA issues accurate warnings for tornadoes, floods, and hurricanes, the unpredictability and sheer number of cloud-to-ground lightning strikes in the United States — 25 million a year — make lightning warnings nearly impossible.

NOAA and its National Weather Service have studied and applied lightning research for decades. In 2001, NOAA organized a team to promote lightning-safety through education and awareness. The team also enlisted the help of non-governmental lightning-safety experts, agencies and organizations to draw public attention to this underrated killer. The team has developed an array of lightning-safety information, including posters, pamphlets, and magnets that are available to the public. See the NOAA



A poster created by the lightning-safety team organized by NOAA in 2001 to promote lightning safety. *Credit: NOAA NWS Lightning Safety Program image*

LIGHTNING SAFETY

With only a vague understanding of lightning risks, most people tend to underestimate the threat and unknowingly expose themselves to great risk. Everyone should understand lightning safety.

- **Plan ahead.** For outdoor activities, know where you can shelter in safety if an unexpected thunderstorm develops. Leaders of organized outdoor activities should have a written lightning safety plan and enforce it.
- **Avoid the lightning threat.** Check the latest forecast before starting an activity. If thunderstorms are forecast, consider canceling or postponing the activity to avoid being caught in a dangerous situation.
- **Observe current weather conditions.** While outside, watch and listen for signs of impending danger such as darkening skies, increasing wind, or lightning. If you hear thunder (even a distant rumble), stop all activities immediately and go to a safe shelter.
- **A safe shelter** is a house or other substantial structure that contains a mechanism to conduct electrical current to the ground, such as plumbing, wiring, or phone lines. A vehicle with a metal roof and closed windows and doors is also safe, as long as metal surfaces are not touched.
- While inside a safe shelter, **stay off corded phones, computers, and any electrical equipment.** Wait 30 minutes after the last thunder before returning outside.
- Someone struck by lightning does not hold an electrical charge. **One cannot be injured by helping the victim.** Therefore, begin proper treatment immediately, including CPR if necessary, and call 911. Most victims will survive a lighting strike, although they may suffer ongoing disabilities afterward, particularly of the brain and nervous system.

NWS Lightning Safety Program – www.lightningsafety.noaa.gov

Time-lapse photography captures multiple cloud-to-ground lightning strikes during a night-time thunderstorm. *Credit: NOAA Central Library Photo Collection, C. Clark, photographer*

LIGHTNING MYTHS

- **Lightning doesn't strike the same place twice.**
  It can and often does, especially tall structures.

- **I can't be struck by lightning inside my home.**
  Lightning can be conducted through a home by wiring, metal pipes, and other conductive materials.

- **Rubber-soled shoes will protect me from lightning.**
  A little bit of rubber will not stop 100,000 volts.

A lightning storm over Boston. *Credit: NOAA Central Library Photo Collection, photo by* Boston Globe

- **The tires on my car will protect me if I'm inside.**
  It's not the tires, but the conductive metal frame of the car that directs the current around the passenger compartment and to the ground.

- **Lightning only strikes when it's raining.**
  A "bolt from the blue" can strike from a storm miles away, even if the sky above is clear blue.

lightning-safety Web site below or directly contact National Weather Service offices. With the slogans "Lightning Kills – Play It Safe" and "When Thunder Roars, Go Indoors!" the team annually declares the last week in June as Lightning Safety Awareness Week. Especially during this week, NOAA and National Weather Service offices across the country work with national and local media, agencies, and organizations to provide safety information to the public. NOAA has also partnered with various national organizations such as the PGA tour, Little League Baseball, and other national sports organizations, to provide information to keep participants and spectators safe. Since the inception of the campaign in 2001, lightning fatalities in the United States have averaged about 43 per year, well below the 30-year average of 73 per year from 1971 to 2000. NOAA believes its educational effort is responsible for at least part of that reduction in fatalities.

National Weather Service – www.nws.noaa.gov

TIME LINE

A cooperative weather station at Granger, Utah, circa 1930. Volunteers observed temperature, precipitation, sky conditions, etc. *Credit: NOAA Central Library Photo Collection*

CELEBRATING 200 YEARS OF SCIENCE, SERVICE, AND STEWARDSHIP

1807 - President Thomas Jefferson establishes Survey of the Coast, America's first physical science agency. Ferdinand Hassler's plan, based on scientific principles, is selected by government. Hassler, later selected to be Superintendent of the Coast Survey, imbues the organization with standards of accuracy, precision, and integrity.

1814 - Surgeon General orders surgeons to keep weather diaries; first government collection of weather data.

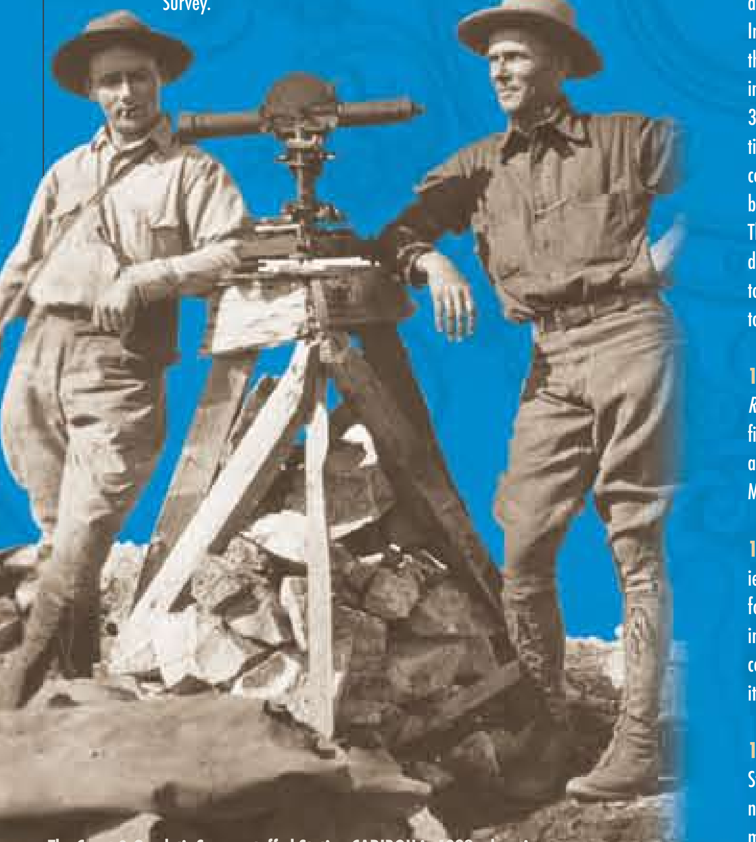
1816-17 – Survey of the Coast performs first horizontal geodetic surveys (triangulation) in the area of New York Harbor.

1832 - An Office of Weights and Measures, the forerunner of the National Institute of Standards and Technology, is formed under the U.S. Coast Survey.

1841 – The U.S. Lake Survey office is established in the Great Lakes, to undertake a "hydrographic survey of the northern and northwestern lakes."

1842 - James P. Espy appointed first official U.S. government meteorologist.

1843 - Alexander Dallas Bache, a great grandson of Benjamin Franklin, is appointed second Superintendent of the Coast Survey.



The Coast & Geodetic Survey-staffed Station CARIBOU in 1922, elevation 9,816 feet. The group was headed by William M. Scaife, seen here on the left. *Credit: NOAA Central Library Photo Collection*

1845 - U.S. Coast Survey begins studies of Gulf Stream, first government–sponsored systematic oceanographic project for studying a specific phenomenon. Physical, geological, biological, and chemical oceanography of the Gulf Stream and its environs serves as a model for all subsequent integrated oceanographic cruises.

1848 - Volunteer Weather Observers recruited through the Smithsonian Institution. The Smithsonian supplies weather instruments to telegraph companies and begins extensive weather-observation network the following year.

1851 - U. S. Coast Survey commissions Louis Agassiz to conduct first scientific study of the Florida Reef system.

1853 - First tide prediction tables published.

1854 - United States Coast Survey begins using self-recording tide gauges. The one installed at San Francisco begins the longest continuous series of tide observations in the Western Hemisphere.

1861-65 - United States Coast Survey serves in all theaters of the Civil War and with all major commanders. Coast Surveyors serve as hydrographers, topographers, and scouts often in advance of front lines. Coast Surveyors given military rank while attached to a specific command.

1870 - President Ulysses S. Grant signs legislation to establish a national weather warning service under the Secretary of War. The weather service is established within the Army Signal Corps.

1871 - President Grant authorizes America's first conservation agency, the U.S. Commission of Fish and Fisheries, which is placed administratively under the Smithsonian Institution. President Grant also authorizes the Coast Survey to conduct geodetic surveys into the interior, beginning the survey of the 39th Parallel. This project, the Transcontinental Arc of Triangulation, ties the east coast and west coast survey networks; the beginning of the national survey network. The Army Signal Service publishes the first daily weather maps, a series that continues to today. The nation's first fisheries laboratory is established at Woods Hole.

1872 - Publication of *Monthly Weather Review* begun by Army Signal Service. The first federally-sponsored fish culture begins at Baird Station on the McCloud River near Mt. Shasta, Calif.

1873 - The Commission of Fish and Fisheries utilizes the Coast Survey steamer *Bache* for its first deep water sampling and dredging cruises. This cooperative relationship continues until the Fisheries Service obtains its own deep water steamers.

1874-78 - Coast and Geodetic Survey Steamer *Blake* implements major innovations, including the Sigsbee sounding machine and the use of steel cable for oceanographic operations; pioneers deep ocean anchoring during Gulf Stream studies.

1879 – Coast and Geodetic Survey creates the first official datum of the United States, the New England Datum. Congress creates the seven-member Mississippi River Commission, including a member from the USC&GS, to address navigation improvements and flood control on the Mississippi River, so essential to the nation's commerce.

1882 - USS *Albatross* launched - first government research vessel built exclusively for fisheries and oceanographic research. *The Bulletin of the United States Fish Commission* begins, a publication which continues as the *Fishery Bulletin*.

1890 - Cooperative Weather Observer Network established, a system that now has over 12,000 observers nationwide.

1891 - Congress transfers weather service from Army Signal Corps to Department of Agriculture; the United States Weather Bureau, a civilian weather service, begins.

1893 - U.S. Fish Commission becomes responsible for northern fur seal research.

1898 - Weather Bureau begins regular kite observations for studying upper air; last kite observations are made in 1933. Weather Bureau begins hurricane warning network.

1900 - Although local Weather Bureau alerts as many persons as possible, the Galveston Hurricane, the greatest single natural disaster to affect the United States or its territories, kills over 6,000.

1901 - National Bureau of Standards (now the National Institute of Standards and Technology) established from U.S. Coast and Geodetic Survey Office of Weights and Measures.

1903 - Commission of Fish & Fisheries transferred to Bureau of Fisheries in Commerce and Labor Depts. Coast and Geodetic Survey transferred from Treasury Dept. to Commerce and Labor Depts.

1909 - Weather Bureau begins balloon observations.

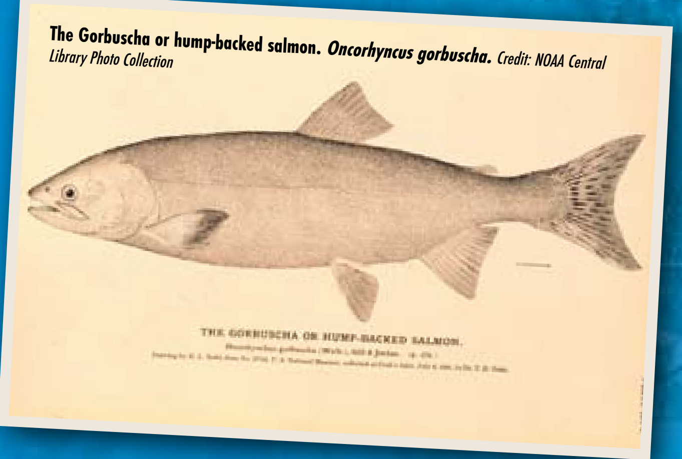
1911 –North Pacific Fur Seal Convention, the first international treaty to protect wildlife, places a five-year moratorium on harvesting Alaskan fur seals. This legislation becomes a model for protecting marine and terrestrial species.

1912 - First Fire Weather Forecast issued; fire weather service formally inaugurated in 1926.

1915 - First radio broadcast of a weather forecast from Illiopolis, Ill.

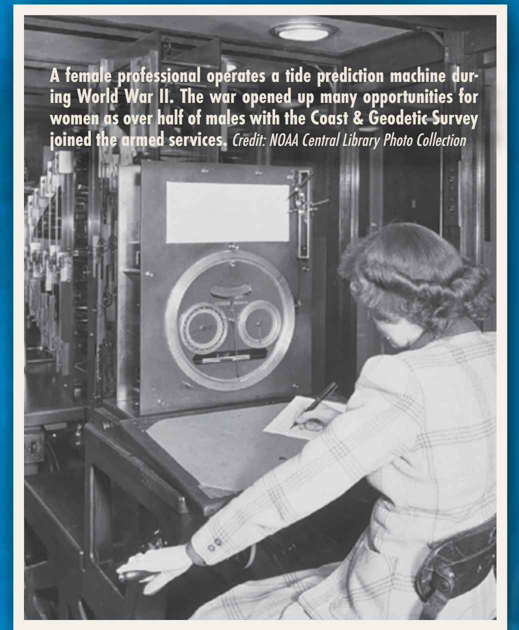
1917 – U.S. enters WWI. Commissioned Officers Corps, now known as NOAA Corps, created from field corps of the Coast and Geodetic Survey; half of commissioned officers transferred to armed services; ships *Surveyor*, *Bache*, and *Albatross* transferred to Navy. Personnel from Weather Service serve as meteorologists.

1918 - Weather Bureau begins issuing bulletins and forecasts for domestic military flights and new air mail routes.



The Gorbuscha or hump-backed salmon. *Oncorhyncus gorbuscha.* *Credit: NOAA Central Library Photo Collection*

1923-24 - Coast and Geodetic Survey begins use of acoustic sounding systems; develops radio acoustic ranging, the first marine navigation system not relying on visual means for position determination. This system leads to discovery of the deep sound channel, the SOFAR channel, invention of telemetering radio sono-buoys, and development of marine seismic techniques. Creation of the Pacific Halibut Commission to conserve that species.



A female professional operates a tide prediction machine during World War II. The war opened up many opportunities for women as over half of males with the Coast & Geodetic Survey joined the armed services. *Credit: NOAA Central Library Photo Collection*

1926 - Air Commerce Act directs Coast and Geodetic Survey to begin charting the nation's airways and directs the Weather Bureau to provide weather support to civilian aviation.

1928 - Teletype replaces telegraph and telephone as the primary method for communicating weather information.

1930 – First federal fisheries law enforcement unit established under Bureau of Fisheries.

1931 –International Whaling Commission created to conserve and regulate whale harvests.

1934 - Weather Bureau establishes Air Mass Analysis Section, leading to objective scientific forecasting methods as opposed to empirical methods.

1934-37 - "Dust Bowl" drought in southern plains causes severe nationwide economic damage; Coast and Geodetic Survey employs over 10,000 for surveys and field offices.

1937 - First Weather Bureau balloon carries radio-meteorograph, or Radiosonde, ending the era of manned aircraft soundings.

1939 - Coast and Geodetic Survey begins war mapping efforts. Bureau of Fisheries transferred from Commerce Dept. to Dept. of the Interior Fish and Wildlife Service; forerunner of NOAA Bureau of Commercial Fisheries.

1940 - Weather Bureau transferred from Agriculture Dept. to Commerce Dept.; Army and Navy establish weather centers; President Roosevelt orders Coast Guard to support ocean weather stations.

1942-45 - Over 1,000 civilians and over half of the commissioned officers from the Coast and Geodetic Survey enter military service; serve as hydrographers, artillery surveyors, cartographers, Army engineers, intelligence officers, and geophysicists. Civilians produce over 100 million maps and charts for the Allied forces. Weather Bureau is declared a war agency. Over 700 Weather Bureau members join the armed forces. Women are recruited to backfill positions, marking the first widespread professional opportunities for women in meteorology.

1942- Joint Chiefs of Staff establish a Joint Meteorological Committee to coordinate civilian and military weather activities. Central Analysis Center, forerunner of the National Centers for Environmental Prediction, is created to prepare and distribute analyses of the upper atmosphere.

1942 - Navy provides 25 modified aircraft radars to Weather Bureau for ground meteorological use, marking the beginning of a weather radar system in the United States. Navy aerologists play key support role for U.S. carrier-based Navy planes in mid-Pacific Battle of Midway Island in June 1942, marking a turning point in the Pacific front.

1942 - A cooperative thunderstorm research effort is begun by the Weather Bureau, military services, and the University of Chicago.

1944 – Accurate weather forecasts of tides and winds support decision to invade Normandy on June 6th.

1945 - Coast and Geodetic Survey seismologists provide first fallout forecast for the Trinity nuclear explosion at Alamagordo, N.M., by monitoring air and ground vibrations. Coast Survey adapts "Gee" aerial bombardment electronic navigation system to hydrographic surveying, beginning the era of marine electronic navigation.

1946 - The U.S. Weather Bureau selects Cincinnati, Ohio, and Kansas City, Mo., for the nation's first hydrologist-staffed River Forecast Centers (RFC). Eventually, 13 RFCs established nationwide. Central Radio Propagation Lab in Boulder, Colo., is established to focus on wartime experiences with radio communications. Later divisions include severe storms and weather research, climate monitoring, and atmospheric modeling to address environmental research needs.

A Navy biplane with a meteorograph on the starboard wing strut takes meteorological measurements for pressure, temperature, and humidity. Manned flights were inefficient for routine observations as cost was high. However, such flights paved the way for aircraft weather research projects. *Credit: NOAA Central Library Photo Collection*

1948 - USAF Air Weather Service meteorologists issue first tornado warnings. Princeton's Institute for Advanced Studies begins use of a computer for weather forecasting; now the National Geophysical Fluid Dynamics Laboratory. Coast and Geodetic Survey establishes Pacific Tsunami Warning System.

1949 – Creation of Inter-American Tropical Tuna Convention to conserve transboundary stocks of tunas and other highly migratory pelagic fishes.

1950 – Creation of the International Commission for the Northwest Atlantic Fisheries to conserve New England fisheries.

1951 - National Weather Records Center established in Asheville, N.C.; now the National Climatic Data Center.

1952 – Weather Bureau organizes Severe Local Storms Forecasting Unit in Washington, D.C., and begins issuing tornado forecasts.

1954 - Joint Numerical Weather Prediction Unit established from Weather Bureau, Navy, and Air Force; precursor to today's National Centers for Environmental Prediction. First radar is designed for meteorological use, the AN/CPS-9, and is unveiled by the Air Weather Service, USAF.

1955 - Coast and Geodetic Survey Ship *Pioneer* conducts surveys off United States West Coast; tows magnetometer invented by Scripps Institution of Oceanography; discovers magnetic striping on the seafloor, a key element in the Theory of Plate Tectonics.

1956 - Dept. of Interior divides fisheries duties of Fish and Wildlife Service into Bureau of Commercial Fisheries and Bureau of Sport Fisheries and Wildlife.

1956 - Weather Bureau initiates a National Hurricane Research Project.

1957 - International Geophysical Year provides first concerted worldwide sharing of meteorological research data. Weather Bureau supports first study to modify Navy Doppler radars for severe storm observations; the beginnings of modern Doppler weather radar.

1958 - Carbon dioxide measurement records begin at Mauna Loa, Hawaii; now the Air Resources Laboratory. Air samplings form baseline measurements of trace gases in the atmosphere.

1959 - Weather Bureau's first weather surveillance radar is commissioned at Miami hurricane forecast center.

1960 - World's first weather satellite, TIROS I, successfully launched. Weather Bureau meteorologists issue first advisories on air pollution for the Eastern United States.

1961 - World-Wide Standardized Seismic Network is established by the Coast and Geodetic Survey to monitor earthquakes and nuclear testing. The network played a central role in supplying data about continental drift and plate tectonics.

1962 - National Severe Storms Laboratory established in Norman, Okla. Great Lakes Research Center established in Ann Arbor, Mich.

1963 - Weather Bureau obtains two DC-6 aircraft, forming the nucleus for the Research Flight Facility.

1965 - Environmental Science Services Administration created, consolidating Coast and Geodetic Survey and Weather Bureau, a major precursor to today's NOAA.

1966 - National Sea Grant Colleges and Programs Act provides for uses of marine resources, economic opportunities, and for coastal and marine research. Five years later, the first Sea Grant Colleges are designated - Texas A&M University, University of Rhode Island, Oregon State University, and the University of Washington.

1966 - NASA transfers control of ESSA 2 satellite to the National Environmental Satellite Center, beginning a national operational weather satellite system.

1967 - Research centers Atlantic Oceanographic Laboratory, Pacific Oceanographic Laboratory, National Severe Storms Laboratory, and National Hurricane Research Laboratory established; forerunners for NOAA's present laboratory system. National Council for Marine Research, Resources and Engineering Development endorses the formation of the National Data Buoy Development Program within the U.S. Coast Guard; forerunner of NOAA's National Data Buoy Center.

1968 - World Weather Watch implemented.

1969 - Stratton Commission report "Our Nation and the Sea" recommends a new oceanic and atmospheric agency.

1969 - Geophysical Fluid Dynamics Laboratory develops its general circulation model, the first for projecting future climate change, and still a significant development for climate science and weather forecasting.

1969 - Barbados Oceanographic and Meteorological Experiment, the first project of the Global Atmospheric Research Program, is conducted. Environmental Science Services Administration ship and aircraft support this experiment to investigate the ocean-atmosphere interface. Category 5 Hurricane Camille strikes Mississippi Coast, causing widespread damage.

1969 - International Commission for the Conservation of Atlantic Tunas established, providing regulatory measures and intensive scientific research on tunas, billfish, and other tuna-like resources.

1969 - National Environmental Policy Act requires federal agencies to integrate environmental values into decision-making processes by means of Environmental Impact Statements.

1970 - Oct. 3, NOAA created within Dept. of Commerce combining Bureau of Commercial Fisheries, Weather Bureau, Coast and Geodetic Survey, Environmental Data Service, National Oceanographic Data Center, National Satellite Center, Research Libraries, and other components. Four fisheries research centers are established.

1972 – Major marine conservation laws passed, including the Marine Mammal Protection Act and the Coastal Zone Management Act. Marine Protection, Research and Sanctuaries Act establishes NOAA's National Marine Sanctuary Program.

1973 - Endangered Species Act enacted; National Marine Fisheries Service designated responsible agency for marine species.

1974 - Historic judicial ruling affirms rights of Indian tribes (Washington State) to fish in accustomed places with specific allocations of annual catches.

1974 - Great Lakes Environmental Research Laboratory established following a joint U.S.-Canada effort that focused scientific research on Lake Ontario in1973; combines the U.S. Lake Survey and the International Field Years in the Great Lakes Office.

1975 - GOES-1, NOAA's first owned and operated geostationary satellite, launched. USS *Monitor* designated as NOAA's first National Marine Sanctuary. P-3 Orion "Hurricane Hunter" aircraft acquired.

1975-93 - NOAA's National Geodetic Survey creates the North American Datums of 1983 (horizontal) and 1988 (vertical), computerizing, redefining, and readjusting the agency's surveying networks.

1976 - Magnuson Fisheries Conservation and Management Act provides for NOAA's National Marine Fisheries Service to study and protect commercially fished species and the environmental factors affecting their numbers and health; establishes eight citizen-member Regional Fishery Management Councils. Pacific Marine Environmental Laboratory deploys the first successful moored equatorial current meter; forerunner of the Tropical Atmosphere Ocean buoy array.

1977 – NOAA's Manned Undersea Science and Technology Office establishes the first regional underwater habitat, HYDROLAB.

1978 - Ocean Pollution Planning Act recognizes need to investigate effects of pollutants on marine environment; beginning of NOAA's Hazardous Materials Response and Assessment.

1980 - National Undersea Research Program (NURP) established.

1982 - National Snow and Ice Data Center (NSIDC) established in Boulder, Colo.

1983 - President Ronald Reagan declares a United States Exclusive Economic Zone (EEZ) that extends out 200 nautical miles from shore. NOAA begins multi-beam surveying of the EEZ, leading to many discoveries including economically important salt domes in the Gulf of Mexico.

1984 - Tropical Ocean-Global Atmosphere program begins in response to 1982 El Niño. Moored buoy arrays with ocean temperature sensors monitor changes in temperature of the tropical Pacific Ocean. Honolulu Laboratory, Southwest Fisheries Science Center, develops marine ecosystem model, ECOPATH, to describe the ecosystem and energy budget for a coral reef ecosystem in the Northwestern Hawaiian Islands; used by ecosystem modelers throughout the marine community.

1985 –Researchers at National Geodetic Survey expand Global Positioning System for surveying and kinematic positioning, revolutionizing surveying and the national transportation infrastructure. National Acid Precipitation Research Office established to coordinate the study of acid rain.

1986 - NOAA's Aeronomy Laboratory begins investigation of the Antarctic ozone hole at McMurdo Base, Antarctica.

1989 - North American Datum of 1983 (NAD83) approved for federal surveying and mapping activities. This is followed by approval for usage in 1993 of North American Vertical Datum of 1988 (NAVD88).

An early TIROS satellite is mounted on the nose of a rocket prior to launch. TIROS satellites were 18-sided polygons, 22 1/2 inches high with a 42-inch diameter. They weighed between 270 and 300 pounds. *Credit; NOAA Central Library Photo Collection*

1989-90 – Climate and Global Change Program Office established to conduct research on global climate change phenomena; becomes the Office of Global Programs to provide scientific research on climate variability, predictions, and assessments.

1990 – National Marine Fisheries Service's Mississippi Laboratories develop protocols and devices to reduce the take of endangered sea turtles in shrimp trawls. NOAA assumes operation of Cospas-Sarsat (Space-Based System for the Search of Vessels in Distress) program from the U.S. Air Force. National Meteorological Center installs a supercomputer to run more sophisticated numerical weather production models. Nation's first restricted rights fishery implemented with quotas on the annual catch of northeast surf clam and ocean quahog.

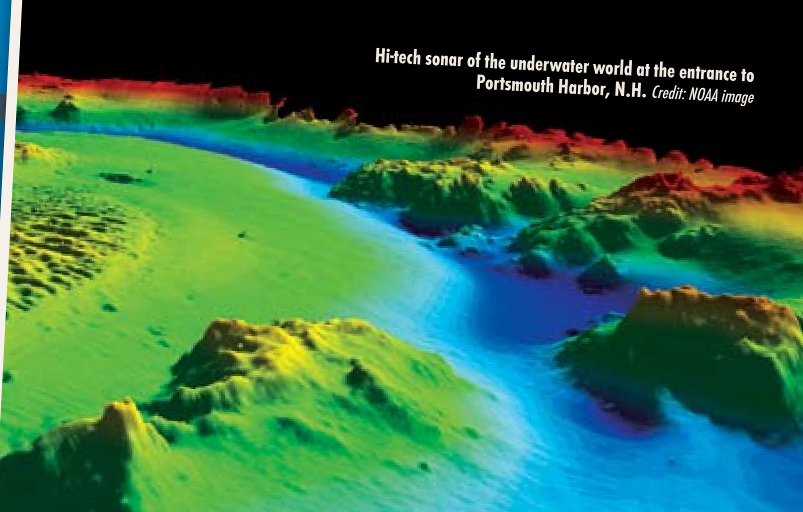
1992 - First Doppler Weather Radars installed at Weather Service Forecast Offices around the country. First Automated Surface Observing Systems established.

1994 - National Polar-Orbiting Operational Environmental Satellite System Office established to coordinate civil and military satellites.

1995 – Geophysical Fluid Dynamics Laboratory develops first hurricane prediction system based on a three-dimensional hurricane model. NOAA's Space Environment Center uses coronal imager LASCO in NASA's Solar and Heliospheric Observatory spacecraft; revolutionizes operational space weather forecasting and prediction methods. High Seas Driftnet Fishing Moratorium Protection Enforcement Act prohibits large-scale high seas driftnets that entangle protected mammals and commercial fish species.

1996 – Magnuson-Stevens Fishery Conservation and Management Act ("Sustainable Fisheries Act") provides for National Marines Fisheries Service authority and responsibility to conserve and protect fishery resources and their habitat.

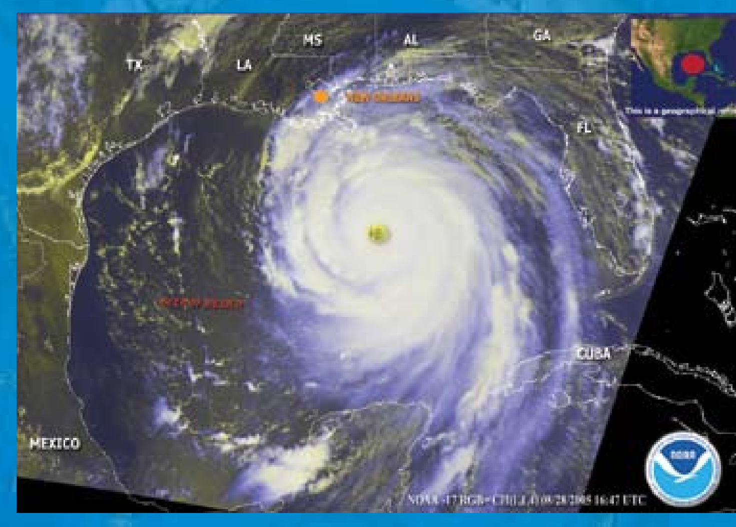
1997-98 - NOAA successfully forecasts worldwide impact of El Niño using data gathered by the Tropical Atmosphere Ocean array in the tropical Pacific.



Hi-tech sonar of the underwater world at the entrance to Portsmouth Harbor, N.H. *Credit: NOAA image*

1998 – Harmful Algal Bloom and Hypoxia Research and Control Act passed.

2000 - Presidential Executive Order establishes NOAA's Marine Protected Areas (MPA) Center. The Coral Reef Act of 2000 establishes NOAA's Coral Reef Conservation Program. Modernization of the NOAA weather services completed; doubles lead times for tornado and flash flood warnings; reduces tornado-related fatalities by 40 percent. Advanced Weather Interactive Processing System integrates disparate data, putting critical data at forecasters' fingertips.



GOES-12 satellite imagery of Hurricane Katrina on Aug. 28, 2005, over the Gulf of Mexico at its peak intensity of 175 mph. *Credit: NOAA Satellite Services Division*

2001 - NOAA's Office of Ocean Exploration created.

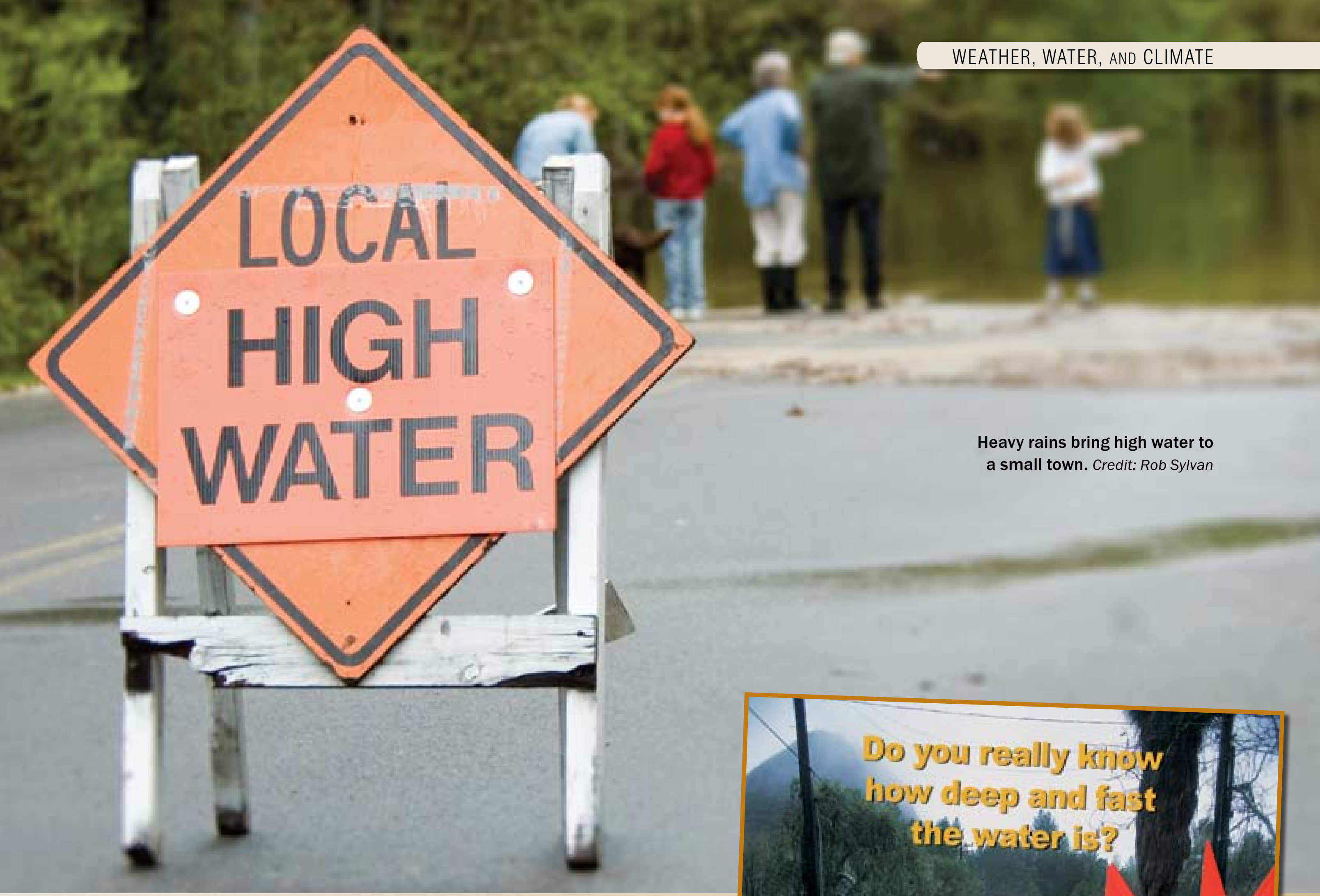
2002 - NOAA Weather Radio adapted for use in national emergencies; expanded to reach 95 percent of the American public in 2003.

2003 – NOAA hosts the Earth Observation Summit in Washington, D.C. Emergency Personal Locator Beacon System becomes operational nationwide.

2005 – Hurricane Katrina generates "One-NOAA response;" NOAA's National Hurricane Center, Navigation Response Teams, National Weather Service Remote Sensing Division, NOAA HAZMAT teams, NOAA ships, the Coastal Services Center, and Sea Grant offices are examples of many forms of assistance provided by NOAA. NOAA begins expansion of U.S. tsunami detection and warning capabilities in response to the December 2004 Indian Ocean tsunami.

2006 - Establishment of the Northwestern Hawaiian Islands Marine National Monument.

CELEBRATING 200 YEARS of Science, Service, & Stewardship



Heavy rains bring high water to a small town. *Credit: Rob Sylvan*

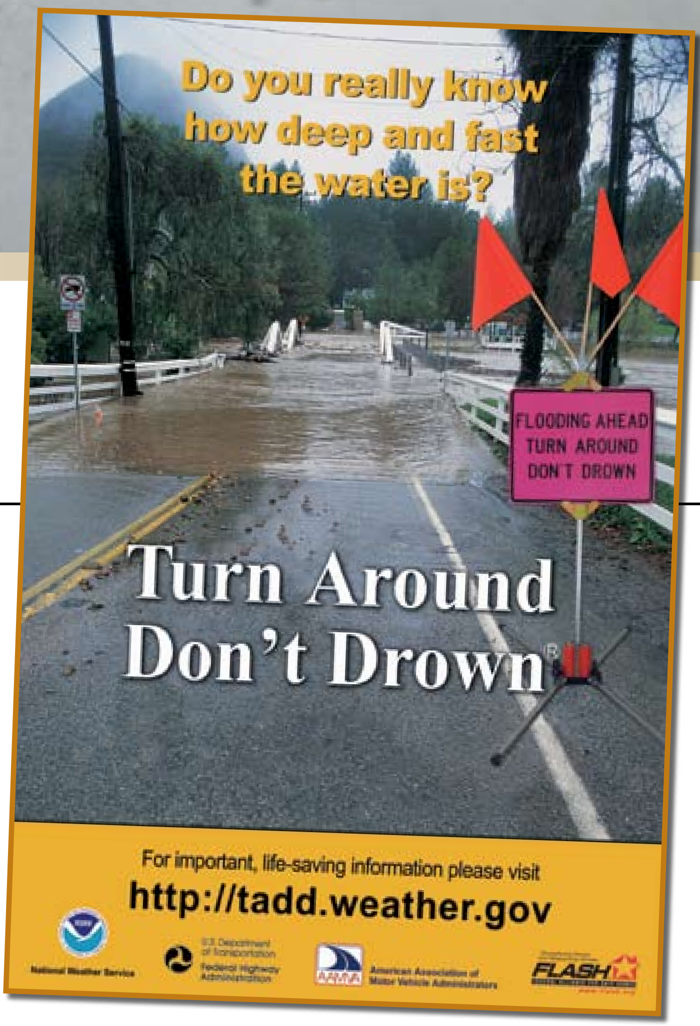
FLOODING DANGERS:
TURN AROUND, DON'T DROWN!

BY BARBARA STAHURA

Floods are one of the deadliest forces on Earth, able to roll car-sized boulders, rip large trees out of the ground, and float houses off their foundations. In an average year, 100 people in the United States are killed by floods, with more than half of them killed trying to drive across flooded roadways. The annual cost of flood damage in the United States averages nearly $5 billion. Surprisingly, more than half of all presidential natural disaster declarations are issued for floods — more than for tornadoes and hurricanes.

Fortunately, advance warnings of floods help save lives and reduce property losses. Therefore, the River and Flood Program of NOAA's National Weather Service maintains a constant vigil of rivers across the United States and prepares hydrologic (water-related) forecasts through its 13 River Forecast Centers and 122 Weather Forecast Offices. When the potential for flooding arises, they issue watches and warnings whose advance warning time and accuracy they are continually striving to improve.

NOAA's National Weather Service is constantly modernizing its forecasts to best meet customer needs. As society becomes more



A poster created by the NWS to inform people of the dangers of walking or driving through flood waters.

Children observing an interactive flood forecast model at the National Weather Service offices in Chanhassen, Minn., in August 2006. *Credit: Andrea Holz, NWS Chanhassen, Minn., photographer*

complex, community leaders need prompt and accurate information to ensure that people and property are protected. Decision-makers need answers to questions like: How long will the river rise? When will it reach its peak? Where will the flooding occur? How long will the flood last? The River and Flood Program benefits anyone making water-related decisions, including farmers, emergency managers, water supply officials, river boat pilots and river shippers, dam operators, and people who enjoy water recreation or live near water.

River floods typically occur when heavy rain falls over many hours or days, from persistent large scale moist weather fronts, tropical cyclones that threaten communities hundreds of miles inland, or from an ice and snow pack that melts quickly in the spring. Through effective advance warnings, people downstream have enough time to prepare or evacuate before river flooding occurs.

Flash floods, on the other hand, often give very little notice and catch people unaware. In a flash flood, water rises rapidly within minutes or after a few hours of a heavy rain, after a dam or levee failure, or when an ice or debris jam suddenly gives way.

NOAA's NWS promotes a campaign to inform people of the dangers of walking or driving through flood waters. It's called "Turn Around Don't Drown." People often underestimate the force and power of moving water, and will enter a flooded roadway or low water crossing expecting to simply drive through. Unfortunately, more than half of all flood deaths occur when vehicles are swept downstream. Many people don't know that a heavy SUV can be swept away in only two feet of water. Furthermore, floods can wash away roadbeds or quickly inundate underpasses while the rest of the road remains clear.

NWS Hydrologic Services – www.weather.gov/om/water

BE FLOOD SAFE

To stay safe in times of flooding, follow these safety rules:

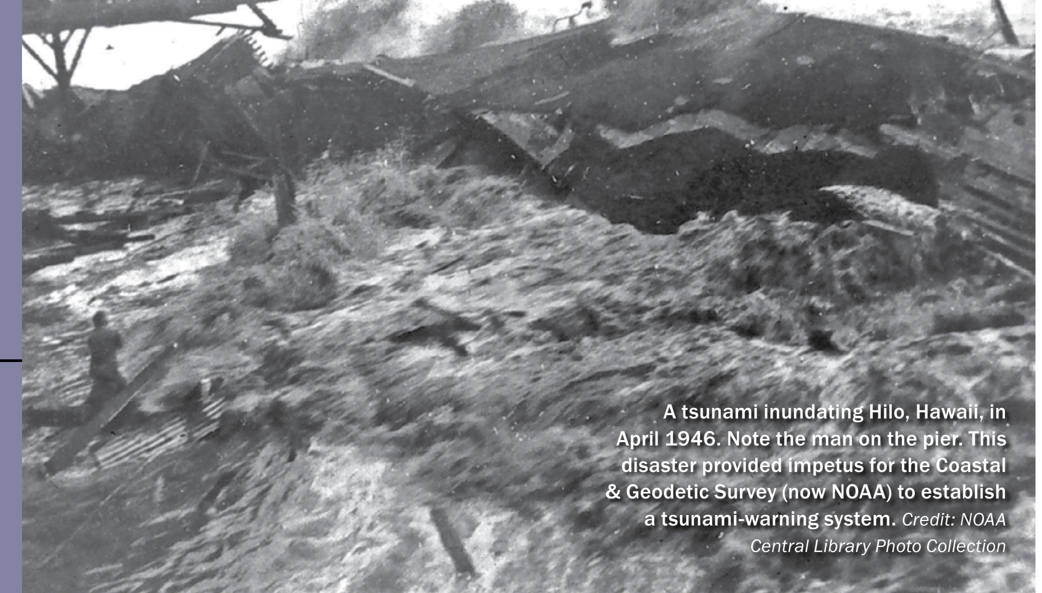
- Monitor NOAA Weather Radio All Hazards (broadcast on one of seven VHF frequencies ranging from 162.400 MHz to 162.550 MHz) or favorite news sources for weather information.
- If advised to evacuate, do so *immediately*! Move to a safe area before access is cut off by flood waters.
- If flooding occurs, go to higher ground and avoid areas subject to flooding, including low spots such as dips, canyons, washes, and underpasses.
- NEVER drive through flooded roadways. "Turn Around Don't Drown!"
- Do not camp or park your vehicle along streams and washes, especially during threatening conditions at night, when it is harder to recognize flooding dangers.

Turn Around Don't Drown!
www.weather.gov/om/water/tadd

BY BARBARA STAHURA

WALL OF WATER: TSUNAMI

A Deep-ocean Assessment and Reporting of Tsunamis (DART) buoy is deployed in the Pacific Ocean from the NOAA Ship *Ronald H. Brown* in October 1999. *Credit: NOAA Center for Tsunami Research*



A tsunami inundating Hilo, Hawaii, in April 1946. Note the man on the pier. This disaster provided impetus for the Coastal & Geodetic Survey (now NOAA) to establish a tsunami-warning system. *Credit: NOAA Central Library Photo Collection*

It is difficult to imagine a wall of water rapidly moving in from the ocean that had been so peaceful just a few moments earlier. Yet that was the terrifying reality on Dec. 26, 2004, as a powerful earthquake beneath the Indian Ocean set in motion a tsunami of immense proportions. The large waves killed more than 200,000 people and destroyed communities across South and Southeast Asia.

There have also been several deadly tsunamis in the United States. In 1946, a magnitude 8.0 earthquake in the Aleutian Islands resulted in a tsunami that killed 159 people in Hawaii. The magnitude 9.2 "Good Friday" earthquake of 1964 caused 106 deaths in Alaska, four deaths in Oregon, and 13 deaths in California. Although most tsunamis happen in the Pacific, the Atlantic Ocean and Caribbean Sea are not immune. In 1918, a magnitude 7.5 earthquake northeast of Puerto Rico killed 140 people.

Tsunami (soo-NAH-mee) is a Japanese word meaning "harbor wave." It is a series of long ocean waves created by the sudden displacement of water. Tsunamis are distinguished from ordinary ocean waves by the great length between wave peaks, often exceeding 100 miles in the deep ocean. Most tsunamis are generated by undersea earthquakes, but they can be caused by other sudden displacements of sea water, such as submarine landslides, volcanic eruptions, and in very rare instances, meteor strikes.

There are two types of tsunamis: local tsunamis and teletsunamis. A local tsunami is the result of an earthquake or water-displacement event occurring very close to shore. People in local tsunami-affected areas have only minutes to act. Teletsunamis are waves that travel from the source across the open ocean. These may take several hours to reach affected populations. There can be five minutes to one hour between the wave crests, and the series of wave crests can last for hours. The first wave may not be the largest. The second wave is often deadlier because it carries more debris.

NOAA's National Weather Service (NWS) operates two U.S. Tsunami Warning Centers (TWCs) that are staffed 24 hours a day, seven days a week. The TWCs are responsible for issuing tsunami advisories, watches, warnings, and information to emergency-management officials and the public. Warnings are broadcast through NOAA Weather Radio All Hazards, NOAA Weather Wire, the Emergency Alert System, and the Emergency Managers Weather Information Network, and can be accessed at http://www.weather.gov/view/national.php?map=on.

The West Coast & Alaska Tsunami Warning Center in Palmer, Alaska, is responsible for the U.S. Atlantic, Gulf of Mexico, Alaska, U.S. West Coast, and the British Columbia and Atlantic coasts in Canada. The Richard H. Hagemeyer Pacific Tsunami Warning Center in Ewa Beach, Hawaii, provides warnings to most countries in the Pacific Basin as well as to Hawaii and all other U.S. interests in the Western Pacific, Puerto Rico, and the U.S. Virgin Islands.

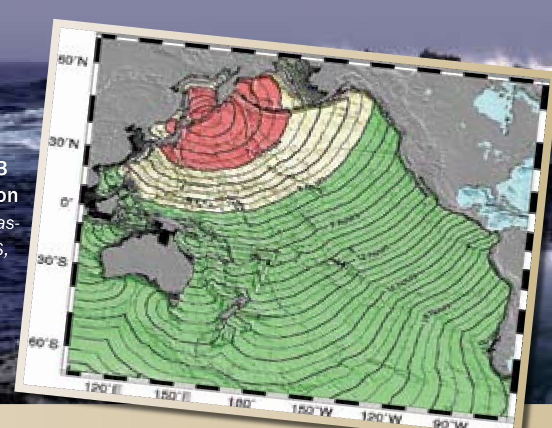
Tsunami forecasting is the key critical element of tsunami-warning operations. It is achieved by: monitoring and processing of seismic data and water-level measurements; data interpretation; model forecasting; warning creation, issuance and dissemination; data monitoring; and warning cancellation.

Once seismic information indicates an undersea or coastal quake, NOAA monitors the gauges and deep-ocean detectors to determine whether a tsunami has formed and, if so, its severity. Using sophisticated numerical modeling, NOAA produces faster and more reliable forecasts of its movement, called "transoceanic propagation," and where it will strike. The models also reveal inundation patterns for the at-risk coastal areas. NOAA's NWS issues tsunami watches and warnings — similar to hurricane and other severe weather watches and warnings — based on these models. Warnings and education save lives in the event of a tsunami.

As part of its Tsunami Warning System, NOAA's NWS established TsunamiReady, an initiative promoting tsunami preparedness in the United States that brings together federal, state, and local emergency management agencies, the public, and the NWS warning system. A voluntary program, TsunamiReady helps coastal communities gain the skills and education to prepare for and survive a tsunami.

NOAA's Tsunami Warning Centers work with other agencies, including the U.S. Geological Survey, the Federal Emergency Management Agency, and other federal, state, and local agencies through the National Tsunami Hazard Mitigation Program. NOAA's NWS office in Honolulu operates the International Tsunami Information Centre (ITIC), which was established in 1965 by the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific, and Cultural Organization, or UNESCO.

NOAA Tsunami Warning Centers – www.noaa.gov/tsunamis.html
TsunamiReady – www.tsunamiready.noaa.gov
NOAA Center for Tsunami Research — http://nctr.pmel.noaa.gov/DART/index.html
West Coast/Alaska Tsunami Warning Center — http://wcatwc.arh.noaa.gov



A travel-time map of a tsunami that resulted from a magnitude 8.3 earthquake near the Kuril Islands on Nov. 15, 2006. *Credit: West Coast/Alaska Tsunami Warning Center, NOAA/NWS, http://wcatwc.arh.noaa.gov/previous.events/11.15.2006/11-15-06.html*

An F3 tornado sets down in a field. *Credit: Clint Spencer*

DEADLY TWISTERS: NOAA ON THE ALERT

BY BARBARA STAHURA

An approaching tornado is not a welcome sight. A menacing tube of rotating air descending from clouds to earth, spiraling so violently as to cause internal wind speeds of more than 100 mph (and occasionally more than 200 mph), tornadoes are the most violent type of weather. The worst ones — fortunately rare — obliterate everything in their paths. They have been up to a mile wide and along a mile long path.

A supercell thunderstorm, which contains organized, spiraling updrafts called mesocyclones, generates a tornado. The geography of the midsection of the United States is more prone to supercell formation than anywhere else on Earth. While every continent, except Antarctica, has been visited by tornadoes, the United States has the misfortune of being struck by an average of 1,200 every year. They occur usually east of the Rockies and across the Midwest, and typically in the spring and summer. However, tornadoes do occur elsewhere, such as the Carolinas outbreak in March 1984 that caused damages of $200 million and killed 57 people. U.S. tornadoes have also occurred in autumn, as with the November 2005 tornado in Evansville and Newburgh, Ind., with 22 fatalities.

Fortunately, NOAA and its advanced weather and meteorological systems and dedicated employees make it possible to accurately forecast thunderstorms that may develop into supercells, and issue warnings. NOAA's Doppler radars across the country track the increasing rotation within a thunderstorm that could generate a tornado — early detection is crucial to issuing lifesaving warnings.

NOAA's National Weather Service Storm Prediction Center issues a tornado watch when conditions are favorable for a tornado to develop. A warning is issued by the local National Weather Service (NWS) office when a tornado has been sighted or indicated by weather radar. NOAA passes these watches and warnings to local radio and TV media and also broadcasts them over NOAA Weather Radio, NOAA's 24-hour broadcasting service. (See "In Case of Emergency: NOAA Weather Radio All Hazards" on page 58.)

"Seeing" Inside Tornadoes

When Union City, Okla., was devastated by a tornado in May 1973, NOAA successfully tracked it with Doppler radar — for the first time. The entire life cycle of this tornado was recorded, providing researchers at NOAA's National Severe Storms Laboratory (NSSL) in Norman, Okla., with significant data to begin developing an improved tornado warning system.

Doppler radar can "see" the signature of a developing tornado, an extremely valuable tool that permits forecasting with enough lead time to issue effective warnings. That glimpse inside the Union City tornado data led to the development of an improved Doppler system called the Next Generation Weather Radar, or NEXRAD, in 1988 and a network of radar stations across the United States. NOAA's NSSL and NWS have continued to improve NEXRAD. One enhancement is dual polarization, which provides more accurate information about precipitation within clouds. NSSL is also adapting shipboard radar technology to track severe weather on land. This phased array radar reduces the radar scan time from six minutes to under one minute, which extends the lead time for tornado warning beyond the current 13-minute average. A third radar improvement, the Shared Mobile Atmospheric Research and Teaching Radars — SMART-Radars — penetrates into the tornado, which unravels the mysteries of its formation. Since the high-point of U.S. tornado fatalities in the 1950s, tornado-related deaths have been decreasing, even as the number of tornadoes seemingly increased in the 1990s and early 2000s. NOAA's advanced technology, coupled with better communication and public education, can be credited with life-saving efficiency.

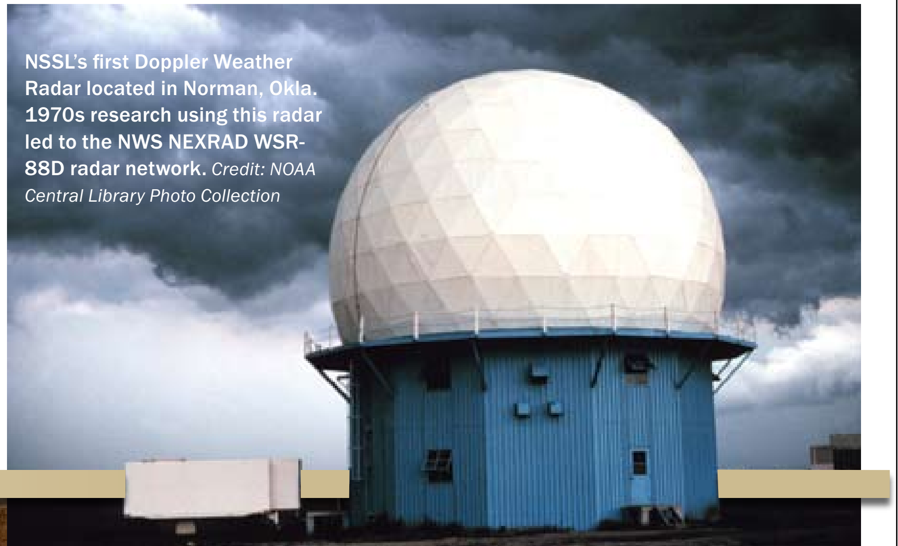
Enhanced Fujita Scale

A tornado is too short-lived and concentrated to determine its intensity while it is happening. Consequently, tornadoes are rated after the fact by observing and evaluating their destruction. Dr. T. Theodore Fujita developed his Fujita scale, or F -Scale, in 1971. By estimating the wind-speed ranges capable of causing varying amounts of damage, he determined six categories of increasing devastation. The lowest, F0, causes "light damage" with wind speeds of 73 mph or less. The highest, F5, is rated "incredible damage," from wind speeds estimated to be 216-318 mph.

The Fujita Scale has been used to label every U.S. tornado since 1950, and all this information is in a comparative database, a very valuable tool. However, precise wind speeds are difficult to verify and are open to bias.

Therefore, an Enhanced Fujita Scale, or EF-Scale, was introduced by NOAA's NWS on Feb. 1, 2007. While it will still depend upon estimated wind speeds, it will include 28 damage indicators, each with 3 to 12 degrees of damage. It also lowers the estimated winds, using a 3-second wind instead of a 1/4-mile wind. The new EF-Scale takes into account building technology that is better able to withstand stronger winds. It will provide consistency within the historical tornado database and include the ability to enter damage data and calculate the EF-Scale on a PDA or other portable device.

National Weather Service Storm Prediction Center – www.spc.noaa.gov



NSSL's first Doppler Weather Radar located in Norman, Okla. 1970s research using this radar led to the NWS NEXRAD WSR-88D radar network. *Credit: NOAA Central Library Photo Collection*

MONITORING OUR CHANGING CLIMATE

BY BARBARA STAHURA

Over the millennia of Earth's history, natural causes have often shifted the planet's climate, sometimes rather rapidly. Ice ages, wobbles in solar radiation, and massive volcanic eruptions are some of the culprits. Today, however, human influences are undeniably transforming climate in ways not easily or quickly reversed.

Earth is surrounded by a protective envelope of gases – the atmosphere – and climate results from established patterns of energy flows within that envelope, created by the movement of warm and cool air among land masses, oceans, polar ice, the biosphere, and the atmosphere. When something alters the Earth's envelope, the energy flows are disturbed, changing the climate. The human practice of burning massive amounts of oil and coal, which releases carbon dioxide and other "greenhouse gases" into the atmosphere, is now fueling such an alteration. Since these accumulating gases hold in the heat like a blanket and can remain for centuries, this human-caused, or anthropogenic, climate change, is likely to last for many generations.

As we begin to experience the results of this change, we stand at the door of a climate change not witnessed by modern civilization. Life and societies around the world could be severely disrupted by temperature and rainfall unlike any in the past several thousand years. This includes more frequent heat waves and droughts, rising sea levels that will flood low-lying coastal areas, and related events such as changes in vegetation that will affect food production, wildlife habitat, and insect populations. In order to effectively plan for, adapt to, and ultimately manage changes in water resources, energy use, agriculture, and even health care, we must have reliable information about global climate.

The Mauna Loa Observatory in Hawaii is located at the 11,200-foot level of Hawaii's Mauna Loa volcano. The facility has enabled NOAA and its predecessors to monitor and collect data relating to climate change, atmospheric composition, and air quality. The Keeling Building, pictured here at the end of the boardwalk on Oct. 1, 2004, is the original building at the observatory. *Credit: Forrest M. Mims III*

Greenhouse gases, released when oil and coal are burned, have contributed to climate change. *Credit: Photo by Daniel Bendjy*

Monitoring climate change is like monitoring the Earth's vital signs – from land, sea, and space, using tools such as satellites, ships, weather stations, buoys, balloons, and aircraft. This is a monumental task, requiring advanced technology and many dedicated scientists and technicians. Many NOAA line offices play a role, including NOAA's Satellites Information Services, NOAA Research, NOAA's National Weather Service, and NOAA's Ocean Service.

In the longest-running example of climate monitoring, NOAA and its predecessors have for five decades monitored atmospheric greenhouse gases with stations in Antarctica and at Mauna Loa Observatory in Hawaii (see sidebar on page 75). Predecessors of the NOAA Earth System Research Laboratory began expanding air sampling of carbon dioxide in the late 1960s; by 1980, enough sites were in use around the world to construct accurate global averages. Later, NOAA began sampling other greenhouse gases, including methane, nitrous oxide, and CFC-11 and 12. By creating the Annual Greenhouse Gas Index (AGGI), NOAA tracks, in a single index, the accumulation of various greenhouse gases in the atmosphere, the most important factor in long-term climate change. The AGGI is a scientific tool easily understood by policy makers, who will be the ones to legislate actions necessary in dealing with climate change.

Understanding past and current climate changes is crucial to projecting how climate will change in the future, and for this task, NOAA uses sophisticated climate models of the Earth system on supercomputers. Using differential equations derived from physics, fluid motion, and chemistry, the models simulate and project into the future the climate's behavior, its components (such as wind, heat transfer, solar radiation, humidity, and precipitation), and their interactions in three dimensions. Climate models are constantly improving, thanks to improved data sets as well as enhanced computing power.

Climate change isn't happening only in the United States. It is a global issue, perhaps humanity's most pressing challenge. Therefore, NOAA works with other countries and international groups such as the World Meteorological Organization, the World Climate Research Program, and the Intergovernmental Panel on Climate Change to name a few.

Climate Program Office – www.climate.noaa.gov

MAUNA LOA OBSERVATORY: MONITORING THE ATMOSPHERE

Sitting 11,000 feet above the Pacific Ocean on the Big Island of Hawaii, the Mauna Loa Observatory (MLO) is located in a prime spot for sampling the Earth's background air. This atmospheric baseline station on the north side of the Mauna Loa volcano is high enough to be in the free troposphere, above the region's strong marine temperature inversion layer that acts like a lid on the more polluted portions of the atmosphere below.

Over its half-century of operation, MLO has been continuously monitoring and collecting data relating to climate change, atmospheric composition, and air quality. It is best known for the measurement of rising carbon dioxide concentrations produced by human activity, called the "Keeling Curve" or "Mauna Loa Curve." MLO also measures ozone and the chemicals (CFCs and HCFCs) that destroy it, solar radiation, and tropospheric and stratospheric aerosols. NOAA uses the observatory's data to calibrate and verify data from satellites.

MLO operates under NOAA's Earth System Research Laboratory, Global Monitoring Division. It is a model for other atmospheric baseline stations located around the world. MLO supports cooperative research and monitoring projects with universities and government agencies in many countries. MLO's 50th anniversary will be celebrated in Hilo, Hawaii, in November 2007.

Mauna Loa Observatory – www.mlo.noaa.gov.

NOAA FORECASTS AIR QUALITY

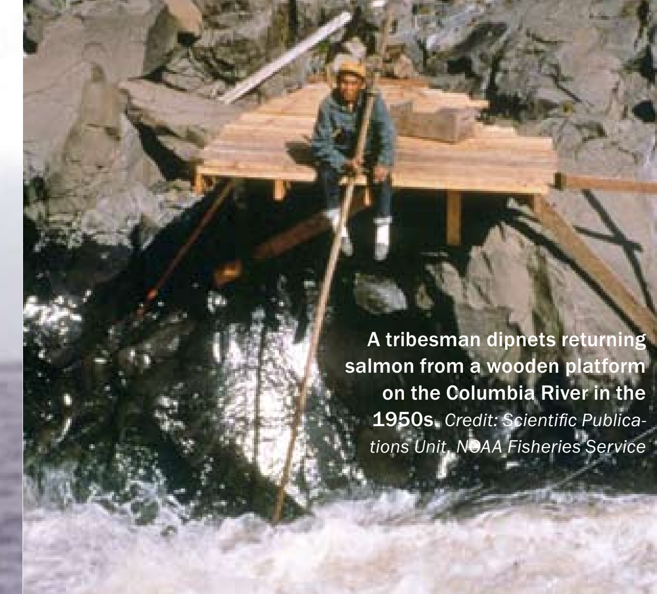
NOAA began predicting air quality operationally in 2004. As directed by Congress, the National Weather Service built this forecast capability in partnership with the Environmental Protection Agency. Today it provides the eastern United States with hour-by-hour predictions of ozone (a principal ingredient of smog) in the air we breathe, in a grid of 12-kilometer squares showing the location of elevated ozone concentrations. Such information on the location, onset, severity, and duration of high ozone concentrations is vital for people in cities, suburbs, and rural areas alike, so they can act to protect themselves from the harmful effects of poor air quality. For example, they can limit their exposure and especially outdoor exercise. Air quality (AQ) forecasts affect the bigger economic picture as well: The United States could save $1 billion every year for every 1 percent drop in health problems caused by poor air quality.

Ground-level ozone concentrations can change by the hour, depending on many factors including time of day, pollution levels, and amount of sunlight, wind, and rain. NOAA's highly-detailed AQ forecasts can accurately predict when and where these changes will take place over the next day. NOAA's new AQ predictions are greatly improving the science basis for local AQ forecasters, who were previously limited to using simple statistical tools for projecting ahead from current ozone readings; such approaches are especially problematic when conditions change suddenly or deviate significantly from historical patterns. As a result, NOAA's air quality forecast guidance is becoming a principal tool for local AQ forecasters in participating cities – currently about 300 – who issue categorical alerts, typically based on the expected next-day worst case over their entire communities.

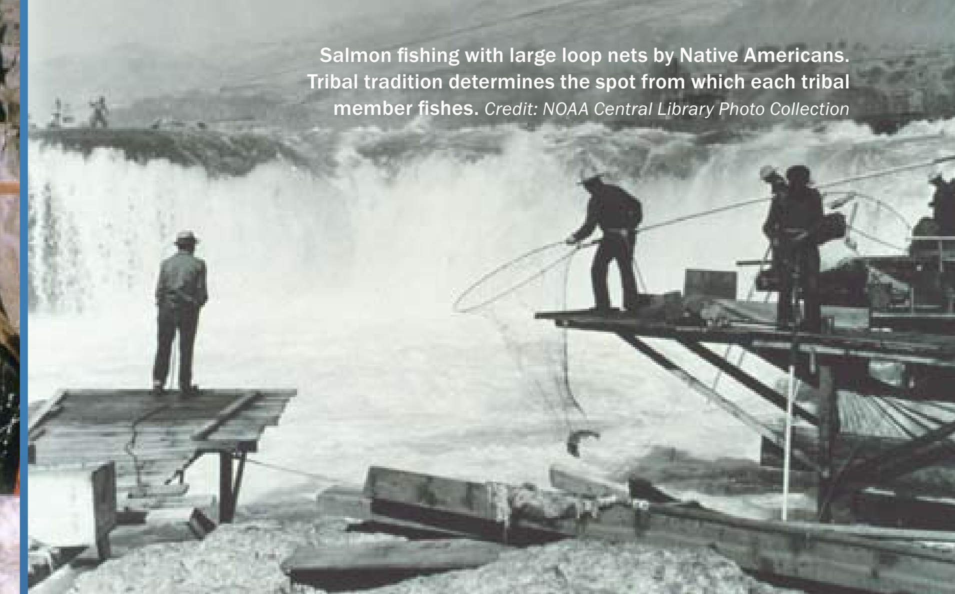
NOAA is expanding its air quality forecast capability. It currently provides predictions of ground-level ozone, responsible for respiratory problems and nationally up to 10,000 premature deaths each year. The initial capability, deployed in 2004 over the northeastern United States, was expanded in 2005 to cover the eastern half of the country. By 2006, the lower 48 states were covered on an experimental basis; Alaska and Hawaii will be added next. In the next few years, predictions will add airborne particulate matter — responsible for as many as 40,000 additional premature deaths each year — and will then be extended further ahead, to day 2 or beyond.

Air Quality Forecasts – www.weather.gov/ost/air_quality

Modern Alaska Tupik fishermen set out for a day of salmon netting in Bristol Bay, Alaska. *Credit: NOAA Central Library Photo Collection, Karen Ducey, photographer*



A tribesman dipnets returning salmon from a wooden platform on the Columbia River in the 1950s. *Credit: Scientific Publications Unit, NOAA Fisheries Service*



Salmon fishing with large loop nets by Native Americans. Tribal tradition determines the spot from which each tribal member fishes. *Credit: NOAA Central Library Photo Collection*

NATIVE FISHERS

PRESERVING RIGHTS AND TRADITIONS

BY DAVID A. BROWN

Forty-four million – that's how many recreational anglers bend a rod each year in this country. No doubt, American Sport Fishing Association statistics paint this pastime as a rewarding outdoor pursuit.

But in some cases, the practice of harvesting fish from local waters reaches much deeper than just a fun, wholesome family activity. For certain well-defined groups, fishing stands as a pillar of their society – a time-honored tradition appearing in art, rituals, and folklore.

"As an individual recreational angler, fishing can be very important, even on a spiritual level, but most people probably don't consider it an important expression of the state in which they reside," said Gary Sims, Tribal Liaison for NOAA Fisheries' Northwest Region, "whereas a lot of tribal fishers are very aware that their ability to fish is the expression of their right as a people that they reserved when negotiating with the U.S. government."

In the Pacific Northwest, tribes of the Columbia River Basin and Puget Sound/Washington Coast exemplify the rich heritage of native fishing. Carrying on the salmon-centered lifestyle of their ancestors, many of these groups are often referred to as "treaty tribes," in recognition of their agreements with the United States government.

In 1855, these tribes ceded most of their land and agreed to settle on reservations in exchange for monetary payments and governmental assistance such as health care, education, protection, and legal assistance. Treaties recognized tribes as sovereign entities with the rights of self-government and religious freedom.

Columbia River Indians made their agreements in the Treaty with the Walla Walla, Cayuse, and Umatilla Tribes; the Treaty with the Yakama; the Treaty with the Nez Perce; and the Middle Tribes of Oregon Treaty. Tribes in the Puget Sound area agreed to the treaties of Medicine Creek, Neah Bay, Olympia, Point Elliott, and Point No Point.

Integral to each of these treaties were the tribal rights to hunt and fish not only on their reservations, but also on the land that they ceded to the U.S. government. (Treaty text states the right to take fish "at usual and accustomed grounds and stations.") Believing that the fishery resources were not theirs to sell in the first place, the Indians reserved these rights, as spelled out in the treaties that were ratified by Congress.

Now, Native American fishing ranges from Alaskan tribes to the Penobscot and Passamaquoddy tribes of eastern Maine; and to Western Pacific indigenous groups of Guam, American Samoa, the Mariana Islands, and the Hawaiian Islands. But, while treaties do not apply to all indigenous groups of the United States and its territories, the tribes of the Pacific Northwest provide a vibrant example of NOAA's ongoing efforts to balance resource management with the customs of native fishers, whose very identity exists in union with the fish swimming throughout the coastal and riverine waterways of their ancestral lands.

"You need to think of it as a spiritual, cultural, and sovereign experience," Sims said of the region's native fishers. "Most of the tribes in the Columbia River Basin and Puget Sound/Washington Coast area will call themselves a 'Salmon People' because the fish have a long, deep, and abiding history among these people.

"So there's a spiritual connection, not only with the salmon but also with the Creator who gave them the salmon as a gift and made them responsible for protecting it. As individuals and as individuals coming together as a group, salmon helped define them as a people and how they related to the world."

Since the treaties of the 1850s, many questions regarding interpretations of and challenges to these agreements have arisen. Some have led to court cases with great significance for the Indians of the Pacific Northwest.

The first major fishing rights case to reach the Supreme Court, *U.S. v. Winans* (1905), did much to uphold the honor and trust of the treaty agreements. Justices ruled that treaty Indians had reserved the right to cross non-Indian lands to fish at the "usual and accustomed" places, and that treaties are to be interpreted the way Indians had understood them.

Two of the most historic decisions came through *U.S. v. Oregon* (1969) and *U.S. v. Washington* (1974). In the former, U.S. District court Judge Robert Belloni held that tribes were entitled to a "fair share"

Center of page: The Gorbuscha or hump-backed salmon. *Oncorhyncus gorbuscha.* *Credit: NOAA Central Library Photo Collection*
Above: An early-20th century Northwest tribal elder cures salmon fillets on a smoking frame. *Credit: Courtesy of Pacific Fishing Magazine*

A Native Alaskan radios to shore with good news about his salmon catch.
Credit: NOAA Central Library Photo Collection

of the fish runs and that the state can only regulate treaty Indian fisheries when "reasonable and necessary for conservation." The ruling clarified that state conservation regulations were not to discriminate against the Indians and must use the least restrictive means.

Known as the "Boldt decision" in reference to the presiding judge, the *U.S. v. Washington* ruling mandated that a "fair share" was 50 percent of the harvestable fish destined for the tribe's usual and accustomed fishing places. The decision also reaffirmed tribal management powers. The Boldt decision's 50/50 principle was applied to Oregon's Columbia River fisheries.

Other relevant cases included:

- *Tulee v. Washington*, 1942: The Supreme Court ruled that because a treaty takes precedence over state law, Indians with tribal treaty rights cannot be required to buy state fishing licenses.

- *Settler v. Lameer,* 1974: The Ninth Circuit Court of Appeals ruled that the treaty fishing right is a tribal right, not an individual right. Therefore, the tribes had reserved the authority to regulate tribal fishing on and off the reservations.

- *U.S. v. Washington* (Boldt decision), 1979: Upheld by U.S. Supreme Court.

In actions related to the Boldt decision, Columbia River, Puget Sound, and Washington coastal tribes sued the Secretary of Commerce in 1979 because many treaty fish were being caught in ocean waters managed by the Department of Commerce. (Columbia River tribes also sued in 1980, 1981, and 1982.) Ultimately, the court ruled that the federal government was legally obligated to regulate ocean fisheries to ensure that a reasonable number of salmon reached tribal fishing places on the Columbia River.

Tribes of the Pacific Northwest have also faced challenges related to progress and development. Dams on the Columbia and Snake Rivers have drastically altered tribal access to salmon that historically had migrated considerable distances upriver. Notwithstanding legitimate concerns, not every issue requires litigation, and NOAA Fisheries has a strong history of interacting with tribes, the Bureau of Indian Affairs, and tribal representation groups.

In Oregon, the Columbia River Inter-Tribal Fish Commission (CRITFC) is the technical support and coordinating agency for the fishery management of the Columbia River treaty tribes. In Western Washington, the treaty tribes are supported by the Northwest Indian Fisheries Commission (NWIFC). Such groups staff their own biologist, researchers, and political representatives – all of whom help tribes best represent their positions during discussions with the U.S. government.

Bob Ziobro, Chief of Management and Administration in NOAA's Office of Management and Budget, formerly served as Native American Liaison for NOAA Fisheries. He mentions a key point of perspective: "It is always important to remember that we have a government-to-government relationship with the tribes.

"Our goals are the same. The tribes want species recovery so that they can exercise their treaty rights. And we want species to recover because we're mandated under the Endangered Species Act and also by common sense to keep these species from becoming extinct."

Tupik fishermen from Togiak Bay, Alaska, remove the day's salmon catch.
Credit: NOAA Central Library Photo Collection

Ziobro said that because of their cultural bond with natural resources, tribes are typically conservation-minded and often institute their own management initiatives. For example, the CRITFC salmon restoration plan ("Spirit of the Salmon") outlines objectives and actions for halting the decline of salmon, lamprey, and sturgeon populations above the Bonneville Dam and rebuilding stock levels to sustainable levels.

Elsewhere, in summer 2006, the Hoh Indian Tribe (NWIFC), launched an innovative program to mark young wild coho salmon (with colored elastomer injections into fins) for the purpose of determining where thousands of these fish go to survive the winter in the Hoh River watershed. Comparing data from recaptured coho will show tribal biologists how fish change their habitat when water levels are lower or higher. Such knowledge will help prioritize the tribe's habitat-restoration initiatives.

As Sims said, NOAA's support of native fishers also means showing due respect for tribal opinions, considering their independent research findings, and factoring all of these elements into management decisions.

"There's a special relationship between the U.S. government and treaty tribes," Sims said. "We have a responsibility to be conferring with tribal governments when we're engaged in activities that may impact tribal resources."

Ziobro stresses that maintaining good rapport proves intrinsic to effecting positive outcomes. "Communication is necessary, along with being forthright. We may not always like what we are hearing, but we have to be able to listen as well as say what is important to us.

"We want the resources to remain sustainable, and from our perspective it's important to understand [the tribes'] cultures and beliefs. It's a highly cooperative adventure, and it has to be, because we can't accomplish anything without one another's help."

Alaska Native Fisheries
North Pacific Fishery Management Council — www.fakr.noaa.gov/npfmc/current_issues/CDQ/CDQ.htm

Indigenous Fishing Rights/Community Development
Western Pacific Fishery Management Council — www.wpcouncil.org/indigenous.htm

Tribal Fishing History and Practices
Northwest Indian Fisheries Commission — www.nwifc.wa.gov/

Pacific Northwest Tribal Harvests and Management
NOAA Fisheries Northwest Regional Office — www.nwr.noaa.gov/Salmon-Harvest-Hatcheries/State-Tribal-Management/Index.cfm

Nineteenth-century Makah tribesmen hunt whales in the Pacific Northwest.
Credit: NOAA Central Library Photo Collection

ABORIGINAL WHALING AND CONSERVATION

It's a delicate issue with justifiably emotional elements. But balancing prudent preservation practices with ancient traditions yields an atmosphere that tries for respectful tolerance for aboriginal whaling.

The International Whaling Commission (IWC), established under the 1946 International Convention for the Regulation of Whaling, governs aboriginal and commercial activities. In 1982, the IWC approved a moratorium on all commercial whaling, starting in 1986. However, the Commission regards aboriginal subsistence whaling differently than commercial operations, whose excess plunged several whale species into dire straits.

The IWC's criteria for allowing aboriginal whaling include: ensuring risks of extinction are not seriously increased (highest priority); enabling harvests in perpetuity appropriate to cultural and nutritional requirements; and maintaining stocks at the highest net recruitment level, with corrective actions taken if that level declines.

American aboriginal whaling is practiced by the Alaskan Eskimos (Inuits) and by the Makah tribe of northwestern Washington State. The targeted species are bowhead whales for the former and gray whales for the latter.

Working in concert with the IWC, these groups have spent considerable time and resources to develop humane whale-hunting techniques that preserve as much of their ancestral heritage as possible. The Makah use high-powered rifles to quickly dispatch their quarry, while Alaskan

Modern native Alaskan villagers in Pt. Barrow celebrate their heritage after a successful whale hunt. *Credit: NOAA Central Library Photo Collection*

hunters use a harpoon with a penthrite grenade (exploding tip) for piercing the thick blubber of large bowhead whales.

Kevin Chu, presently in NOAA's Northeast Regional Office, served on the U.S. delegation to the IWC during the 1990s. He said that NOAA has long supported aboriginal whaling in a manner consistent with IWC criteria.

"Our effort to maintain aboriginal whaling is predicated on the requirement that whaling not harm the stocks," Chu said. "If it were driving the stocks to extinction, then there would be no sense in encouraging subsistence whaling, because you would lose the resource, and hence the tradition, anyway."

Steeped in cultural history, whaling links indigenous tribes to their past, while a reverent respect for the resource helps ensure its survival. "It's very important to the community spirit, and we at NOAA have fought hard to keep that going – always with the assumption that the hunts would not harm the whale populations."

Regarding the IWC's acceptance of aboriginal whaling, Chu notes that "subsistence" is not just food. "(Most aboriginals) could get food from a grocery store. But hamburgers don't have the same historical significance as whale meat. So the cultural aspect is very important. It's keeping body and soul fed."

Chu points out that the tradition of blessing whale meat and giving it to another individual carries deep significance in both the Inuit and Makah societies. "It's very powerful – someone making a gift of whale meat really means something special in the whaling villages."

Makah Whaling — www.makah.com/whaling.htm
International Whaling Commission — www.iwcoffice.org/index.htm
NOAA Fisheries Alaska Regional Office/Alaska Eskimo Whaling Commission — www.fakr.noaa.gov/omi/grants/aewc.htm

BRAVING THE SEAS

LIFE ON A NOAA FISHERIES RESEARCH VESSEL

BY DAVID A. BROWN

Sometime between midnight and dawn, Laurie Weitkamp hears a "thump" outside her bedroom. She turns her back to the sound, but it doesn't go away.

The night is dark and the air chilly. Footsteps and muffled voices resonate nearby. What does she do?

She rolls over and goes back to sleep.

After all, she can't very well ask the engineers to halt their after-hours engine room maintenance. And as far as the crab pot thumping against the hull, well things like that get caught on transducers now and then.

Such is life on a NOAA research vessel. Driven to the seas by the quest for data that fuels effective fisheries management, Weitkamp knows well the ups and downs of living on the waves.

A biologist with the Northwest Fisheries Science Center, Weitkamp spent five years on NOAA research vessels, including the 93-foot, wooden-hulled *John N. Cobb* (NOAA's oldest active research ship, built in 1950) and the 175-foot *McArthur* (decommissioned on May 20, 2003). Most recently, she has been conducting research cruises on chartered commercial vessels in the 120-foot range.

Focusing on the estuarine and marine ecology of Pacific salmon, her trips have taken her up to 30 miles off the coasts of Washington, Oregon, and southeast Alaska into depths of 3,000 feet.

Most trips run 10 days, with the first and last used mainly for transit and the rest occupied with a steady routine of taking water-quality measurements, collecting zooplankton, and trawling for juvenile salmon over predetermined sampling stations.

Research crews on this survey work only the 12 daylight hours, so seasons influence productivity. But a typical cruise can cover approximately 55 stations. "We can sample about six stations a day, and you work the meals in around that," Weitkamp said.

Laurie Weitkamp has grown accustomed to life on the water, thanks to five years spent on NOAA research vessels. *Credit: Photo courtesy of Laurie Weitkamp*

As Weitkamp attests, you have to really love your work to spend a week and a half away from home in a relatively small environment with very little personal space. As with most jobs, there's plenty of rote repetition on a research ship – but crews balance the doldrums with anticipation of what the next trawl might deliver.

"It's not a Jacques Cousteau special on every trip," Weitkamp said. "We're doing the exact same thing every day. We're doing it in different locations, but after awhile, you can do it in your sleep.

"But it's always exciting because you never know what you're going to catch. You may catch tons of jellyfish or a 15-foot thresher shark – it's quite a challenge getting one of those off the deck."

Many NOAA cruises operate 24 hours per day, depending on their objectives. For Weitkamp, days are best because her targeted juvenile salmon is one of the few species swimming high in the water column when the sun's up.

Nighttime work sees the upper water layers abounding with hake, mackerels, and other species that stay low during the day. Interesting catches, but the time-consuming exercise of sorting through excessive bycatch would impede Weitkamp's salmon priority.

But that doesn't mean the show stops when the sun goes down. One late September evening, a very dark night found Weitkamp and others aboard playing Scrabble in the galley area when a crewman came running below to report that large schools of fish were amassing where the glow of deck lights hit the water.

Just as everyone gathered near the railing, several Humboldt squid appeared with clear predatorial intent. Dashing through the schools of forage, the tentacled terrors provided an unforgettable glimpse of the sea's daily dramas.

"We watched these 5-foot squid hunting the fish in the lights – it was an incredible sight," Weitkamp recalled. "Sometimes we saw 30 to 40 squid at one time. The next day, we caught two in the net. So seeing them in hand, changing color from blue to red to black in a matter of seconds, was just amazing."

Between such moments of excitement, Weitkamp said she and her research teammates pass their downtime by watching movies and playing board games. Cribbage seems to be a favorite among seafaring types.

Fisheries surveys aboard NOAA ships operating in the North Pacific often face daunting environmental conditions. *Credit: NOAA Central Library Photo Collection*

Scientists spend hundreds of hours sorting the catches brought up in NOAA ship survey trawls. *Credit: NOAA Central Library Photo Collection*

Meals are filling and frequent, but research vessels are always "dry" to ensure optimal working conditions.

Most cabins are below decks, so crews don't see much daylight when foul weather keeps everyone inside. Room arrangements are usually two to a cabin with a pair of community head and shower facilities.

Weitkamp's research cruises include four to six scientists – often the same faces each time. Vessel confines foster camaraderie. "There's a limited number of places to hang out, and you get to know people really well," she said.

Weitkamp's Alaskan research cruises target mostly protected waters, but the open ocean off the Washington and Oregon coasts can turn nasty in a hurry. She can generally expect at least a couple of bouncy days on each trip.

Rough seas can make deck work challenging and turn temperaments sour. But with sample goals at stake and the clock ticking on the vessel's charter, researchers often have to zip up the foul-weather gear and tough it out. Most trips include a weather day provision, generally exercised when winds exceed 25 knots.

Left: Assessing fisheries resources requires assessing the environment at each station of a survey, as with this water sampler. *Credit: NOAA Central Library Photo Collection* **Above: The crew hauls up a trawl net full of pollock during a NOAA groundfish survey.** *Credit: NOAA Marine and Aviation Operations*

Safety is always paramount, but so is the mission's performance. "We're more concerned about the quality of samples we collect," Weitkamp said. "So we're trying to make sure we are sampling consistently."

The appeal of the unknown and the satisfaction of contributing to fisheries management are common motivators for those who ply the seas aboard NOAA research vessels. Weitkamp finds a good blend of challenges and rewards.

"Some days when I'm out there, I can't believe I get paid for doing this, but then there are days they don't pay me enough," she joked. "There are some really cool days when we see whales and other incredible sights. But for every one of those, there are 10 hours when absolutely nothing is going on."

Nevertheless, Weitkamp notes that the scenery beats the confines of a terrestrial office. "You get to go see some spectacular areas like southeastern Alaska, where we pull into bays with these giant glaciers. Things you'll probably never see anywhere else."

Looking Back

NOAA fisheries research traces its roots to the Bureau of Fisheries steamer *Albatross* – the first vessel built specifically for such tasks by any government. A 234-foot, iron, twin-screw vessel propelled by two independent two-cylinder steam engines, this ship conducted its first scientific cruise in the summer of 1883.

Designed especially for dredging and gathering specimens from all depths, the first *Albatross* achieved world renown for amassing one of the greatest collections of marine organisms ever gathered by a single vessel. The work of the ship's crew provided data for volumes of scientific publications and no doubt inspired countless others who followed in their footsteps.

In addition to its extensive gatherings, the first *Albatross* made deep soundings, sampled subsurface water, recorded sea temperatures, and measured salinities. With the aid of Edison electric lamps lowered on a 940-foot cable, the crew was able to observe marine organisms at night.

During nearly four decades of service, the first *Albatross*'s illustrious career carried it from the Northwest Atlantic to the Caribbean, the Bering Sea to the Galapagos Islands, and throughout western Pacific islands. Complementing its scientific duties, the *Albatross I* was detailed to the Navy during the Spanish-American War and World War I.

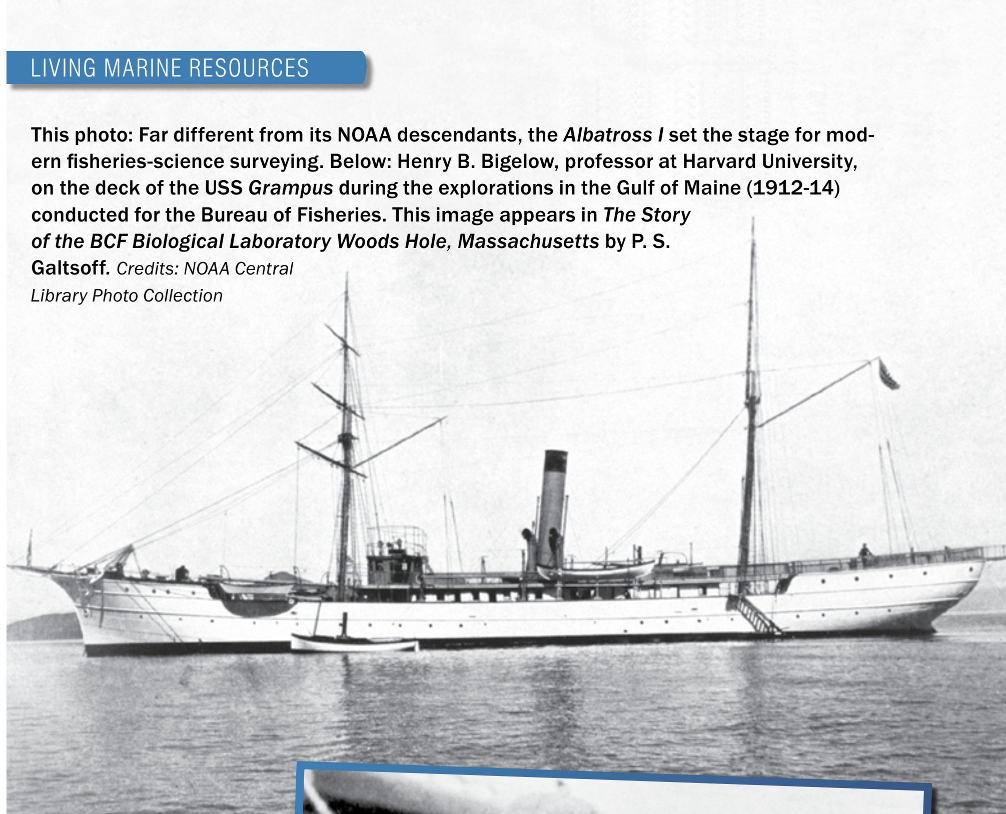
Linda Despres of the Northeast Fisheries Science Center in Woods Hole, Mass., has been working on research vessels since 1973. Noting how the *Albatross*'s tools and technology would seem primitive by contemporary standards, she views the work of its scientists with reverent admiration.

"I'm in awe at what they did accomplish," Despres said. "Considering the primitive conditions they had, like the lack of computers, these people were pioneers. They had to develop the technology to take samples and design the equipment they needed.

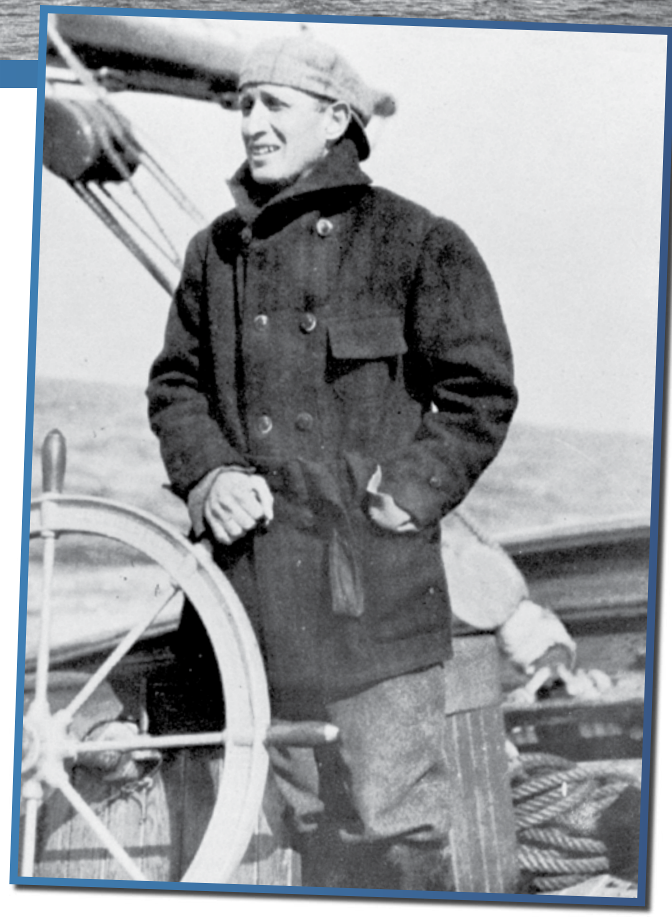
"And then they were able to produce incredibly detailed information – again without computers or other technology to help with the analyses. This gives us a baseline to compare what we are currently doing. Those findings tell us what things were like at their time – how many fish there were, what sizes there were, what the distributions were."

Weitkamp notes that while those early researchers performed their duties in the same, often harsh, conditions as

"It's always exciting because you never know what you're going to catch," says Weitkamp of her work on NOAA ships. *Credit: Photo courtesy of Laurie Weitkamp*



This photo: Far different from its NOAA descendants, the *Albatross I* set the stage for modern fisheries-science surveying. Below: Henry B. Bigelow, professor at Harvard University, on the deck of the USS *Grampus* during the explorations in the Gulf of Maine (1912-14) conducted for the Bureau of Fisheries. This image appears in *The Story of the BCF Biological Laboratory Woods Hole, Massachusetts* by P. S. Galtsoff. *Credits: NOAA Central Library Photo Collection*



today's scientists, the challenge of functioning with limited tools and facilities puts an exclamation point on their monumental work.

"It's amazing that they accomplished what they did and gained as much insight as they did without any of the modern electronics and equipment that we have," she said. "Even simple things like raingear that keeps you dry – they were really hardy people."

The spirit of that pioneering vessel continues today, as NOAA's research mission has spawned a fleet of high-tech vessels tasked with a broad array of exploratory and data-gathering duties. Among them, the 187-foot *Albatross IV* has carried on the heritage of the first *Albatross* through assessment work such as groundfish surveys and ecosystem-monitoring surveys.

Serving the Northeast Fisheries Science Center's Woods Hole Laboratory in Woods Hole, Mass., the ship's operating area includes the Gulf of Maine, Georges Bank, and the continental shelf and slope from Southern New England to Cape Hatteras, N.C. Data generated by the *Albatross IV*'s work

USING SUBMERSIBLES FOR FISHERIES RESEARCH

There's nothing like getting up close and personal to see someone's true complexion. The same is true for ocean exploration, and when NOAA researchers want a tight look at life beneath the surface, they send in the submersible.

Comprising various forms tasked for specific objectives, submersibles are like souped-up, teched-out underwater go-karts. Packing multiple lights and equipped with tools for hydrographic measurements and sample collection, these vessels also provide viewing ports for scientific observation.

Defying temperature extremes and the crushing pressure of deepwater environments, submersibles enable their small crews to explore otherwise unattainable depths. Peering into the midnight abyss, scientists have discovered and recorded new marine communities living well beyond the reach of daylight.

Exemplifying this capability, Delta Oceanographics' manned submersible, *Delta*, has been highly effective in characterizing rockfish habitat and documenting species distribution and abundance in the Cordell Bank Sanctuary ecosystem off the coast of central California. Launched from the contract research vessel *Velero IV*, the *Delta*'s exploration of this richly diverse marine habitat has influenced its management.

Some of the most famous submersible work was completed in 1975 by the crew of the Helgoland undersea habitat. Working in the Gulf of Maine, scientists from West Germany, Poland, Canada, the United States, and the Soviet Union completed enlightening studies on the spawning behavior of sea herring. Additionally, the mission's highs and lows provided invaluable insight into the strengths and vulnerabilities of undersea habitats.

Submersibles have evolved greatly since the Helgoland, but despite significant developments in safety and functionality, some jobs are better left to remotely operated vehicles (ROVs). Ranging in size from that of a bread box to a small truck, these deep-sea robots connect to a surface vessel with cables that allow an operator to remotely control direction and propulsion, as well as cameras and other task-specific equipment.

Manned submersibles have the advantage of human eyes and firsthand observation, along with greater freedom of motion with no tethering to a surface vessel. But when trouble befalls occupied vessels, ROVs can often render assistance such as removing entanglements or latching onto a submersible so the operator can raise both units to the surface.

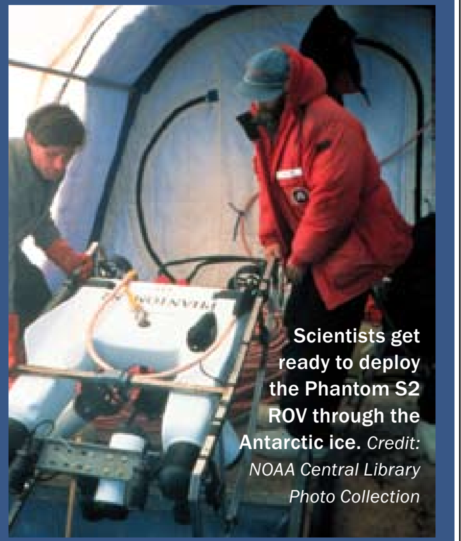
ROVs play back-up and lead roles equally well. When rough weather or maintenance issues keep a submersible from its scheduled mission, an ROV can often substitute. Conversely, deploying an ROV to scout new dive sites reduces the risk to machine and man.

Operated by the NOAA Undersea Research Center (NURC), the S2 Phantom ROV works independently and supports wet-diving and submersible operations. Carrying video and still cameras, sector scanning sonar, and a three-function manipulator arm with multiple sampling attachments, the S2 Phantom measures conductivity, temperature, depth, light transmission, and oxygen with real-time surface readout.

This ROV has proven intrinsic to ground-truthing multi-beam sonar surveys to create habitat maps in the Florida Keys, Flower Garden Banks, and Gray's Reef Sanctuaries, and the Madison/Swanson, Dry Tortugas, Florida Middle Grounds, Oculina Bank, and proposed South Atlantic shelf-edge Marine Protected Areas. The S2 Phantom has also served in fish behavior studies, search and recovery, mapping hypoxic water masses, environmental monitoring, and education/outreach.

Like the Helgoland experience, each time a submersible or ROV enters the ocean, it brings back more than biological samples and water measurement. These ever-evolving deep-sea wonders reveal new ways of prospecting the environmental treasures held in the great abyss.

NOAA Ocean Explorer Program, Submersibles — http://oceanexplorer.noaa.gov/technology/subs/subs.html



Scientists get ready to deploy the Phantom S2 ROV through the Antarctic ice. *Credit: NOAA Central Library Photo Collection* help explain the physical and biological processes affecting year-class strength of key economical fish, shellfish, and zooplankton species.

A New Breed

Making a big splash in marine research, the *Henry B. Bigelow* – the second in a quartet of technology-rich vessels – represents NOAA's efforts to modernize its fleet of fisheries, oceanographic, and hydrographic survey ships.

Notably, the ship's namesake, Henry Bryant Bigelow, directed the final scientific voyage of the first *Albatross*. A Harvard-educated zoologist, Bigelow helped establish the scholarly foundation for oceanography as a scientific discipline.

At 208.6 feet, the *Henry B. Bigelow* epitomizes 21st century research with cutting-edge equipment designed to measure water temperature, conductivity, and fluorescence; deploy and recover floating and bottom-moored sensors; and trawl at depths to 6,000 feet. Working primarily in U.S. waters from Maine to North Carolina, the *Henry B. Bigelow* can carry a crew of 39, including 19 scientists, with a 40-day endurance.

Fit for the task, the *Henry B. Bigelow* includes a 1,560-square-foot aft working deck, a 602-square-foot fish/wet laboratory along with four other labs (chemistry, dry, hydrographic, and acoustic/computer), a scientific freezer, and a preservation alcove. An Acoustic Doppler Current Profiler measures water currents, while a multibeam sonar system examines the content of the water column, as well as the type and topography of the seafloor while the ship is underway.

Most significant is the vessel's stealth. Built to be acoustically quiet, the ship has a very low radiated noise signature. Studies have shown that underwater radiated noise affects fish behavior, and sonar self-noise can impair functions such as hydroacoustic surveys.

Setting the bar for marine research worldwide, the International Council for Exploration of the Seas (ICES) has established a standard for ships' underwater radiated noise in order to effectively employ hydroacoustic stock-assessment techniques. The *Bigelow* was built to keep its radiated noise below the ICES standard.

Chuck Byrne, vessel coordinator for NOAA's Northeast Fisheries Science Center, was involved in the design and outfitting of the *Bigelow*. "We're moving into the next generation of research vessel," he said. "We're increasingly employing remote sensing technology, which senses the subject without capturing it.

"If we're going to do that effectively, we need a platform that will allow us to study these animals without affecting their behavior while they're being studied. That's what this ship gives us."

As Byrne notes, the *Bigelow*'s remote sensing technology will allow more marine organisms to remain in their habitat, even though they've contributed to scientific studies.

"We use the trawl to quantify what we're seeing, because we still have to collect biological samples to study such things as pathology and maturity, but we won't have to do it with the same frequency," he said. "This technology also helps us get closer to marine mammals than we ever have. So, we're improving estimates of not only fish species, but also of other protected species."

The *Henry B. Bigelow* will work primarily in U.S. waters from Maine to North Carolina. In addition to its undersea surveys, the ship will also observe weather, sea state, and other environmental conditions; conduct habitat assessments; and survey marine mammal and marine bird populations.

Since the days of the first *Albatross*, the driving force behind NOAA's continuous development in its survey vessels has always been an unquenchable thirst for the knowledge integral to responsible marine stewardship.

NOAA Marine and Aviation Operations, NOAA Fleet — www.omao.noaa.gov/visitors.html
NOAA Photo Library, Sailing for Science — www.photolib.noaa.gov/ships/index.html
Northeast Fisheries Science Center, Research Vessel Surveys — www.nefsc.noaa.gov/sos/vesurv/vesurv.html

The new national monument is home to such colorful inhabitants as these Hawaiian squirrelfish swimming on French Frigate Shoals. *Credit: NOAA National Marine Sanctuary Program*

A NEW TOOL TO PROTECT MARINE RESOURCES

BY DAVID A. BROWN

It was a real shot in the arm for the state's image, but when President George W. Bush signed a proclamation that created the Northwestern Hawaiian Islands (NWHI) Marine National Monument on June 15, 2006, it was much more than a PR move.

Using his authority under the Antiquities Act of 1906, which empowers the president of the United States to restrict the use of particular public land by executive order, President Bush awarded this site the nation's highest level of natural resource protection.

Relatively free from invasive human activity, now this astounding environment located at the northwest end of the Hawaiian Islands encompasses 137,792 square miles of pristine Pacific water. Included are 4,500 square miles of relatively undisturbed coral reef habitat harboring more than 7,000 marine species, many of which are unique to the Hawaiian archipelago. Among the notables are the endangered Hawaiian monk seal, the threatened Hawaiian green sea turtle, and other rare marine, terrestrial, and avian species.

As the nation's largest single area dedicated to conservation and the largest protected marine area in the world, the NWHI Marine National Monument stands at more than 100 times larger than Yosemite National Park. This site is bigger than 46 of the 50 states, and more than seven times larger than all U.S. National Marine Sanctuaries combined.

Through the years, the area's remoteness has been an ally in preserving some of the world's most immaculate marine environment. Included

The endangered Hawaiian monk seal is among the rare creatures afforded protection in the new national monument. *Credit: NOAA National Marine Sanctuary Program* **Below: Protection of such endangered animals as the green sea turtle is a primary goal of the area's designation as a national monument.** *Credit: NOAA Office of Public Affairs* **Bottom: The Northwestern Hawaiian Islands are home to more than 7,000 marine species, including the bluefin trevally.** *Credit: NOAA National Marine Sanctuary Program*

are the Hawaiian Islands National Wildlife Refuge and the Midway Atoll National Wildlife Refuge.

Prior to the presidential proclamation, this unique area had been part of a five-year study under a National Marine Sanctuary designation process in which federal and state entities, native Hawaiian leaders, and the public engaged in collaborative planning for a comprehensive management plan.

The decision to move forward with the National Monument designation bespeaks the consensus among state and federal officials who recognized the need for expedient action to protect this Pacific paradise. With the president's action, measures included in the management plan developed during the sanctuary designation process took effect immediately.

Mike Tosatto, Deputy Administrator for NOAA Fisheries Service's Pacific Islands Regional Office in Honolulu, said that with a National Monument designation come the safeguards provided through a variety of federal acts dealing with protected natural resources. This bolsters the cooperative management arrangement involving NOAA, the U.S. Fish and Wildlife Service, and State of Hawaii officials.

"The monument proclamation brought all the federal authorities into the management picture, so that provides much more backbone," Tosatto said.

In 1999, President Clinton declared what is now a National Monument, the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve. Calling the new title an "upgrade in status," Tosatto said, "If nothing else, it sets the place aside for research and to be the ecological engine that it is."

In addition to what he termed the "history-making significance" of the NWHI Marine National Monument's designation, Tosatto noted that this chain of 10 islands and atolls also holds important historical and cultural elements. The Battle of Midway Atoll was a turning point in World War II. Moreover, important indigenous cultural sites have been found on the islands of Nihoa and Mokumanamana.

The monument's proclamation preserves access for Native Hawaiian cultural activities and allows for consideration of other appropriate uses. Tosatto said that a range of activities, including tourism, may be allowed, but only in the Midway Atoll Special Management Area.

"We hope to make Midway a window, so people can see a representative sample of the area without impacting the rest of the National Monument," Tosatto said. "That's the only area in which infrastructure exists, and we don't expect to create any additional infrastructure, because of the impact. Our goal is to bring this place to people, so people don't have to come to this place," Tosatto said.

Permitted vessels can still pass through monument waters, but landfall is prohibited, as is removing any natural resource. Commercial fishing in this area will be phased out over a five-year period.

Of course, the forbidden fruit tastes sweetest, so NOAA Fisheries Office for Law Enforcement (OLE) will keep an eye on the NWHI Marine National Monument through its Vessel Monitoring System (VMS). The satellite-based technology enables OLE to remotely track vessels equipped with VMS devices. The presidential proclamation creating the NWHI Marine National Monument also requires approved VMS devices for all vessels permitted to operate in this area.

Northwestern Hawaiian Islands Marine National Monument — www.hawaiireef.noaa.gov

National Marine Sanctuaries — http://sanctuaries.noaa.gov

NOAA divers check the installation of a test Turtle Excluder Device (TED) in a shrimp trawl net.
Credit: NOAA Fisheries Service

NEW GEAR HELPS FISHERMEN CONSERVE MARINE RESOURCES

Despite the vast area beneath the ocean's surface, proximity between marine species is unavoidable. Couple that with the somewhat unpredictable nature of fishing and the possibility of boating something in addition to, or in place of, intended species becomes commonplace.

For commercial fishing the term is "bycatch," defined in the Magnuson-Stevens Fishery Conservation and Management Act as "fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic and regulatory discards." Nothing is wasted when returned to the sea, but every harvested fish affects the species' stock, whether it's kept or not.

Bycatch is particularly common to trawl gear — essentially a net dragged through the water to collect fish with "sweeps" on the leading edge herding fish into the net. One of the most basic elements of gear selectivity is mesh size (when considered along with factors such as tow speed, trawl design, area fished, and ground contact). The larger the openings, the more undersized fish can slip through (also true for gill nets).

Another factor influencing the selectivity of trawl gear is the sweep design. For maximum exclusion of bottom species, as well as minimum impact to the sea floor, a raised footrope trawl excels. Here, 42-inch-long chains connect the sweep to the footrope, thereby raising the trawl 18-24 inches off the bottom.

Flatfish (sole, flounder) and other bottom dwellers slip under such nets, while targeted species like cod and whiting are easily captured. When trawlers seek flatfish buried in the sand, "tickler" chains hung from the front of the trawl stir such species.

Commercial longliners targeting tuna, dolphin, and swordfish can limit their bycatch of sea turtles with large (18/0) circle hooks and large baits that turtles can't ingest. Designed with an inward-facing point, these hooks typically end up in the corner of a fish or turtle's mouth, whereas both species often swallow standard "J" hooks. The latter can also snag drifting turtles.

A circle hook yields a solid connection and allows relatively easy dehooking from the mouth – a helpful trait for fishermen and any bycatch in need of live release. Because fish remain alive longer on circle hooks, the economic incentive of a better catch quality motivates most commercial fishermen to use this design. Recreational anglers also benefit from the convenience and conservation aspects of circle hooks.

Another protection for marine amphibians is the Turtle Excluder Device (TED) required for U.S. shrimpers. A grid/panel installed in trawls allows shrimp to pass to the back of the net while directing sea turtles out an escape opening. TEDs are estimated to reduce sea turtle bycatch by approximately 97 percent.

Reducing the environmental impact of bycatch requires effort and forethought. But such proactive steps reward fishermen by helping to perpetuate the marine resources that support their business and recreational pursuits.

Sea turtles/Turtle Excluder Devices NOAA Fisheries Office of Protected Species — www.nmfs.noaa.gov/pr/interactions/

NOAA and Marine Aquaculture: A Long History, a Promising Future

BY DAVID A. BROWN

We've heard it for years: "Fish is good for your brain." Well, some of the top brains at NOAA Fisheries are committed to ensuring that American consumers have plenty of cerebral fuel.

But here's the dilemma: Americans love their seafood, but Mother Nature can only provide so much. Ideally, effective resource management will help ensure thriving populations of wild fish stocks. But the law of supply and demand compels us to seek supplemental options.

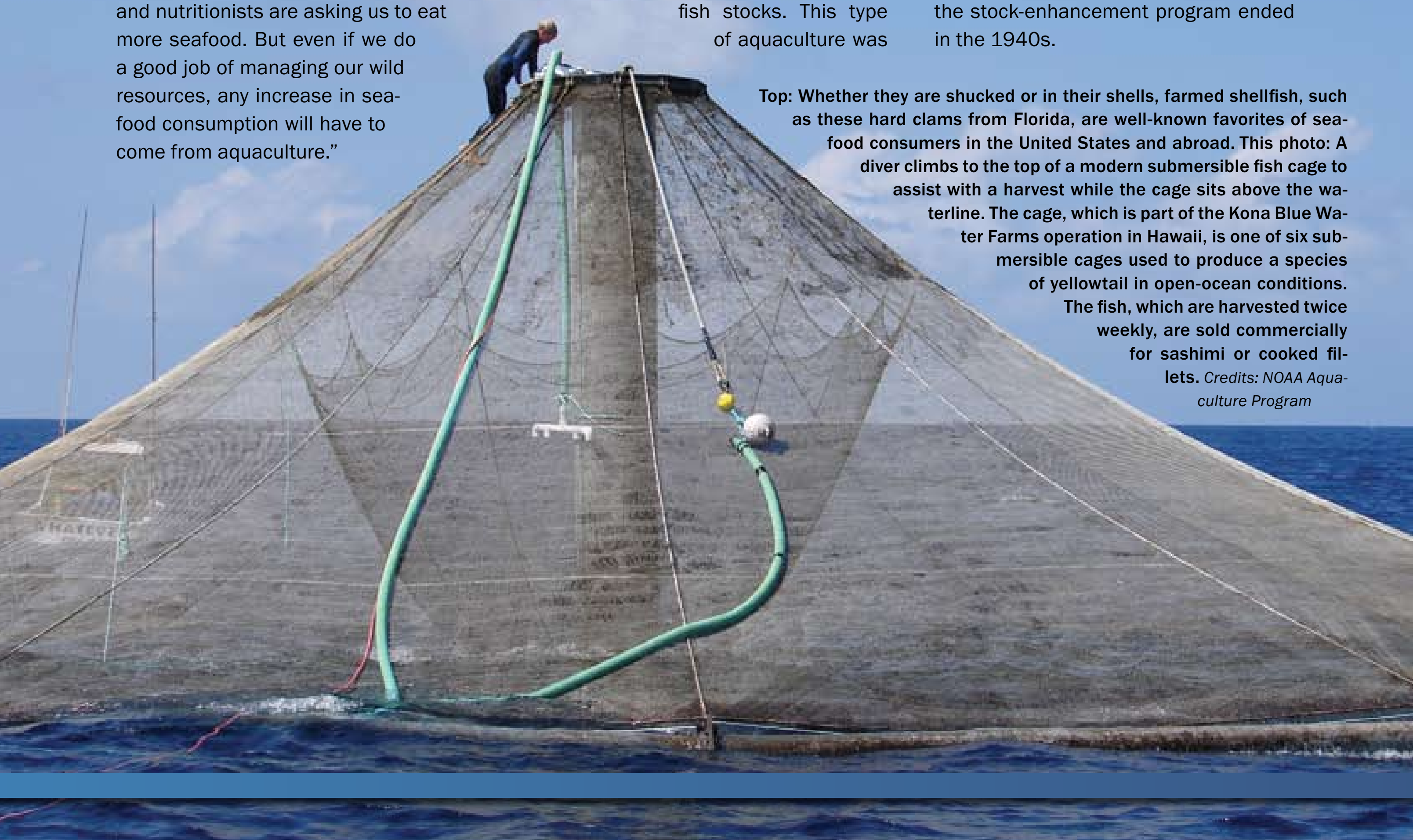
One of the answers is aquaculture, or seafood farming, and NOAA envisions a bright future for American fish farming.

Michael Rubino manages NOAA's Aquaculture Program. He said, "Doctors and nutritionists are asking us to eat more seafood. But even if we do a good job of managing our wild resources, any increase in seafood consumption will have to come from aquaculture."

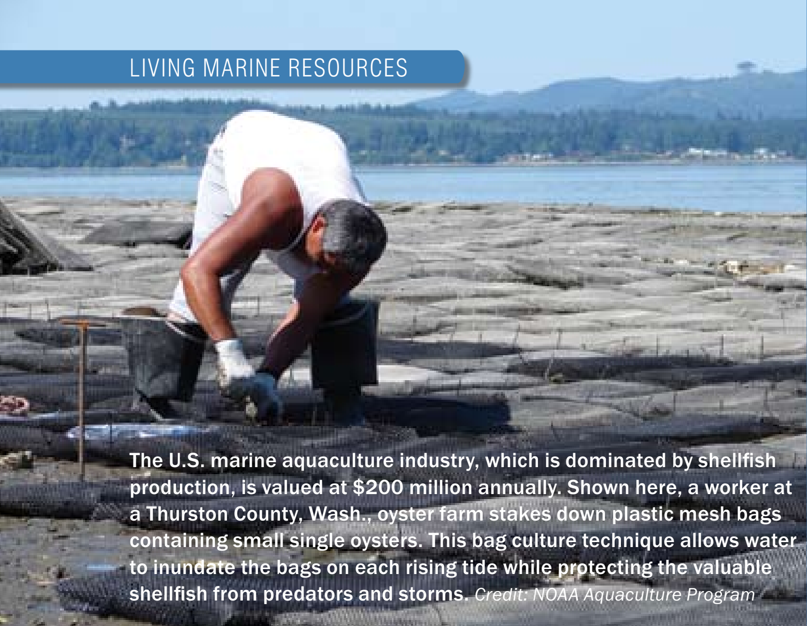
Currently, almost 70 percent of the seafood Americans consume is imported, and foreign aquaculture accounts for at least 40 percent of those imports. NOAA's plan: Reduce dependency on foreign seafood and bolster domestic production.

Similar to agriculture, this type of food production includes the breeding, rearing, and harvesting of freshwater and marine plants and animals in all types of water environments, including ponds, rivers, lakes, and oceans. Aquaculture also takes place on land, in human-created environments.

Modern U.S. aquaculture traces its roots to 1871, when Spencer Fullerton Baird, as head of the newly formed United States Commission of Fish and Fisheries, advised Congress of his belief that fish culture could alleviate declining wild fish stocks. This type of aquaculture was dubbed "stock enhancement." Governmental support enabled Baird's ideas to be put into motion through research projects and shore-based marine fish hatcheries. These facilities produced and released young fish to the wild, but the stock-enhancement program ended in the 1940s.

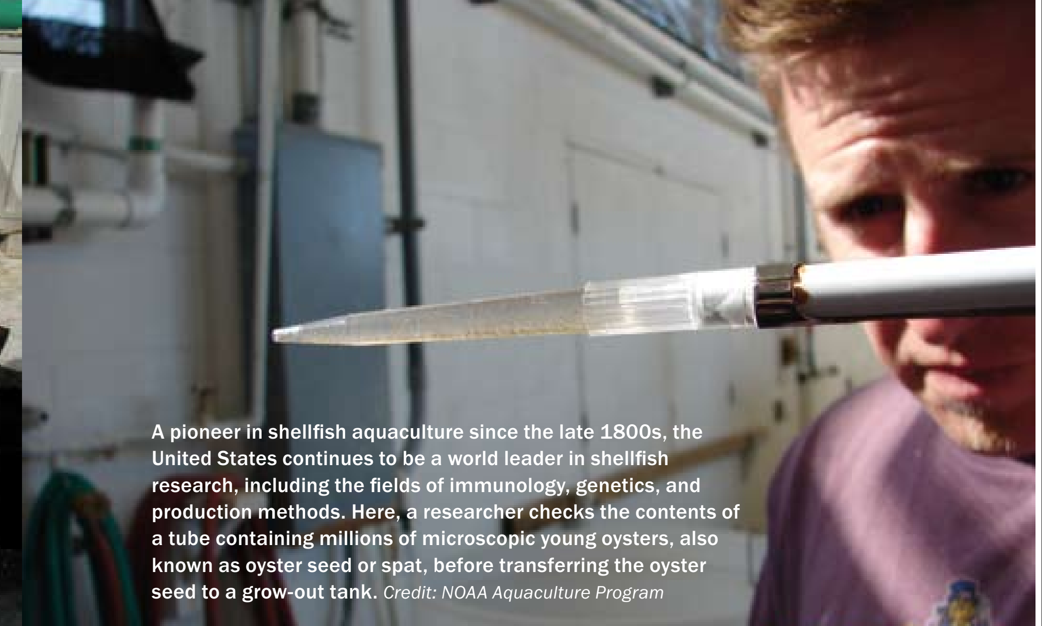


Top: Whether they are shucked or in their shells, farmed shellfish, such as these hard clams from Florida, are well-known favorites of seafood consumers in the United States and abroad. This photo: A diver climbs to the top of a modern submersible fish cage to assist with a harvest while the cage sits above the waterline. The cage, which is part of the Kona Blue Water Farms operation in Hawaii, is one of six submersible cages used to produce a species of yellowtail in open-ocean conditions. The fish, which are harvested twice weekly, are sold commercially for sashimi or cooked fillets. *Credits: NOAA Aquaculture Program*



The U.S. marine aquaculture industry, which is dominated by shellfish production, is valued at $200 million annually. Shown here, a worker at a Thurston County, Wash., oyster farm stakes down plastic mesh bags containing small single oysters. This bag culture technique allows water to inundate the bags on each rising tide while protecting the valuable shellfish from predators and storms. *Credit: NOAA Aquaculture Program*

Fish harvested from an offshore cage in Hawaii are seen on a dewatering table. *Credit: NOAA Central Library Photo Collection*



A pioneer in shellfish aquaculture since the late 1800s, the United States continues to be a world leader in shellfish research, including the fields of immunology, genetics, and production methods. Here, a researcher checks the contents of a tube containing millions of microscopic young oysters, also known as oyster seed or spat, before transferring the oyster seed to a grow-out tank. *Credit: NOAA Aquaculture Program*

The post-World War II era saw a shift toward aquatic farming. Federal laboratories conducted landmark culture research with mollusks (at Milford, Conn.), salmonids (Manchester, Wash.), and marine shrimp (Galveston, Texas). In the late 1960s, NOAA's research and development work on salmon provided the basis for the development of aquaculture industries in the United States as well as Chile, Norway, and the United Kingdom. Much of this work has been instrumental in the development of culture operations for shellfish, shrimp, and salmon throughout the world. Although these efforts were successful, federal research support dwindled during the 1980s, and further research and development were left to the private sector.

In the 1990s, rising consumer demand for seafood, declining market share of domestic wild-caught fish, and increasing levels of seafood imports led to renewed interest in the potential of marine and freshwater aquaculture in the United States.

Presently, freshwater aquaculture, mostly farm-raised catfish and trout, dominates the $1 billion-a-year U.S. aquaculture industry. And, while salmon farms have long been a fixture in the Pacific Northwest and Maine, shellfish farming accounts for the majority of United States marine aquaculture production. Leading the way are oysters, mussels, and clams, which are high in food value, plus these filter feeders benefit their environments by cleaning the surrounding water.

Other promising aquaculture species include cod (New England); cobia, red drum, pompano, and red snapper (Caribbean and Gulf of Mexico); yellowtail (California); sablefish/black cod (Pacific Northwest); and moi and amberjack (Hawaii). Sea urchins and abalone are also viable options. The possibilities are many, and Rubino lauds the diversity.

"NOAA is working across a broad spectrum," he said. "If we're to produce more seafood in the United States, we will need onshore, coastal, and offshore technologies for finfish, shellfish, plants, and algae. We'll need it all."

Just like agriculture is very diverse with its pork, beef, and chicken industries, aquaculture is also very broad in scope. And that scope is extending farther into the ocean. Increasingly, the United States aquaculture industry is casting its glance to the distant waters within the Exclusive Economic Zone (EEZ – 3-200 miles offshore), an area of about 3.4 million square miles.

"The United States has invested a lot in offshore aquaculture research," said former NOAA Aquaculture Manager Conrad Mahnken, now retired. "One reason is that there's a lot of space out there and it's unhindered, unlike inshore environments. Another reason is that much of the inshore waters has become polluted. In aquaculture, you need good, clean, clear water, and that's what you get offshore."

Although there are currently no fish farms in federal offshore waters, there are several in state, territorial, and foreign waters. Demonstration projects and businesses in Hawaii, New Hampshire, and Puerto Rico exhibit the range of options for aquaculture techniques in a variety of conditions. For example, open-ocean operations range from mussel farming, where the succulent shellfish grow on ropes linked in a grid to submersible cages for finfish equipped with automatic feeders, underwater cameras, and sensors that monitor feeding and fish behavior.

One of the key factors needed for offshore aquaculture to flourish is a definitive set of rules. While the Magnuson-Stevens Act extended federal jurisdiction into the EEZ, the text was written primarily for wild fisheries. The National Offshore Aquaculture Act, submitted to Congress in June 2005, would provide the Secretary of Commerce with the necessary authority to establish and implement a regulatory system for offshore aquaculture.

Linda Chaves, NOAA Fisheries' Senior Advisor for Seafood Industry Issues, said such clarity should provide important assurances for offshore facilities. "You want to make sure that if you have a site offshore, you own the cage system or pen, and the fish in it."

Aquaculture, Rubino said, is not just about commercial fish production. There's also much potential for habitat restoration (i.e., replenishing marsh grass and shellfish beds), and stock enhancement to replenish wild fish stocks important to both commercial and recreational industries.

Regardless of the objective, aquaculture offers unquestionable economic benefit to local communities. From growing red snapper, white sea bass, snook, or abalone to planting sea grass beds and cultivating oyster colonies, aquaculture means jobs.

And they're not just seasonal positions, as in the case of some wild fish processing plants, which scale back to skeleton crews between runs. With proper planning, labor needs can be spread across the calendar. Permanent populations mean burgeoning economic development, and that means even more jobs and greater benefit for areas in need of economic stimulus.

Rubino said that inviting more commercial fishermen to embrace aquaculture would provide a base of skilled workers with an existing affinity for marine operations. Aquaculture can fill in the gaps between commercial fishing seasons and provide fishermen with dependable employment. Moreover, cultured fishing can relieve pressure on wild stocks.

"We have to stop thinking about fisheries and aquaculture as diametrically opposed," Rubino said. "Aquaculture is supplying additional opportunities in a growing market. The wild stocks are limited, so aquaculture is another way to use existing infrastructure – boats, docks, and processing plants."

Similarly, the challenge of feeding cultured fish may create opportunities for the nation's agricultural industry. Clearly, the amount of various feed sources needed for cultured stocks will increase as global aquaculture grows. To help avoid supply limitations, NOAA is supporting research into alternative fish foods produced by domestic farmers, including soybeans, barley, rice, and other crops.

Chaves said that NOAA's aquaculture vision encompasses more than U.S. dietary needs. "We're not looking at aquaculture only for domestic use. There's going to be seafood demand all over the world, so we might as well take the opportunity to meet some of that demand as well."

To usher the process forward, NOAA awarded $3.6 million in competitive grants to 11 sustainable marine aquaculture demonstration and research projects in September 2006. Made possible by the National Marine Aquaculture Initiative (NMAI), the funding supports projects to assess the commercial potential of marine aquaculture, stock enhancement feasibility, and environmental impacts. Other projects will research aquatic animal nutrition and health issues.

As U.S. aquaculture continues to develop, Rubino said it's important for the role of NOAA Fisheries to remain clear and steadfast. "Our job is to enable aquaculture by providing a regulatory framework that allows it to happen in a businesslike manner.

"We have a responsibility to the public trust to provide an environment in which aquaculture can thrive, while also maintaining the safeguards for protecting wild stocks and the environment, and balancing all this for multiple uses. And I think that can happen.

"There are many challenges, but it's also a great opportunity."

NOAA Aquaculture Program — www.aquaculture.noaa.gov
Aquaculture Information Center — www.lib.noaa.gov/docaqua/frontpage.htm

Far left: A NOAA enforcement officer helps shrimp fishermen check a Turtle Excluder Device (TED) installed in their trawl net. *Credit: NOAA Central Library Photo Collection* **Left: Fisheries officers check the catch to ensure compliance with stringent resource-management laws.** *Credit: NOAA Central Library Photo Collection*

GOING UNDERCOVER:

BY DAVID A. BROWN

FISHERIES ENFORCEMENT OFFICERS MAKE THEIR CASE

There was a time when marine resource violations fell into just a few categories. "Too big," "too small," "too many," or "wrong month" described most of what faced NOAA Fisheries' Office for Law Enforcement (OLE).

That was yesteryear. Today, OLE Director Dale Jones said that the ever-increasing challenges of 21st-century compliance issues have necessitated the agency's evolution: "We've moved from primarily inspection operations and a dockside presence for regulatory compliance to a much wider scope of operations. Today we are primarily an investigative unit."

Day to day, enforcement officers inspect plenty of fish boxes and conduct vessel boardings, while special agents are more often the ones following leads and poring through records. But with OLE handling some 3,200 cases a year, those in the field could find themselves spending a couple of hours on a regulatory incident or working a case that could become a multiyear investigation with multinational and multimillion-dollar implications.

Sometimes, it's just a straightforward violation of a closed fishery. Elsewhere, OLE officers and agents have to contend with the creatively misleading transportation schemes, concealed compartments, and fraudulent documentation common to persons intent on circumventing U.S. import regulations.

For example, lobsters fetch high prices in U.S. markets – particularly around the holidays – so the lure of easy money constantly tempts unscrupulous types into smuggling the popular crustaceans from foreign locales such as Central America, Canada, and South Africa.

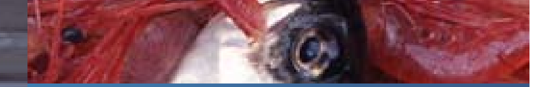
Mislabled seafood products and those caught illegally by foreign fishermen represent recurring problems. One in particular, the Patagonian toothfish, is not necessarily an import violation. Unless, of course, it's harvested by poachers and/or transported to the United States without proper documentation.

The toothfish is a slow-growing species that's highly susceptible to exploitation by illegal, unregulated, and unreported fishing. During the 1990s, U.S. restaurants and markets began selling toothfish under the name "Chilean sea bass." Rising popularity spurred increased fishing effort, and not all of it has been legal.

The species is managed through the international Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) – the organization responsible for conserving marine life in the Southern ocean. As a CCAMLR member, the United States has helped implement an international system of tracking legally caught toothfish through a catch document that must be certified by the vessel's flag nation.

"We've had to put a lot of work into this, but we've also been able to disrupt some significant operations – some involving Patagonian toothfish and also South African rock lobsters," Jones said.

As OLE Deputy Director Mark Spurrier points out, illegally imported seafood does more than affect consumer confidence by compromising quality and health-related aspects; it competes with domestic commercial fishing operations, drives down prices, and harms local job markets. Moreover, the threat to



Opposite page: NOAA enforcement officers consult with the Coast Guard to coordinate at-sea operations. *Credit: NOAA Central Library Photo Collection* **Left: A NOAA Fisheries officer prepares to board a Gulf of Mexico shrimp trawler to enforce sea turtle conservation measures.** *Credit: NOAA Central Library Photo Collection* **Below: Fisheries enforcement officers play a key role in ensuring that America's seafood is legally caught and accurately labeled.** *Credit: NOAA Central Library Photo Collection, William B. Folsom, photographer*

sustainable fisheries, habitat destruction, and endangerment of protected marine mammals always looms large with unlawful activities afoot.

And of the OLE job hazards, Jones said: "In the routine daily operations, there's always the potential for dangerous situations. There can be sea-related dangers and contact with people who can be problematic. The threat and the possibility is always there, but fortunately the frequency has not been that high."

Spurrier is quick to note that the majority of recreational and commercial fishermen OLE officers and agents encounter plays by the rules. For those who do not, strict penalties await. Catches are usually seized at the start of an investigation, but violators can also face civil and criminal fines, vessel seizure, and federal prison.

When details warrant, NOAA Fisheries agents and officers can refer the case to NOAA's Office of General Counsel for Enforcement and Litigation (GCEL), which may assess civil penalties or refer the case to the U.S. Attorney's office for criminal proceedings. Repeat offenders and those who inflict severe resource damage may face huge fines and/or imprisonment.

Headquartered in Silver Spring, Md., OLE maintains six divisional offices and 54 field offices throughout the United States and its territories. Working with local, state, tribal, federal, and international law enforcement partners, OLE has the authority to enforce over 37 statutes and numerous international treaties involving marine resources throughout 3.36 million square miles of water.

Most NOAA Fisheries Enforcement activities are conducted under one of the following laws: the Magnuson-Stevens Fishery Conservation and Management Act, the Endangered Species Act of 1973, the Marine Mammal Protection Act of 1972, the Lacey Act Amendments of 1981, and the National Marine Sanctuaries Act. The OLE also enforces the Convention on International Trade in Endangered Species of Wild Fauna and Flora relevant to marine wildlife, and supports NOAA's National Ocean Service with enforcement services at National Marine Sanctuaries.

OLE maintains 19 patrol boats ranging in size from a 17-foot Zodiac to a 39-foot Chris Craft. Expanding its reach, OLE works with the U.S. Coast Guard, Bureau of Customs and Border Protection, Civil Air Patrol, and federally-deputized state marine enforcement agents on sea, land, and airborne patrols.

Technology is also a prudent partner. For example, the satellite-based Vessel Monitoring System (VMS) developed in 1988 allows the OLE to monitor and survey vessels over broad areas of open ocean without disclosing fishing locations. Monitoring compliance, tracking violators, and collecting evidence for prosecution can all be done from great distances.

"The reality is that we have fewer than 200 sworn personnel for over 3 million square miles of water," said Spurrier. "So without the ability to leverage technology, our enforcement abilities would be minimized.

"VMS allows us to target our efforts and those of the Coast Guard toward violations in closed areas. It allows us to more effectively and efficiently use the resources available to us for the enforcement of fishery laws."

Through VMS capabilities, OLE can identify a vessel entering a closed area and email an advisory to the crew. "If we can inform them and prevent a violation, then that's much better than having to investigate it after it has happened," Spurrier said.

Encouraging constituent cooperation also helps, as evidenced in the Community Oriented Policing and Problem Solving (COPPS) program, through which OLE employs public awareness and educational efforts to promote voluntary compliance.

Jones said OLE officers and agents face ongoing challenges related to the expansive and complex nature of enforcing regulations and treaties across geographically diverse regions, each with its own needs and issues. Throughout the process, budget maximization remains a constant concern.

"We're being pushed and pulled in a lot of directions with a limited amount of resources," he said. "So we're always looking for force multipliers and ways to improve our relationships with our partners.

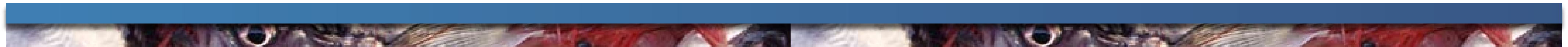
"There's a dynamic nature to this work – it's always changing. It seems like every month there's a new priority, and we're continuing to manage things in that direction."

The job never gets easier, but suffice it to say that no one puts in the time, training, and sacrifice required to earn the NOAA Fisheries OLE badge because they want "easy." Rather, Jones said, the motivation comes from the fervent desire to ensure that something workable continues to work.

"It's the satisfaction of knowing that this job is important to the conservation of marine species," he said. "Our role in enforcement is to ensure compliance, so when all the science is done and all of the management decisions are made, the resources remain healthy and sustainable. We hope that our efforts would help support that."

Spurrier adds, "It's important to know that for our children and their children, these species will still be around."

NOAA Fisheries: Office for Law Enforcement — www.nmfs.noaa.gov/ole/



CARING FOR OUR COASTS

BY BARBARA STAHURA

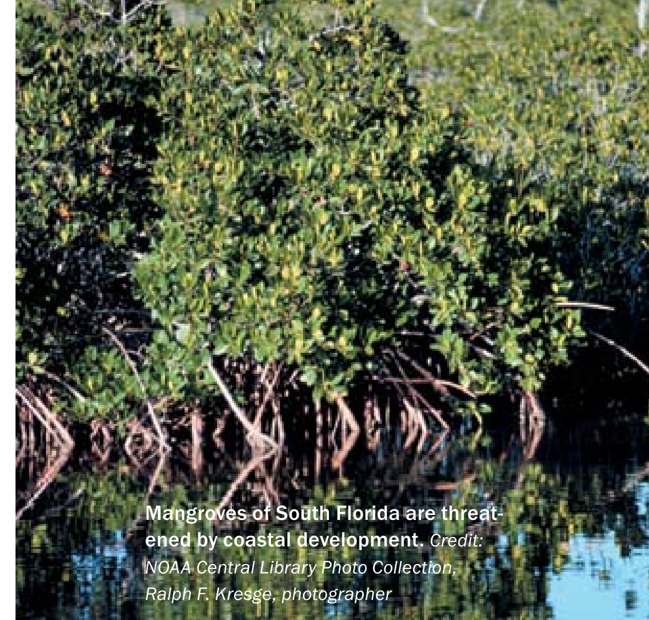
America's coasts are essential to our country's prosperity and well-being. Our seaports and harbors serve as busy gateways to regional and international commerce, and our beaches and waterways are favored vacation destinations. Indeed, the nation's economic well-being is directly linked to our coastal and marine resources. However, the impact of increasing population growth and development on the coast has been rapid and profound.

As a result of our love for water, many of our coastlines have become congested places where cities large and small rise up literally at the water's edge — Miami, San Francisco, New York, Chicago, and Boston are just a few well-known coastal metropolitan areas. Today, the coastal ribbon within about 50 miles of the Atlantic Ocean, Gulf of Mexico, Pacific Ocean, and Great Lakes is home to 150 million Americans. Insured property worth $2 trillion lies within 20 miles of the Atlantic coast alone — all of it vulnerable to severe coastal weather. According to NOAA's National Hurricane Center, 1.7 hurricanes come ashore each year, and that number is expected to rise, along with their intensity. Furthermore, as global climate change continues, sea levels will rise, leaving coastal areas vulnerable to permanent inundation.

Volunteers replant marsh grass in an effort to protect and rebuild a beach near Annapolis, Md. Credit: NOAA Central Library Photo Collection, Mary Hollinger, NODC biologist, photographer

In addition to natural events, heavy development damages coastlines. Building projects, from homes to highways and malls to marinas, can disrupt natural forces that maintain fragile coastal areas. Development overtakes wetlands, marshes, estuaries, dunes, and other sensitive ecosystems that often protect developed areas further inland and harbor habitats vital to the chain of life. Coastal development can also imperil freshwater supplies for burgeoning populations. Oil spills and other pollution can destroy scenic areas, decimate marine life, and ruin livelihoods and tourism.

As popular and as valuable as coastal areas are, our love for them is costing us dearly: 80 percent of U.S. coastal waters are impaired for human use or aquatic life; costs due to natural hazards are rising (losses due to Hurricane Katrina alone topped $75 billion); more oil enters our coastal waters every year via runoff alone than was spilled by the *Exxon Valdez*; and traditional coastal uses and public waterfront access are shrinking. The Coastal Zone Management Act (CZMA) of 1972 spelled out the legacy of heavy development along U.S. coasts: "increasing and competing demands … have resulted in the loss of living marine resources, wildlife, nutrient-rich areas, permanent and adverse changes to ecological systems, decreasing open space for public use, and shoreline erosion. … Important ecological, cultural, historic, and esthetic values in the coastal zone which are essential to the well-being of all citizens are being irretrievably damaged or lost."



Mangroves of South Florida are threatened by coastal development. *Credit: NOAA Central Library Photo Collection, Ralph F. Kresge, photographer*

Erosion — ironically seen below a sign posting a boating speed limit meant to minimize wake and erosion. *Credit: NOAA Central Library Photo Collection, Mary Hollinger, NODC biologist, photographer*

Protecting our coasts while supporting sustainable human activity, and ensuring that coastal communities do not have to face these mounting challenges alone, is central to NOAA's mission: "… to understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs."

NOAA Collaborates With Coastal Communities

A major portion of this mission involves collaborating with coastal communities to study and integrate critical coastal information in priority areas ranging from climate change to community resilience and preparedness for natural hazards, from coastal and estuarine ecosystem protection to assistance in planning evacuation routes. NOAA's National Sea Grant College Program is responsible for much of this effort. Sea Grant's mission is to promote environmental stewardship, long-term sustainable economic development, and responsible use of America's coastal, ocean, and Great Lakes resources. Much like the Land Grant program founded in the 19th century, which harnessed university resources to transform American agriculture, Sea Grant is widely recognized as a neutral, credible broker of science-based information, built on a foundation of research, education, and outreach. The National Sea Grant College Program includes more than 30 programs based at top universities in every coastal and Great Lakes state, plus Puerto Rico and Guam, all of which work together to help citizens understand, conserve, and better utilize America's resources in those regions.

Sea Grant has created a Coastal Hazards Program to enhance preparedness and to reduce losses of life, property, and natural resources from coastal hazards in the United States, including weather-related hazards such as hurricanes, earthquakes, and tsunamis, and shoreline change through coastal erosion.

Sea Grant is working with other programs, including NOAA's National Ocean Service and National Weather Service, and agencies such as the Federal Emergency Management Agency, the U.S. Geological Survey, and the U.S. Army Corps of Engineers to help communities protect themselves from natural disasters, withstand them when they occur, and then rebuild and rebound. These programs collaborate with local and state decision-makers, emergency managers, urban planners, and coastal-resource managers, among others. Sea Grant's strong connections with its universities and coastal constituencies, along with its capabilities in the areas of basic and applied multidisciplinary research, education, and technology transfer, enable it to contribute critical information and assistance to national efforts. Another outgrowth of these collaborations is the agency's emergent interest in coastal community resilience — an issue that incorporates sustainable land use, coastal hazards planning, and mitigation.

The Future of Our Coasts

With its unique position among federal programs having direct community involvement, NOAA Sea Grant is ready to help U.S. coastal communities prepare for a sustainable future. These communities face many challenges that require regional, and even broader, cooperation to adequately evaluate and begin to remedy. Some of those challenges include:

- environmental degradation resulting from the expansion of the developed environment and human activity
- economic impacts resulting from compromised habitats, loss of fisheries and other water-based businesses, and poorly guided development
- loss of historically public access to the coast due to the changing character of our shorelines
- rising sea levels and land subsidence due to climate change.

NOAA programs such as Sea Grant are working with coastal communities to

A survey of fishes is conducted bi-weekly at the North Inlet - Winyah Bay National Estuarine Research Reserve. Fishes, shrimps, and crabs are collected in a net and brought back to a seawater laboratory for processing. *Credit: NOAA Central Library Photo Collection*

help them meet these challenges. With a strategic plan that embraces sustainable development, Sea Grant works to achieve healthy, vibrant, revitalized coastal communities that retain local character and protect residents from natural hazards. Sea Grant assists the public, coastal planners, and local leaders in understanding the linkages among well-designed communities, strong economies, and healthy habitats, and in recognizing the importance and value of thoughtfully modifying the way their communities grow. NOAA Sea Grant is dedicated to placing the science of ecosystem and economic sustainability in the hands of citizens and local officials, and retaining the cultural and aesthetic qualities that make our coasts unique.

Saving Estuaries Saves Coasts

NOAA is also playing a vital role in protecting estuaries, which are a crucial junction in Earth's hydrologic cycle, yet are sometimes forgotten when we think of a coastline. Estuaries are coastal bays where "fresh water streaming from mountains and plains reaches sea level and mingles with salty ocean tides," according to NOAA. These complex ecosystems form the foundation for much ocean life and help protect inland areas from coastal storm damage. Because estuaries are fed by rivers that start flowing well inland, they are affected by human and natural activities in entire watersheds, not only along the coast.

The 1972 Coastal Zone Management Act established a national system of estuarine sanctuaries protected for long-term research, public awareness, and education. In 1988, the estuarine sanctuaries became the National Estuarine Research Reserve System (NERRS). A partnership among NOAA and U.S. coastal states, NERRS now protects 1.3 million acres of coastal and estuarine habitats in a network of 27 reserves from Alaska to Puerto Rico. They provide essential habitat for wildlife; offer educational opportunities for students, teachers, and the public; and serve as living laboratories for scientists. (See sidebar for one example.) Today, with system expansion no longer a priority, NOAA has begun to focus more on using the network as a foundation for national programs promoting stewardship based on research and education.

The System-Wide Monitoring Program, for example, collects data on weather, water-quality, biological factors, habitat, and land-use changes and is a backbone element of the Integrated Ocean Observing System. These ocean observations are a vital part of the effort to understand coastal systems and protect both human and natural communities.

NOAA's National Ocean Service — www.oceanservice.noaa.gov

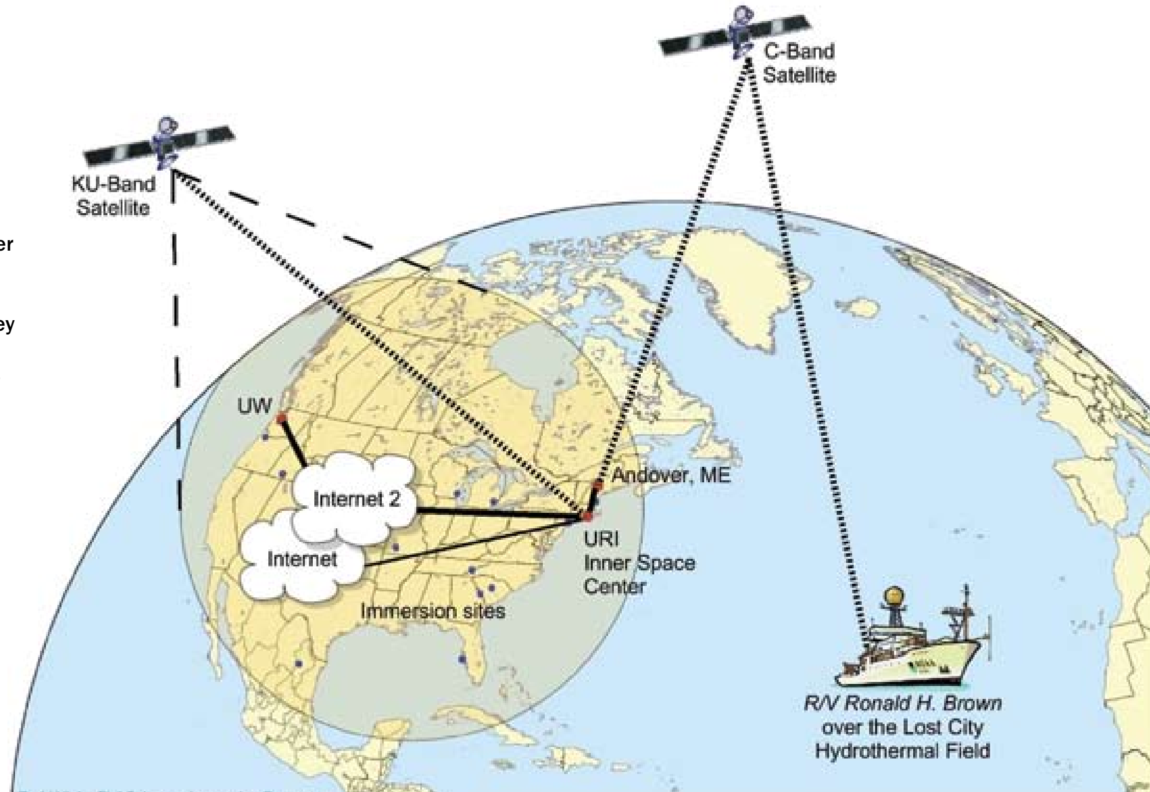
OLD WOMAN CREEK ESTUARINE RESERVE

Of all 27 National Estuarine Research Reserves, only one is on the Great Lakes and only one is freshwater: Old Woman Creek in Huron, Ohio, which empties into Lake Erie. Designated as part of NERRS in 1980 and also an Ohio State Nature Preserve, Old Woman Creek is a cooperative partnership between the Ohio Department of Natural Resources and NOAA. Like all estuaries, the transition between land and water here creates rich habitats worth preserving, both for healthy ecosystem diversity and as a place for education and scientific research.

The Old Woman Creek reserve and Ohio Sea Grant were established at about the same time, allowing for the creation of a strong collaboration. For instance, Ohio Sea Grant offers college courses through Ohio State University, and many of the classes take field trips to Old Woman Creek to collect specimens. Teachers can also attend a one-week OSU course at the reserve. OSU also partnered with the Old Woman Creek reserve and Ohio's Coastal Management Program to develop the state's Coastal Training Program, which provides scientific information, skill-building opportunities, and other information to individuals responsible for making decisions affecting coastal resources.

Credit: NOAA Central Library Photo Collection

Right: Diagram showing how video and data will be transmitted between the NOAA Ship *Ronald H. Brown*, via satellite and Internet2, to the Inner Space Center at the University of Rhode Island, the University of Washington, and other participating sites. *Credit: Image courtesy of Todd Viola, Phil Scheuer, Immersion Presents* Below: Deb Kelley from the University of Washington and Jeff Karson from Duke University are flanked by students from Woodstock High School in Illinois who won a nationwide contest to name NOAA's new ship for ocean exploration. They are connected by "telepresence" to Robert Ballard on NOAA Ship *Ronald H. Brown*, and to seafloor images of Lost City chimneys, nearly 5,000 miles away in the mid-Atlantic ocean. *Credit: NOAA Office of Ocean Exploration, Fred Gorell, photographer*



The Institute for Exploration's undersea robot, *Hercules*, approaches a ghostly, white, carbonate spire in the Lost City hydrothermal field, 2,500 feet deep in the Atlantic Ocean. *Credit: IFE, URI-IAO, UW, Lost City science party, and NOAA*

FROM SEAFLOOR TO SCIENTISTS ASHORE

BY BARBARA STAHURA

At least as mysterious as outer space and more important to life on Earth, the pulsing, thriving ocean overlays nearly three-quarters of Earth's surface. Its deepest recesses, while close in actual miles, seem just as unreachable as space because of the hazards involved in staying alive there. But just as technology is now exploring space – like rovers meandering around Mars and transmitting back incredible photos – so is technology exploring the ocean.

In the early days of sailing ships, sailors' log books of ocean observations – mainly what they could see on the surface – took months, if not years, to reach people ashore. Today, explorers aboard ship send data including images from the seafloor by satellite and Internet2, the next generation of the Internet that allows high-speed transmission of vast amounts of data in real time to reach teams of scientists ashore. And scientists post daily logs and images from sea on Web sites such as oceanexplorer.noaa.gov.

Communications from sea were limited even in 1977, when an ocean expedition to the Galapagos Rift unexpectedly discovered life forms near hydrothermal vents in the ocean floor, so far below the surface that no sunlight ever reached them. Living in absolute darkness, these tubeworms, shrimp, and clams didn't require sun-charged photosynthesis, like other life on Earth. Instead, they depended on chemosynthesis, or absorbing superheated, chemical-rich volcanic gases spewing from the vents. This amazing find was one of the most significant discoveries of modern science.

But the expedition scientists, including then-graduate student Kathy Crane, who now manages NOAA's Arctic Research program, were woefully unprepared to communicate their unexpected find in the days before instant, worldwide communication. Scientists aboard had to send telexes (telegrams) with descriptions of the creatures to researchers ashore. Photos taken from the Woods Hole Oceanographic Institution's (WHOI) deep submergence vehicle, *Alvin*, and with other specialized equipment, were developed onboard, but there was no satellite capability to send those images to scientists ashore. Since no provisions had been made to preserve specimens – none had been expected – vodka was used to preserve the alien creatures gathered from the deep.

When an American and French team led by famed oceanographer Dr. Robert Ballard discovered the wreck of the *Titanic* 12,400 feet down on the Atlantic floor in 1985, they used WHOI remotely-operated vehicles (ROVs); *Argo* was a deep-towed sonar and video camera, and *ANGUS*, or Acoustically Navigated Geological Underwater Survey, another towed vehicle, took 35mm photos. The next year, they used *Alvin* to dive to the massive hulk and transmit information to the ship overhead.

In 2000, scientists discovered the mid-Atlantic "Lost City" hydrothermal field, where carbonate chimneys 180-feet tall rose from the sea floor, venting 90-degree Celsius methane- and hydrogen-rich fluids that supported chemosynthetic life. They returned with *Alvin* to take samples and images. Within five years, NOAA supported a mission to Lost City wherein remarkable advances in telepresence technology allowed scientists at Lost City to participate instantaneously with scientists thousands of miles away at the University of Washington and the University of New Hampshire, at specially designed remote consoles. The ROVs *Argus* and *Hercules*, owned and operated by the Institute for Exploration in Mystic, Conn., streamed data and high-resolution video through a fiber-optic cable to the NOAA research vessel *Ronald H. Brown*, then in turn to a satellite, a downlink in Maine, and Brown University in Providence, where the information was streamed on Internet2 to the University of Rhode Island's Inner Space Center and to the University of New Hampshire and the University of Washington. From 2,100 feet below the mid Atlantic, data and live video traveled 4,500 miles to Washington in under 1.5 seconds! The payoff is that teams of scientists ashore controlled the science of a mission at sea, and they could call in additional scientific specialists as needed. It was a huge addition of intellectual capital, and a new and exciting paradigm for exploring the unknown ocean.

NOAA's Office of Ocean Exploration (OE) and its partners at Immersion Presents, The Jason Foundation for Education, and elsewhere, are dedicated to educating the public about the sea, and to working with institutions – from schools and Boys and Girls Clubs to marine sanctuaries and aquaria – to encourage ocean literacy among people of all ages across the United States. With exciting expeditions forming the core of this program, telepresence technology brings underwater habitats to land-based audiences.

A major reconnaissance vessel with telepresence capabilities is poised to join NOAA in 2008: *Okeanos Explorer*, the only federal U.S. ocean-exploration vessel. It is being outfitted with deep-water mapping capabilities, satellite data transmission technology, and a deep-water ROV system to explore unknown and poorly known regions of the world's ocean.

Through the *Okeanos Explorer*, ongoing telepresence efforts, and continuing research, education, and public outreach, NOAA is leading the way to expanding ocean literacy and unlocking the mysteries of the deep.

NOAA Ocean Explorer – http://oceanexplorer.noaa.gov

A diver returns to Aquarius from an excursion on the reef. *Credit: NOAA Central Library Photo Collection, NURP Center at the Univ. of North Carolina Wilmington*

MAN IN THE SEA

BY BARBARA STAHURA

The moon is 238,857 miles from Earth, yet we know far more about it than we know about the oceans of our own planet. About 71 percent of Earth is covered by the ocean, but due to the challenges and dangers posed by surviving underwater, particularly at depth, we have so far explored less than 5 percent of this aquatic world. While recent advances in remotely-operated technology have allowed more detailed, longer exploration at deeper depths, nothing can tease out more of the ocean's secrets than direct, hands-on contact. Filling this need is NOAA's Undersea Research Program (NURP), which offers the specialized ability to access this environment in person with fixed underwater habitats and advanced diving techniques.

Aquanauts check instrument panels in Aquarius' main lock. *Credit: NOAA Central Library Photo Collection, NURP Center at the Univ. of North Carolina Wilmington*

Captain George F. Bond paved the way for underwater habitats with his groundbreaking laboratory experiments for the U.S. Navy in the late 1950s. Bond, often referred to as the "Father of Saturation Diving," demonstrated that a diver's tissue would absorb compressed gases until it became "saturated," meaning it couldn't absorb anymore gas. Once the tissues were saturated, the diver could stay at the given depth for days, weeks, or longer, and the decompression would require the same time as that for a short dive.

Bond's experiments led to the development of underwater habitats by the French and the U.S. Navy. The U.S. Navy's habitats, known as SEALAB I, II, and III, allowed for further study of saturation diving and the ability of humans to live in the isolated, alien environment found several hundred meters under the sea — and in space. Astronaut Scott Carpenter also became an aquanaut, the undersea equivalent of an astronaut, when he lived in SEALAB II for a record 30 days.

Another early underwater habitat was Hydrolab, built in 1966 by Perry Oceanographics, Inc. Funded in part by NOAA, Hydrolab, which could house four people, hosted 180 research missions from 1970 to 1985, first in the Bahamas and then in the U.S. Virgin Islands.

In 1986, NOAA established what is now the world's only underwater lab dedicated to science. Called Aquarius, its 400 square feet of living and lab space can house up to six people for weeks at a time. Aquarius is an ambient pressure habitat, meaning that the interior atmospheric pressure is equal to the surrounding water pressure. The Wet Porch, its main entrance, remains open to the ocean to equalize the pressure and keep water out.

Damaged when Hurricane Hugo struck its original site in the U.S. Virgin Islands, Aquarius was repaired and moved in 1992 to the Florida Keys National Marine Sanctuary, 3.5 miles from Key Largo. Located near a coral reef and sited 62 feet below the surface, Aquarius offers the perfect location from which to study sensitive coral reef habitats in a way not possible with short dives. Divers from the surface can last only one or two hours, but Aquarius residents can be in the water for up to nine hours, allowing significantly longer observation of the reef and environs.

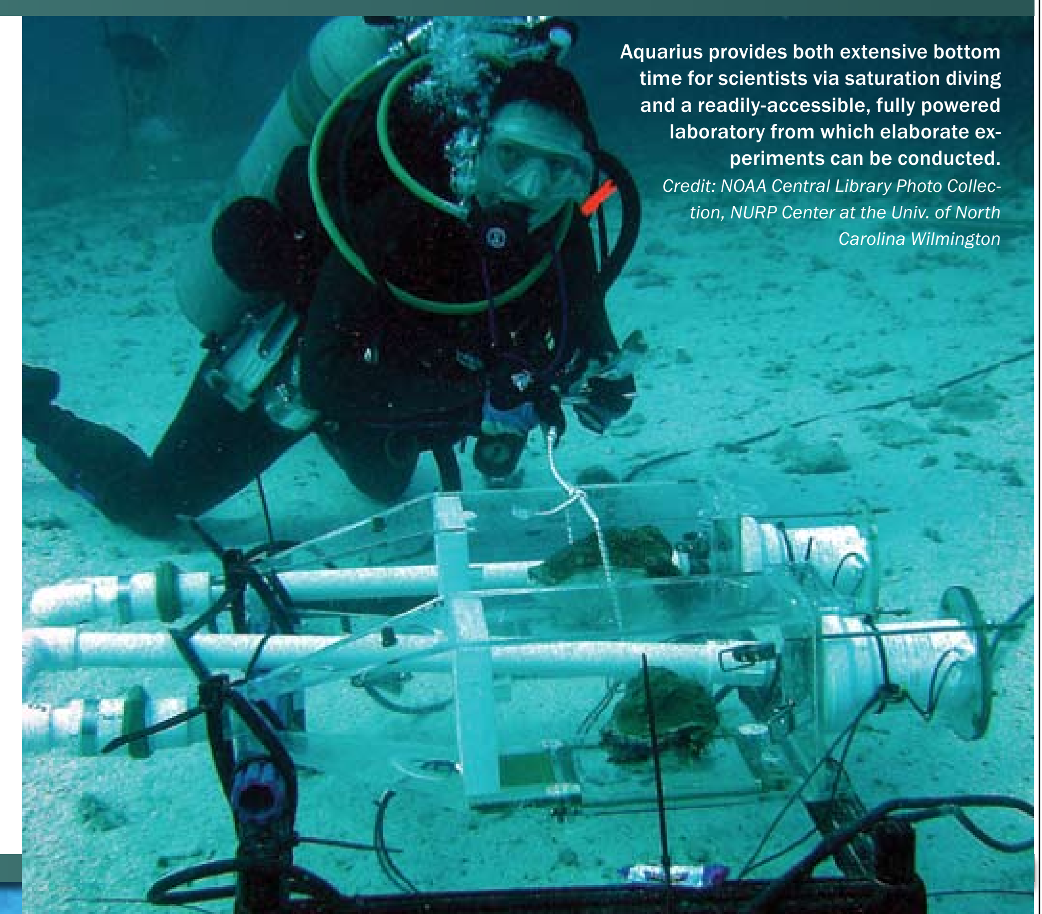
Aquarius residents have included more than 200 scientists from more than 90 organizations, including U.S. and foreign universities. Many of them went there particularly to study the coral reef, which, like other reefs around the world, is now threatened by growing pollution, climate change, disease, and overfishing. This research has been valuable, discovering, among other things, the damage known as coral bleaching done to corals by ultraviolet light, reef changes caused both by humans and by variations in natural systems, and the surprising growth and distribution patterns of sponges.

NOAA and NURP are also looking beyond Aquarius. Part of their underwater scientific vision for the long term is to develop improved habitats that will allow humans to live and work under the ocean in depths of up to 3,000 feet. This next generation of undersea habitats will be mobile, increase bottom time, accommodate more scientists, and offer enhanced research capabilities.

Advanced diving is another way to improve scientific research underwater. In conjunction with the NOAA Diving Program, NURP is working to advance diving techniques that will increase the safe dive depth from 130 feet to 300 feet, lengthen bottom time, and introduce closed circuit mixed gas rebreathers (CCR) into NOAA dive programs. Unlike standard SCUBA, in which the diver's breath is exhaled into the water, CCRs recycle the diver's exhaled breath, remove the carbon dioxide, and replace the consumed oxygen. With CCRs, divers can carry less bottled gas while extending their dive times.

While we may never explore all of the most mysterious and deepest underwater regions of our planet, NOAA continues its task of enabling greater human presence in the sea and closer examination of its wonders.

NOAA's Aquarius Undersea Laboratory — www.uncw.edu/aquarius/



Aquarius provides both extensive bottom time for scientists via saturation diving and a readily-accessible, fully powered laboratory from which elaborate experiments can be conducted. *Credit: NOAA Central Library Photo Collection, NURP Center at the Univ. of North Carolina Wilmington*

TO OUR HEALTH!

OCEANS AND HUMAN HEALTH

BY BARBARA STAHURA

Without oceans, the Earth would be little more than a cinder orbiting the sun. Covering more than 70 percent of the planet, the oceans comprise the largest, most important performer in an intricate dance of elements that allows our world to support a vast and vigorous variety of life forms. Humans exist in a delicate relationship with the ocean, and many of our interactions with this vast body of water — pollution, global climate change, and coastal development — are creating unhealthy effects. As we disrupt the health of the ocean and its inhabitants, we also affect our own.

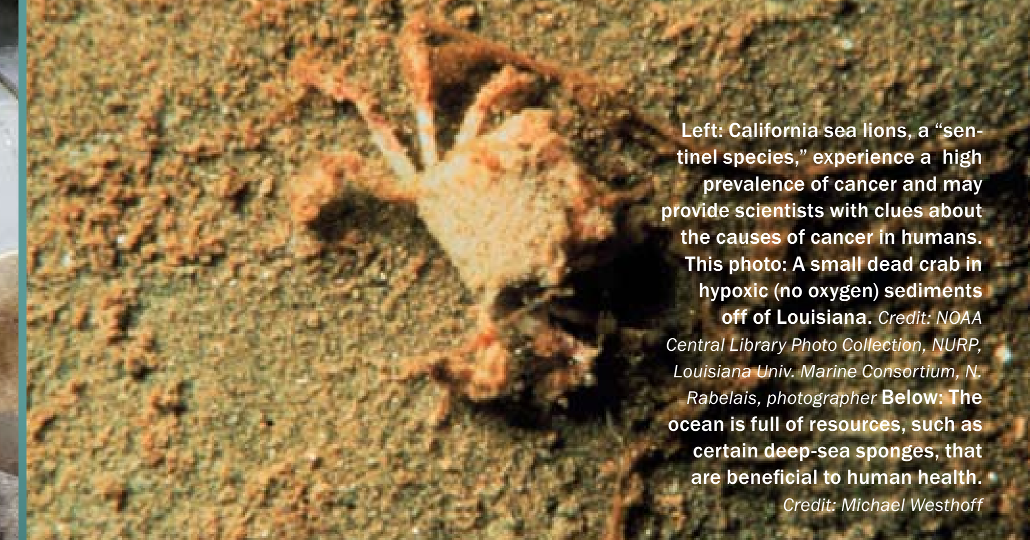
In its capacity as the major U.S. agency with a mandate to investigate the ocean and the Great Lakes, NOAA has long studied this watery world (see sidebar on page 114). NOAA's ocean mission expanded in 2004 with the creation of the Oceans and Human Health Initiative (OHHI). Through OHHI, NOAA cooperates with other federal agencies such as the National Science Foundation and the National Institute of Environmental Health Sciences, state agencies, and academic and private-sector organizations as they seek "to understand the nature of interactions between human health and ocean processes, and to provide useful information to policy- and decision-makers."

The OHHI focuses on the ocean's positive and negative effects on human health and well-being. The positive effects include seafood harvesting and the ecologically-sound discovery of natural products and pharmaceuticals from marine life. Ocean exploration has uncovered thousands of resources that could be used for medical purposes. For instance, a deep-sea sponge was found to contain a substance called discodermolide, an anti-tumor agent now in clinical trials. Another sponge contains compounds now under development as additives in anti-inflammatory skin cream. The negative effects on human health include marine toxins and infectious diseases, chemical pollutants, and harmful algal blooms.

The OHHI is taking an ecosystem-based approach to the research and management of our oceans' health — a comprehensive approach that is geographically specified, considers multiple influences, and strives to balance diverse societal objectives. Many of these elements work together in close relationship. Here are a few examples.

The health and well-being of humans is closely tied to the health of our oceans.
Credit: Photo by Stephanie Dankof

The type of algal bloom known as red tide not only kills various marine life but can cause respiratory distress in people. *Credit: Photo by Brian Dombrowski*



Left: California sea lions, a "sentinel species," experience a high prevalence of cancer and may provide scientists with clues about the causes of cancer in humans. This photo: A small dead crab in hypoxic (no oxygen) sediments off of Louisiana. *Credit: NOAA Central Library Photo Collection, NURP, Louisiana Univ. Marine Consortium, N. Rabelais, photographer* **Below: The ocean is full of resources, such as certain deep-sea sponges, that are beneficial to human health.** *Credit: Michael Westhoff*

Harmful Algal Blooms

Blooms — extremely high densities of toxic algae — appear with some frequency on U.S. coasts. For instance, nearly every year the Gulf Coast of Florida experiences an explosion, dubbed a "red tide," which closes shellfish beds, kills fish, dolphins, and manatees, and causes respiratory distress in people. If these toxic blooms can be accurately predicted, communities can take action to deal with their environmental and health effects, as well as economic pressures. Harmful algal blooms now cause about $82 million in losses for the seafood, restaurant, and tourism industries annually.

Dead Zones

An estimated 200 "dead zones" have been identified in the world's waterways. They are created when an explosive growth of very tiny plants called phytoplankton feasts on nutrients in the fertilizers and sewage swept into the water. When the phytoplankton die and sink to the bottom, they in turn are gobbled up by bacteria that deplete oxygen in the water, effectively strangling all life.

The best-known dead zone is in the Gulf of Mexico, stretching hundreds of miles from the Louisiana coast. It is fed by nutrient-rich pollutants from farmlands far north of the Gulf, which are carried into Midwest and Southern rivers that empty into the Mississippi River.

Sentinel Species

Marine animals can be considered the wet version of "the canary in the coal mine." Just as miners once carried caged canaries as sentinels of toxic gases or lack of oxygen, NOAA today studies the health of some marine "sentinel species" to determine developing problems in the ocean. For instance, California sea lions have a high prevalence of cancer, which may be due to high levels of contaminants. By studying these sea lions, scientists may be able to learn more about the causes of human cancer. NOAA has also studied grass shrimp and found them to be a good indicator of ecological conditions along the East and Gulf Coasts.

Oceans and Human Health Initiative — www.eol.ucar.edu/projects/ohhi

CENTER OF EXCELLENCE FOR GREAT LAKES AND HUMAN HEALTH

The Great Lakes are the world's largest source of freshwater and the source of 90 percent of the surface drinking water in the United States. Their shores are lined with more than 500 recreational beaches, and their waters support $4 billion worth of commercial and sport fishing enterprises. To protect the health of these precious resources, NOAA created the Center of Excellence for Great Lakes and Human Health (CEGLHH), a partnership led by the Great Lakes Environmental Research Laboratory (GLERL) in Ann Arbor, Mich. CEGLHH is one of three NOAA Centers for Excellence established under the Oceans and Human Health Initiative; the other two are located in Seattle, Wash., and Charleston, S.C.

Currently funded through 2009, the Center of Excellence for Great Lakes and Human Health uses an integrated approach to study the Great Lakes' water quality as it relates to human health, particularly beach closures, harmful algal blooms, and drinking water. Never before has such a deeply integrated study of these lakes been undertaken. NOAA is clearly the most qualified agency to undertake this work, using a multidisciplinary approach that includes hydrology, climate, meteorology, and other disciplines. Among areas to be studied are urban and agricultural runoff, industrial sewage, shorebird droppings, lake circulation, pathogens, and harmful algae growth — all of which can combine into a toxic soup unhealthy for humans and other living things.

Jeremy Potter tends the safety line for divers beneath the ice. *Credit: The Hidden Ocean, Arctic 2005 Exploration*


Ice divers Katrin Iken (left) and Shawn Harper (right) enter the water while Coast Guard Petty Officer Louis Bishop tends the line and Elizabeth Calvert stands by as the safety diver. *Credit: The Hidden Ocean, Arctic 2005 Exploration*


Mike Nicholson (left) and Joe Caba (right) move the Global Explorer ROV into position for deployment. *Credit: The Hidden Ocean, Arctic 2005 Exploration*

POLES APART: TWO POLAR MISSIONS

BY BARBARA STAHURA

The polar oceans are hostile environments that pose even more challenges to exploration and research than do warmer seas, but this hasn't deterred NOAA from investigating these regions so crucial to the Earth's climate. Not yet heavily explored, the Arctic and the Antarctic seas shelter great varieties of life, harbor numerous resources, and can tell us much about our planet's health. Two recent missions characterize NOAA's efforts to uncover more about these harsh, majestic environments, one to the north and one to the south.

The Hidden Ocean Arctic 2005

Climate change is turning the once-stable Arctic Ocean into the Earth's fastest-changing ocean area. Warmer temperatures are steadily shrinking the region's centuries-old blanket of ice and could lead to several ice-free months on the sea every year. While potentially devastating to plant and animal life adapted to year-round ice cover, this change might also mean new economic opportunities and challenges, such as management of oil exploration and fishing.

In summer 2005, NOAA funded The Hidden Ocean Arctic 2005 expedition to the Canada Basin to gather baseline data as a benchmark in this transformation, by exploring its three habitats: sea ice, water column, and sea floor. Led by Chief Scientist Rolf Gradinger, and traveling aboard the U.S. Coast Guard icebreaker USCGC *Healy*, the international team of 35 scientists took a census of marine life in one of the deepest parts of the Arctic Ocean.

Ice divers, protected against the frigid water by drysuits, descended under ice several meters thick to gather amphipods and obtain still photos and video. To ensure their safe return from beneath the constantly shifting ice, divers were tethered by a line to safety support on the sea ice surface. Other scientists worked atop the sea ice, taking core samples to examine the plants and animals living and growing in the sea ice. Temperature and salinity measurements of the ice core provide information about the environment inside the ice where organisms live, and provide scientists with information about recent air temperatures in the region. A marine mammal expert listened for seals and whales through a hydrophone dipped in the sea. Other scientists gathered specimens of life in the deep by taking core samples of the muddy seafloor, and some collected gelatinous zooplankton floating in the water.

Sophisticated equipment allowed the team to see beneath the ocean in exquisite detail and over longer periods of time than a human could tolerate. Global Explorer, a remotely-operated vehicle (ROV), glided down to 9,000 feet, capturing fragile animals and shooting stunning high-definition video footage, and a drop camera lowered to the sea bottom documented life there through the capture of thousands of still images. The *Healy*'s sophisticated echosounder systems mapped the deep sea floor, while passive sound detectors tracked whales traveling through the region.

Katrin Iken (left) and Bodil Bluhm move deep-sea mud from the trawl net to a bucket. The benthic scientists will sieve the mud to find creatures within it for additional research. *Credit: The Hidden Ocean, Arctic 2005 Exploration*

An unknown species of commensal amphipod captured below 1,000 meters with the multinet. *Credit: Russ Hopcroft, California State University, Monterey Bay*

The Hidden Ocean expedition began painting a more complete picture of the Arctic food web — a valuable record in the face of the uncertainty of climate change.

The Hidden Ocean – www.oceanexplorer.noaa.gov/explorations/05arctic/welcome.html

Sounds of the Southern Ocean

Imagine what you might hear under the Southern Ocean surrounding Antarctica: The grinding of its immense, moving ice sheets against one another and against the land mass. The basso profundo rumbles of undersea volcanoes and earthquakes. The haunting voices of visiting baleen whales.

In December 2005, scientists from NOAA and the Korean Polar Research Institute traveled to this largely unexplored region for an expedition called Sounds of the Southern Sea. A Russian research vessel — and icebreaker — ferried them to the Bransfield Straits and the Drake Passage, where they deployed seven autonomous underwater hydrophones (AUH) in 400 feet of water, each one tethered to an 850-pound railroad wheel anchor. These hydrophones were specially designed to spend a year recording sounds while submerged in the often-turbulent, icy waters. In December 2006, scientists returned to retrieve the hydrophones.

Above, left: Deploying the second hydrophone off Livingston Island. Above, right: The "Haruphone" hydrophone on the deck of the *Yuzhmorgeologiya*. *Credits: NOAA/Vents, Korea Polar Research Institute (KOPRI)*

What might these sounds tell us? Given Antarctica's relative inaccessibility and severe climate, it has never been possible to study the seafloor's active volcanic regions or to understand how the movement of tectonic plates produce earthquakes or landslides in the region. With a better understanding, scientists can monitor volcanic upheavals and plate movements more effectively and perhaps predict how they might affect the Antarctic or the Earth as a whole. In addition, the Southern Ocean is a critical habitat for great whales, so learning more about how these giant, mysterious mammals live will mean better protection for them — and their presence there means a more wondrous world for us all.

Sounds of the Southern Ocean – www.oceanexplorer.noaa.gov/explorations/05sounds/welcome.html

INTERNATIONAL POLAR YEAR

The International Polar Year (IPY) is 2007-08, the fourth time the nations of the world officially turn their attention to better observation and understanding of the Earth's polar regions to gain a deeper knowledge of the importance of these regions to the major atmospheric, ocean, and terrestrial systems that control our planet. The IPY is a joint initiative of the World Meteorological Organization and the International Council for Science, with 60 countries formally involved in the research efforts.

During the last IPY in 1957-58, international cooperation led to the creation of the Antarctic Treaty, which secured Antarctica as a continent of peace and science, forever protected from the control of any nation. During this IPY, participating nations urge continued scientific collaboration and cooperation, and the sharing of the knowledge gained among all the nations of the world for the good of all.

THE OZONE HOLE

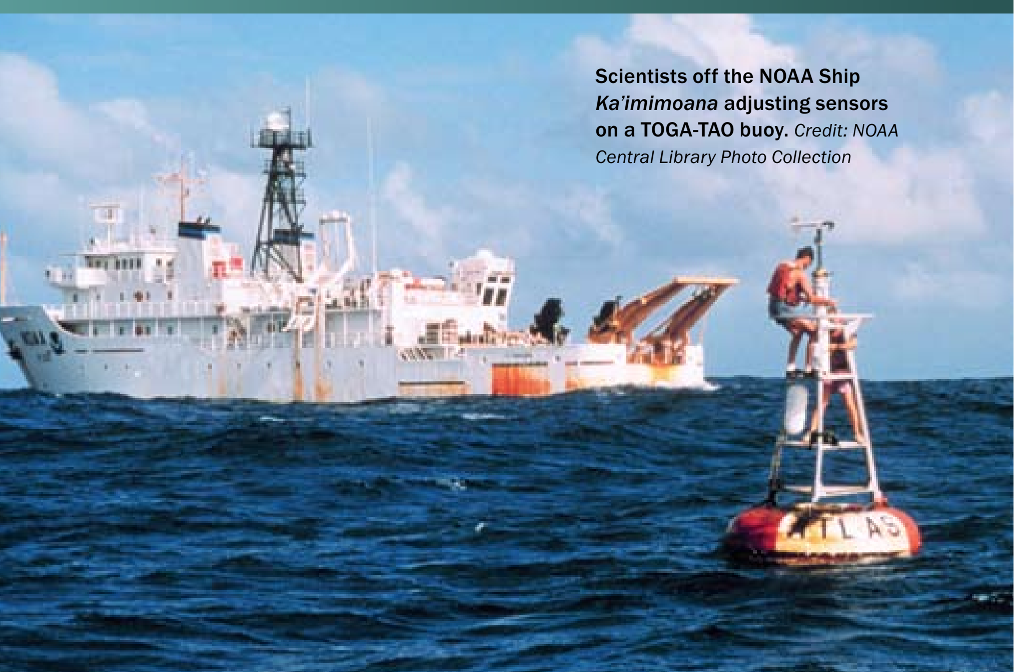
Since the mid-1980s, NOAA has played a key role in understanding the Antarctic "ozone hole," thanks to the work of atmospheric scientist Susan Solomon at the NOAA Aeronomy Lab in Boulder, Colo. Solomon conducted key experiments that identified the mechanism that produces this severe thinning in the Earth's protective ozone layer, namely, chemical reactions involving man-made chlorine. Her work helped bring about the Montreal Protocol, which banned the production of ozone-depleting chemicals, and in 1999, she was awarded the National Medal of Science, the nation's highest scientific honor, for her pioneering research.

When the ozone layer thins, more of the sun's most harmful rays pass through the atmosphere, which potentially increases skin cancers, causes damage to plants, and reduces ocean plankton. Over Antarctica, springtime weather conditions lead to significantly more thinning of the ozone layer than elsewhere in the world.

OCEAN RIDERS: NOAA BUOY ARRAYS

BY BARBARA STAHURA

Personnel off the NOAA Ship *Ronald H. Brown* maintain ATLAS TOGA-TAO buoys on the equatorial El Niño array. These buoys are instrumented to measure ocean temperature at varying depths and give forewarning of El Niño or La Niña events. *Credit: NOAA Central Library Photo Collection, Lt. Mark Boland, NOAA Corps, photographer*



Scientists off the NOAA Ship *Ka'imimoana* adjusting sensors on a TOGA-TAO buoy. *Credit: NOAA Central Library Photo Collection*

Tracking daily weather and long-term climate patterns in the open ocean, as well as occasional events such as tsunamis, is an immense task because of the sheer size of the area to be monitored. In response to this challenge, NOAA has developed sophisticated buoy technology that stands vigilant watch over the vast ocean.

One line of guardians dotted across the equatorial Pacific can give the western hemisphere advance warning of a potentially devastating natural phenomenon that takes months to develop. Maintained by NOAA, this array of moored, deep ocean buoys monitors winds, sea surface temperature, relative humidity, air temperature, subsurface temperatures down to 500 meters, and more — all in order to detect and forecast the weather pattern known as El Niño.

When the El Niño of 1982-83 exploded into one of the strongest of the century, no method existed for forecasting this irregularly occurring — and potentially catastrophic — event. (See “Forecasting El Niño and La Niña,” on page 59.) Not detected until it had nearly reached its peak, by then it was too late to take action to prevent the billions of dollars in damage and the several thousand deaths the weather pattern caused in North and South America.

What was needed was real-time data from the tropical Pacific, gathered and tracked over time, which would enable NOAA to better understand El Niño and the conditions that caused it. In 1984, NOAA's Equatorial Pacific Ocean Climate Studies program and Pacific Marine Environmental Laboratory developed the ATLAS (Autonomous Temperature Line Acquisition System) mooring, a low-cost array of buoys that could transmit the gathered data via satellite relay. A small number of the buoys were deployed as a test, and more were gradually put in place along latitude 110 W beginning in 1985 as part of the 10-year international Tropical Ocean Global Atmosphere (TOGA) program. This was the Tropical Atmosphere Ocean (TAO) array. TAO's full array of 70 moorings included 400 buoys deployed on 83 cruises from six different countries, including the United States.

TOGA ended in 1994, but the TAO array continued under international sponsorship. Later, it became part of the official El Niño observing system, and in 2000, it became the TAO/TRITON array. The eastern sites are occupied by TAO buoys, and those west of 165 E are occupied by TRITON (Triangle Trans Ocean Buoy Network) buoys, which are maintained by the Japan Agency for Marine-Earth Science and Technology.

The NOAA Ship *Ka'imimoana*, or “Ocean Seeker,” maintains and services the TAO/TRITON buoys. A converted Navy vessel, *Ka'imimoana* deploys, recovers, and services the deep-sea moorings, and it also assists in NOAA's oceanographic, climatic, and fisheries research in the Pacific.

Unlike El Niño, which develops over months, a tsunami can begin to form and travel in the minutes it takes for an undersea earthquake or landslide to occur. However, the seismometers that detect earthquakes cannot accurately predict the birth of a tsunami, and tsunamis that begin in the deep ocean cannot be immediately detected along a coast. Only a real-time monitoring and warning system in the deep ocean can hope to issue rapid alerts to the regions in the path of these sometimes monstrous waves. (See “Wall of Water: Tsunami” on page 68.) In 1995, NOAA addressed this challenge with the DART (Deep Ocean Assessment and Reporting of Tsunamis) Project.

DART is operated by NOAA's National Data Buoy Center and is part of the U.S. National Tsunami Hazard Mitigation Project, a combined federal/state effort designed with two goals: reduce the loss of life and property because of tsunamis along the U.S. Pacific coast and reduce or eliminate false tsunami alarms, which in the past have reached a rate as high as 75 percent.

Developed by NOAA's Pacific Marine Environmental Laboratory, the six DART stations have been placed in regions off the southern Alaskan, northern U.S., and upper South American coasts with a history of generating destructive tsunamis. Each station has two components. Anchored to the sea floor, the bottom pressure recorder (BPR) can measure tsunamis with an amplitude of as little as 1 cm in 6,000 meters of water. Its acoustic modem delivers data to the moored surface buoy, which transmits data from the BPR in real time to NOAA satellites and then to ground stations, which can immediately send it to NOAA's Tsunami Warning Centers.

NOAA also maintains automated weather buoys in the Great Lakes, whose waters support billions of dollars in commercial enterprises such as transportation, recreation, and fishing, and whose shores are home to millions of people in the United States and Canada. These moored buoys provide hourly data about meteorological and marine conditions, which enables the National Weather Service to issue weather forecasts and warnings for the region.

National Data Buoy Center, Deep-ocean Assessment and Reporting of Tsunamis — www.ndbc.noaa.gov/dart/dart.shtml

GET WET — OR NOT — TO LEARN ABOUT THE OCEAN

BY BARBARA STAHURA

Volunteers at the Gulf of the Farallones National Marine Sanctuary receive field training for a seals program. *Credit: NOAA Central Library Photo Collection*

In that now familiar photo from space, Earth looks like a beautiful blue marble. The breathtaking azure that covers most of the planet is, of course, the ocean – the source and sustainer of all life. Beneath its surface hide mountains higher than Everest, creatures one-celled to leviathan, and myriad mysteries awaiting discovery in the depths. In that high view from space, the sheer, vast size of the ocean seems to bestow protection from all harm.

In truth, though, the ocean and its ecosystems are suffering from large-scale human activities: pollution, overfishing, coastal development, climate change. Many elements necessary to maintaining a vibrant chain of life around the globe may be in peril because of what is happening in the ocean. According to NOAA, the best way to reverse these trends is to promote widespread ocean literacy. If we learn to respect the ocean for its important role in our existence, and even become fascinated by its beauty and mysteries, we'll be more likely to protect it and use it wisely.

Sadly, tens of millions of Americans don't understand how the ocean affects them every day, even if they live far inland or have never seen the ocean. Existing in an intricate, delicately balanced relationship, the ocean and the atmosphere together create weather and climate, which in turn affect not just how we dress or whether it's a good day for a picnic but also national economies, the health of all life forms, and global food and water supplies, to name only a few. If the ocean-atmosphere relationship is disrupted by large-scale human activity – say, burning coal and oil, which changes the composition of the atmosphere and so raises ocean temperatures – weather and climate act accordingly, and we will feel the effects.

Visitors to the Gulf of the Farallones National Marine Sanctuary learn about an intertidal region of the sanctuary. *Credit: NOAA Central Library Photo Collection, Maria Brown, photographer*

As part of its educational mission, NOAA has created programs to encourage and foster ocean literacy. While NOAA believes everyone should be ocean literate, it is especially important for children, the decision-makers of the future, to explore the workings of our planet's "inner space." Better knowledge of the ocean could lead them to make wiser choices about how they use its many resources. It could also lead them to a career in an ocean-related science, which will not only allow NOAA to employ the educated, dedicated people it needs, but will also help the nation continue to prosper through its relationships with a healthy ocean.

National Marine Sanctuary Program

Want to see humpback whales migrating? Touch a coral reef? Explore a shipwreck? Examine the life in a tidal pool up close and personal? Then visit the protected marine areas in NOAA's National Marine Sanctuary Program (NMSP). From Lake Huron to the South Pacific and along both U.S. coasts, visitors can have fun while learning about the fascinating ocean and its coastal waters.

The smallest marine sanctuary is Fagatele Bay in American Samoa – a quarter-mile-square bay sheltering a coral reef – and the largest, and newest, is the Northwestern Hawaiian Islands Marine National Monument, at 137,792 square miles. Together, the 13 National Marine Sanctuaries protect more than 150,000 square miles of coastal, open ocean, and Great Lakes waters.

As a leader in marine protection, the NMSP provides whale-migration corridors and safe habitat for many marine species, including some close to extinction. Some sanctuaries protect shipwrecks and archaeological sites with historical significance. Each sanctuary includes research, education, and outreach among its activities and may permit recreation, exploration, commercial fishing, and shipping if they fit within the sanctuary's protection mandates.

Can't visit a sanctuary in person? Check out the Encyclopedia of the Sanctuaries, an online guide of photos, streaming video, and information on 100 marine species. (Encyclopedia of the Sanctuaries – http://marinelife.noaa.gov.)

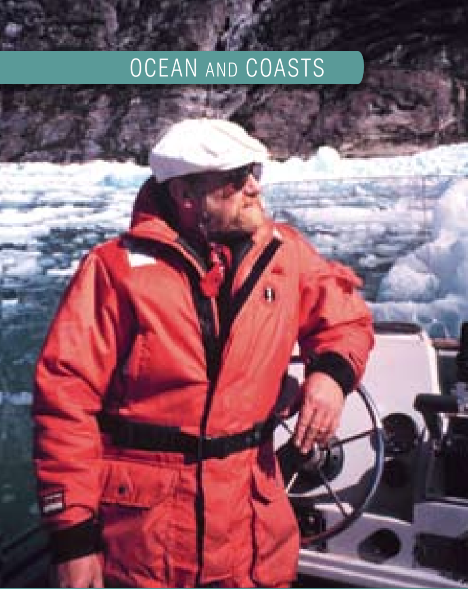
B-WET

In 2002, NOAA established the Bay Watershed Education and Training (B-WET) Program, which offers grants to school districts to educate communities about environmental stewardship in coastal and marine areas. The grants may be used to offer meaningful outdoor ocean-related experiences to K-12 students and to help educate teachers on this topic. So far, B-WET programs have been established at Monterey Bay and Chesapeake Bay watersheds and the Hawaiian Islands. Students have monitored river health, conducted water-quality sampling and intertidal monitoring, kayaked, and been introduced to marine science careers.

OceansLive

It's now becoming possible to explore under the sea without ever getting your feet wet. Along with Immersion Presents, an after-school science education program founded by ocean explorer Robert Ballard, NOAA created OceansLive, an innovative educational program using interactive telepresence technology. By using the Internet to send live, interactive video feeds between underwater sites and land-based locations such as schools, visitor centers, and aquaria, OceansLive will increase ocean and Great Lakes literacy among Americans. For instance, at the Monterey Bay National Marine Sanctuary, visitors have been able to remotely control an underwater vehicle in 50 feet of water, and schoolchildren have been able to interact with divers in Monterey Bay's kelp forest and a Hawaiian coral reef. (See "From Seafloor to Scientists Ashore" on page 108 for more about telepresence.)

National Marine Sanctuary Program – www.sanctuaries.nos.noaa.gov
B-WET – http://sanctuaries.noaa.gov/news/bwet
OceansLive – www.oceanslive.org



Left: Chief Boatswain Nutting takes in the scenery in Tracy Arm. *Credit: NOAA Central Library Photo Collection, personnel of the NOAA Ship* John N. Cobb, *photographers* **This photo: The *John N. Cobb* 1/4 mile from Lamplugh Glacier, Glacier Bay.** *Credit: NOAA Central Library Photo Collection, Commander John Bortniak, NOAA Corps, photographer*

A BOATSWAIN'S STORY: STRYDR NUTTING

BY BARBARA STAHURA

While the public focus often falls on its scientists, NOAA could not perform its various missions without many other people performing innumerable tasks. For instance, there's Boatswain Lowell "Strydr" Nutting of the NOAA ship *John N. Cobb*, NOAA's oldest and only wooden-hulled ship. The scientists aboard would be unable to achieve their missions without him and his crew.

A ship's boatswain — pronounced "bosun" and derived from the Old English word meaning "man of the boat" — is responsible for the deck department, which is basically everything except the machinery that runs the ship and the electronics that guide her. For starters, the boatswain and his crew maintain the ship's exterior and interior, which means keeping it painted and clean. On the 100-foot boat that carries eight crew and four scientists, "hygiene is very important," says Nutting. They also handle mooring and anchoring, maintain and operate all deck equipment, load and stow cargo, and stand watches. On the *Cobb*, however, their duties don't end there.

As a NOAA fisheries and oceanographic ship in Southeast Alaska, the *Cobb* has scientific responsibilities, many of which are performed by the deck crew. "The most important part of our job is satisfying the operational needs of scientists we take with us," says Nutting. "It's my job to figure out how to do what they want without putting anyone in danger."

For these duties, the deck crew members assist in observation of marine mammals and deploy the instruments for oceanographic studies. They collect fish and other samples using methods including trawling, long-lining, and hook-and-line fishing. They have also supported submersible vehicle and diving operations — Nutting used to be a dive master — and they occasionally handle search and rescue missions, which can get "hairy," he says.

After two decades in commercial fishing, Nutting, now 60, went to work for NOAA. He's been aboard the *Cobb* for 17 years. The most appealing aspect of his job is simply being at sea, along with the variety of tasks involved in working on a research vessel.

"A research boat is different than going deep sea," he says. "A deep-sea ship is like a truck carrying things from place to place. Our job is to do things at sea. In addition to actual operations, we do a lot of rigging and fabricating to build equipment for the scientists. We have a wide variety of missions."

Sailing on the *Cobb* is also more interesting than working on more modern ships, he says. As a 50-year-old wooden boat, still in excellent condition and running on its original engine, the *Cobb* requires its crew to know old-fashioned sailing skills such as knot-tying, net mending, rigging, and ship's carpentry. "These are arcane but necessary skills," he says. As the person who teaches these skills and basic seamanship to the new crew members, he says, "It's nice to see their frustration turn to satisfaction."

The *Cobb* is normally out at sea from March through October, requiring seven-day work weeks — and being able to get along with one another. On the 100-foot boat, "You can only get 92 feet away from anybody," explains Nutting. The boat is based in Juneau during its sea time, and its winter port is Seattle.

Nutting has many favorite experiences from his time on the *Cobb*. One of them is running the small boat — a 17-foot Boston whaler — to the base of Alaskan glaciers so scientists can study harbor seals and their pups, who are sometimes hunted by eagles. And there's nothing to equal the thrill of chasing orca in the open sea, getting close enough so the scientists can ID and "dart" them for various studies.

Deck crew of the *John N. Cobb* retrieving a rope trawl. *Credit: NOAA Central Library Photo Collection, personnel of the NOAA Ship* John N. Cobb, *photographers*

So, the next time you hear about a NOAA ocean project making a discovery, remember that, as important as the scientists are, they depend on people like Strydr Nutting to help them make it happen.

NOAA's Office of Marine and Aviation Operations — www.omao.noaa.gov

BY BARBARA STAHURA

“NEW EYES” IN THE OCEAN

DSV *Alvin*, perhaps the most active and successful research submersible.
Credit: NOAA Central Library Photo Collection, NURP, Woods Hole Oceanographic Inst., R. Catanach, photographer

“We now have marvelous new tools that permit exploration in spatial and temporal dimensions that were unachievable 50 years ago. In other words, we will not only go where no one has ever gone, but we will also ‘see’ the oceans through a new set of technological ‘eyes,’ and record these journeys for posterity.”

Report of the President’s Panel on Ocean Exploration: *Discovering Earth’s Final Frontier: A U.S. Strategy for Ocean Exploration*

No matter where on Earth we live, the ocean contributes to our lives. At the most crucial level, the ocean makes the planet livable by regulating global temperatures and providing oxygen. Beyond that, the sea provides paychecks for millions of families. Its bounty includes myriad life forms and other elements that benefit us through medicine, science, and technology. It is a global highway and food storehouse. It holds valuable energy resources and minerals. It provides recreation and increases tourism in ways that add to our joy and support our economy. Even with all the gifts the ocean has already bestowed, and with all the knowledge we have already gained from it, much more awaits: We have explored less than five percent of it. But with advanced technology, we have “new eyes” to see more of the ocean as we venture further into the deep, dark expanse of this mysterious world.

Remote Sensing

The Indian Ocean tsunami of December 2004 could not be seen in the open ocean. Only when the long waves began piling up against coastal slopes did they become all too visible. Yet miles above, radar satellites recorded the tsunami’s height as it literally rippled around the world.

Several days later, NOAA scientists, including Walter H.F. Smith, a geophysicist at the NOAA Laboratory for Satellite Altimetry, used the satellite wave-height data to make depth surveys of the ocean floor, something that will lead to models better able to predict the hazardous effects of tsunamis. Such radar measurements of sea level variations taken from space already are used to make simple charts of unexplored ocean basins and, along with other remote-sensing techniques, can forecast hurricane intensity, the onset of an El Niño, and other weather and climate events. Through the Integrated Ocean Observing System now under development, NOAA and other agencies will be able to deliver enhanced information about the ocean’s activities, protecting more lives and property from harm.

A NOAA-supported mission used new and unobtrusive cameras and lights to image deep-sea animals such as this 3-foot fluorescent cat shark at more than 1,800 feet deep. *Credit: Deep Scope 2005 Science Team*

Underwater Vehicles

Underwater research vehicles are nothing new. Submarines and small submersibles such as Woods Hole's Deep Submergence Vehicle *Alvin* and the *DeepWorker* have been exploring ocean depths for decades on NOAA-sponsored missions and others. Manned submersibles offer some distinct advantages over undersea robots, including the depth perception of a scientist's vision as he or she looks through the sub's viewport. But the operational time of manned submersibles is limited largely by the humans inside. Furthermore, propulsion systems and thruster engines are often noisy, and their lights are very bright so as to accommodate human eyes and cameras, making them disruptive to marine creatures not accustomed to such an intrusive visitor in their watery world. A newer generation of underwater vehicles has greatly enhanced underwater exploration capabilities.

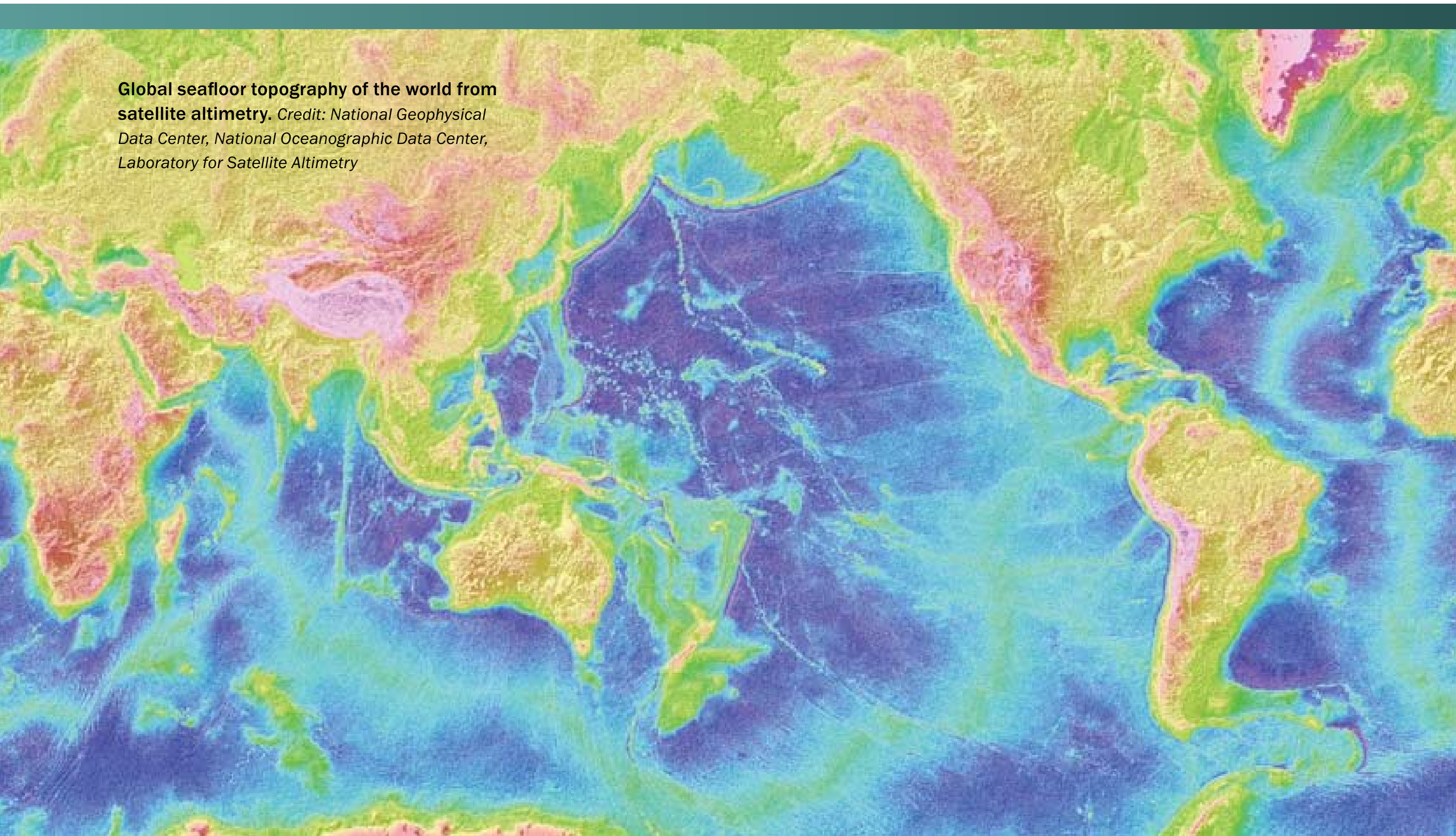
These are remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), and hybrid remotely operated vehicles (HROVs). These tethered and untethered vehicles have taken their place in the inventory of tools now available to ocean explorers and researchers.

NOAA deploys manned submersibles, ROVs, and AUVs on a variety of missions, and is helping to fund an HROV. The unmanned, underwater robots known as ROVs were first developed for industrial uses, such as underwater pipeline inspection. But their use soon expanded into the scientific arena, adding a new dimension to ocean exploration. They are controlled by a human pilot on the support ship through a long, armored cable carrying electrical signals, which also acts as a tether. At minimum, most ROVs carry a video camera and lights, giving scientists the opportunity to view real-time video of regions normally far beyond reach. Sampling systems, still cameras, cutting arms, and measuring instruments can be added to the ROV toolbox. The many advantages of exploring with ROVs include much longer bottom times, decreased human risk, use in harsher environments, and lower cost than human transport vehicles.

AUVs have the added advantage of needing neither a tether nor a pilot. Their preprogrammed onboard computers allow them to conduct various underwater survey tasks and video surveillance, then return to the ship. Some are battery powered, while others are gliders without heavy batteries or fuel, or even propellers. These silent undersea probes can travel long distances, gathering information.

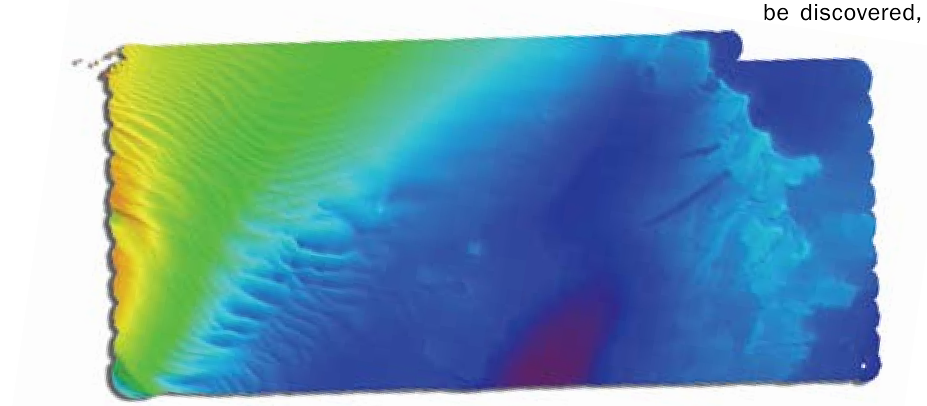
The HROV (currently there is only one, in trials) can operate as either a tethered ROV operated by a pilot, or as a free-swimming, programmed AUV. Because of this split personality, it has been dubbed *Nereus*, after the shape-shifting god of ancient Greece. *Nereus* will not require the typical thick ROV cable. Instead, it will use a micro-thin fiber optic tether up to 25 miles long — a handy device when moving laterally under polar ice, for instance. Instead of the Winnebago-sized housing needed to accommodate typical ROV cable, *Nereus'* tether can be gathered into a box the size of a microwave oven. This cable is fragile — even a 9-pound bass would break it — so *Nereus* is programmed to automatically switch to AUV mode should the tether snap.

Able to withstand extreme pressures and frigid cold, it can dive deeper than Mt. Everest is high — to 36,000 feet — and remain submerged for 36 hours. And with its two modes of operation, it will be able to serve a variety of the exploration and research needs of a deep-ocean expedition.



Global seafloor topography of the world from satellite altimetry. *Credit: National Geophysical Data Center, National Oceanographic Data Center, Laboratory for Satellite Altimetry*

The "Eagle Ray," a deepwater autonomous underwater vehicle (AUV), provides vivid bathymetric imagery of the ocean floor down to depths of 2,200 meters using multi-beam sonar technology. *Credit: NOAA's Undersea Research Program Center at the University of North Carolina at Wilmington* **Below: Example of mapping from the AUV.** *Credit: NOAA's Undersea Research Program Center at the University of North Carolina at Wilmington*



Unobtrusive Eyes

NOAA has worked with Harbor Branch Oceanographic Institution and others to support a series of "Deep Scope" missions that test "new eyes" in the ocean — unobtrusive, innovative, and advanced camera systems, for example, that make it easier to see animals under extremely dim light, so that more ocean animals will be discovered, and more will be seen in their natural habitats.

With these incredible devices, undersea exploration is entering an exciting new era. While the ocean may never be completely explored, we will be able to solve many more of its mysteries in coming years, with "new eyes" in the ocean.

NOAA Oean Explorer: Operation Deep Scope 2005 — www.oceanexplorer.noaa.gov/explorations/05deepscope/welcome.html

SHIPWRECK MUSEUMS: U.S. HERITAGE ON THE SEAFLOOR

BY BARBARA STAHURA

It's been said that more human history has been preserved underwater than in all the museums of the world. That could very well be true. For thousands of years, seagoing ships allowed empires to be built, trade and communication to flourish, and populations to expand. Not surprisingly, many vessels fell victim to weather, war, or other catastrophes, leaving an underwater legacy that now preserves revealing snapshots of human history.

NOAA has become a leader in U.S. maritime archaeology, helping to preserve our national and world heritage in coastal, Great Lakes, and ocean waters through the Office of National Marine Sanctuaries' Maritime Heritage Program, Office of Ocean Exploration, and Marine Protected Areas. NOAA is the steward for 13 National Marine Sanctuaries committed to preserving historical, cultural, and archaeological resources.

Here are two examples of NOAA's work.

NOAA diver John Brooks swims over the shipwreck of the USS *Macaw* on the Midway Atoll, part of the Northwestern Hawaiian Islands Marine National Monument, in 2005. The Office of National Marine Sanctuaries' Maritime Heritage Program, Office of Ocean Exploration, and Marine Protected Areas are avenues through which NOAA works to preserve historical maritime sites. *Credit: Robert Schwemmer*

Ed Grossman holds a firebrick from the steamer *Hassler/Clara Nevada*. *Credit: Alaska's Submerged Heritage Exploration, NOAA-OE*

The USS *Monitor*

The 1975 discovery of the USS *Monitor* led to the creation of the first National Marine Sanctuary to protect this national treasure. This innovative ironclad ship, with her revolving gun turret weighing 120 tons, battled the Confederate ironclad CSS *Virginia* for control of Hampton Roads, Va., during the Civil War. Nine months later, *Monitor* foundered in a storm near Cape Hatteras, N.C. Today, her remains and the surrounding column of water one nautical mile in diameter constitute the *Monitor* National Marine Sanctuary. The *Monitor* was also designated as a National Historic Landmark in 1986.

NOAA teamed with the U.S. Navy and The Mariners' Museum — the principal repository for *Monitor* artifacts — to recover and conserve portions of the vessel.

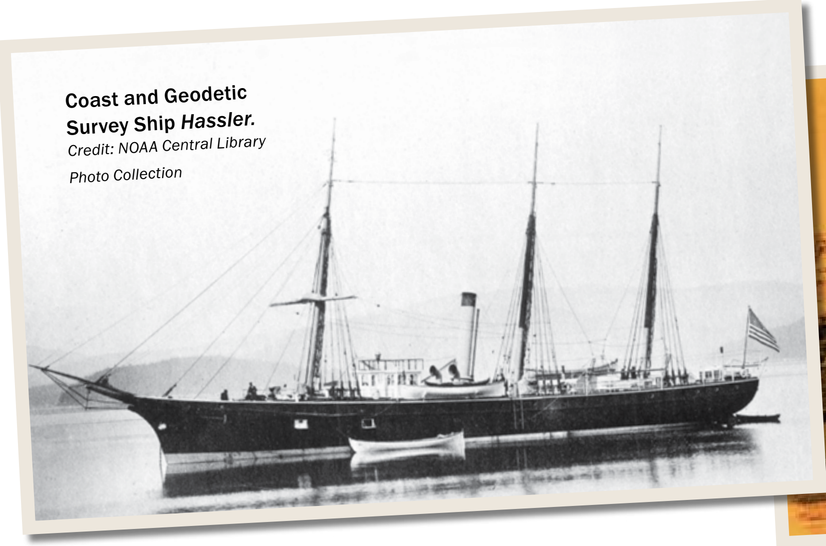
Using the deep-sea submersible *Johnson-Sea-Link II*, archaeologists in 2001 toured the site to document conditions. Not surprisingly, they saw the remains had become home to Moray eels, manta rays, amberjack, octopi, and sponges, to name a few species. Over the next two years, NOAA and Navy divers worked hard to uncover the *Monitor*'s mysteries and prepared to recover major parts of the ship. In 2001, the steam engine and the engine bed frames were raised. The next year, in a 41-day expedition, the massive gun turret was lifted from the sea bottom — after Navy divers removed thousands of pounds of sediment as NOAA archaeologists watched the work via the divers' helmet cameras. The turret was delivered to The Mariners' Museum in Newport News, Va., where it will remain in a conservation tank for five to 10 years. Besides the large cannons, personal items were found inside the turret, including a gold ring, its owner unknown, along with skeletal remains of a Union sailor.

Artifacts from the *Monitor*, including two 17,000-pound cannons, many condiment bottles, dinnerware, and a brass signal lantern used to signal the ship's distress the night she sank, can be found on display in The Mariners' Museum.

Monitor *National Marine Sanctuary – www.monitor.noaa.gov*
Monitor *Expedition – www.ocean-explorer.noaa.gov/explorations/02monitor/monitor.html*

The *Hassler*

Commissioned into service in 1871, the U.S. Coast & Geodetic Survey vessel *Hassler* spent many years working diligently along the Pacific coast before being transferred to work in the cold waters off Alaska in 1892. Named after the first superintendent of the Coast Survey, Ferdinand Rudolph Hassler, the 150-foot vessel transported naturalist Jean Louis Agassiz as he gathered deep-sea samples in the Straits of Magellan. *Hassler*'s crew for many years conducted hydrographic surveys and other government work as part of the U.S. Coast and Geodetic Survey, NOAA's oldest predecessor agency.



Coast and Geodetic Survey Ship *Hassler*.
Credit: NOAA Central Library Photo Collection

USS *Monitor* the night she sank off Cape Hatteras.
Credit: NOAA Central Library Photo Collection

The *Hassler* was decommissioned in 1898 prior to being purchased by the Pacific and Alaska Transportation Company and renamed *Clara Nevada*. On the return leg of her first voyage, *Clara Nevada* was lost just northwest of Eldred Rock near Juneau. No one survived. The cause of the *Clara Nevada*'s demise has never been determined, although people reported seeing a bright orange fireball and the burning ship. It's been speculated that the ship was carrying Klondike gold as well as an illegal shipment of dynamite.

In 2006, NOAA sponsored an expedition with Alaska's Office of History and Archaeology to collect information on several historic shipwrecks in Southeast Alaska, including the *Hassler/Clara Nevada*. The dive team, which included archaeologists and marine biologists, dove down to 88 feet in icy waters ranging from 38 to 41 degrees Fahrenheit to examine the wrecks. They took digital photos and video to record the remains of the ships and their condition. Eventually, they hope not only to better understand changes occurring due to natural processes but also to begin piecing together the traumatic final story of the *Clara Nevada*.

The collaborative project represented one of the first steps toward the development of a management plan for submerged heritage sites off the coast of Alaska — the state with nearly half the nation's coastline. Researchers involved in the project are evaluating the shipwrecks for their eligibility to the National Register of Historic Places.

Hassler *Information — www.oar.noaa.gov/spotlite/archive/spot_hassler.html and www.oceanexplorer.noaa.gov/explorations/06alaska/welcome.html*

NOAA TOP TENS

THE HISTORY MAKERS

Carson's government photo, circa 1940s.

- Cleveland Abbe (1871-1915): Pioneered theoretical dynamic meteorology among many other contributions in the early years of the U.S. Weather Bureau.
- Alexander Dallas Bache (1843-1867): Expanded significantly the mission and geographic domain of the Coast Survey.
- Rachel Carson (1935-1952): Revered as the "mother of the age of ecology."
- George Brown Goode (1872-1888): Established the methods and standards used in fishery research today.

Credit: NOAA Central Library Photo Collection

- Ferdinand Rudolph Hassler (1807-1843): Imbued the Coast Survey, as its first superintendent, with unswerving devotion to accuracy, precision, and scientific integrity.
- David Simonds Johnson (1956-1982): Paved the way for satellite technology in NOAA.
- Ernest Lester Jones (1915-1929): Entrusted by four U.S. presidents to lead the Coast and Geodetic Survey.
- Francis Reichelderfer (1938-1963): Brought modern technology to weather forecasting.
- Joseph Smagorinsky (1953-1983): Combined computers and mathematical models for extended predictions of weather and trends in global climate.
- Susan Solomon (1981–present): Discovered the cause of depleted atmospheric ozone in the Antarctic ozone "hole."

Credit: NOAA Central Library Photo Collection, courtesy of the family of Thomas D. Whitely

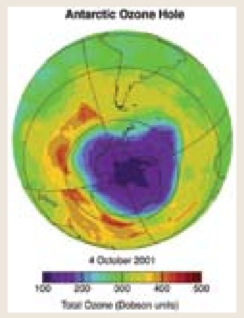
THE BREAKTHROUGHS

- Climate Model (late 1960s): Enabled scientists to understand for the first time how the ocean and atmosphere interacted with each other to influence climate.

Large marine ecosystems (LMEs) produce 95 percent of the world's fish catch, making them the focal point of global efforts for sustained and predictable productivity. Oceanographers and biologists have identified 64 LMEs worldwide. *Credit: www.edc.uri.edu/lme*

- Coronagraph in Space (1995): Enabled improved forecasting of threats to electronic communications on Earth from coronal mass ejections on the sun.
- ECOPATH Modeling (1983): Revolutionized scientists' ability to accurately identify ecological relationships to understand complex marine ecosystems.
- Global Positioning System (1990s): Allowed NOAA's National Geodetic Survey to develop revolutionary methods of positioning and surveying.
- Hydrographic Surveying Methods (throughout the 20th century): Enabled NOAA's Office of Coast Survey to improve surveying efficiency in coastal waters by several different methods, most recently multibeam sonar starting in the 1970s.

- Large Marine Ecosystems (mid-1980s): Advanced the concept of understanding how best to manage large ocean areas for sustained biological productivity.
- Ozone Hole (late-1980s): Theorized and confirmed that man-made chlorine and bromine compounds were causing stratospheric ozone depletion.
- Polar-orbiting and Geostationary Satellites (1960 to present): Revolutionized NOAA's ability to observe the Earth, the atmosphere, the oceans, and space and to forecast natural phenomena.
- Tornado Detection and Warnings (1970s): Discovered that using Doppler radar to peer into storms allows meteorologists to more confidently forecast tornados.
- Warming of the World Ocean (2000-2001): Documented for the first time an increase in heat content of the world ocean for the 40-year period between 1955 and 1998.



The Antarctic ozone hole forms in the southern hemisphere's spring (September to November) following the bitterly cold and dark Antarctic winter when stratospheric ice clouds promote production of chemically active chlorine and bromine. This, in turn, leads to ozone destruction when sunlight returns in the Antarctic spring. *Credit: NASA*

THE HISTORIC EVENTS

- 1970s Conservation and Stewardship Legislation (1972-1976): Ushered NOAA into a significantly increased regulatory role in resource management.
- Earth Day 1970: Established the favorable political climate for enacting five pieces of 1970s conservation and stewardship legislation, thereby creating the "green" side of NOAA.


THE GAYLORD NELSON NEWSLETTER

Washington, D.C.

Earth Day - 1970

Mass Movement Begins

Thousands Marched

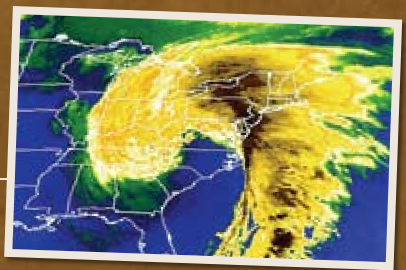
"Everyone's Beautiful"

Special Legislation

500 Invitations

Conceived as an environmental teach-in by Wisconsin Sen. Gaylord Nelson, nearly 10 percent of the nation's population participated in the first Earth Day. Nelson received nearly 500 invitations to speak at various Earth Day events. *Credit: Image courtesy of Wisconsin Historical Society*

- *Exxon Valdez* Oil Spill (1989): Stimulated passage of the Oil Pollution Control Act of 1990, thereby strengthening and enhancing NOAA's capacity to respond to and help reduce impacts from hazardous material spills.
- Hurricane Katrina (2005): Demonstrated the capabilities of all elements of NOAA acting in concert to serve our nation in times of dire emergency.
- National Marine Sanctuary System (1975-2006): Protected areas of U.S. marine and Great Lakes waters for their conservation, ecological, recreational, historical, aesthetic, scientific, and educational value.
- North Pacific Fur Seal Treaty (1911): Served as the forerunner and inspiration for laws such as the Marine Mammal Protection Act of 1972 and other NOAA stewardship legislation.
- Storm of the Century (1993): Marked the first time that NOAA's Weather Service was able to forecast a storm of this magnitude five days in advance and provide storm and blizzard warnings two days in advance.
- Founding of the Survey of the Coast (1807): Marked the beginnings of both the first science agency in an embryonic federal government and NOAA's oldest ancestor agency.



Credit: NOAA National Climatic Data Center

- TIROS I (1960): Ushered in a new era of weather observations from space with the launch of the first meteorological satellite.
- World War II (1941-1945): Transformed, more than any other event since their founding in 1807 and 1871, the technological, geographic, and social landscape of the Survey of the Coast and the Weather Bureau, two legacy agencies of today's NOAA.

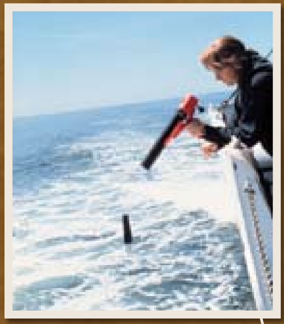
Hydrographic survey signal on Mt. Suribachi, Iwo Jima, February 1945. *Credit: NOAA Central Library Photo Collection*

FOUNDATION DATA SETS AND PRODUCTS

Credit: Smithsonian Fish Specimens, Sandra Raredon, photographer

- The Fish Collection (1856–present): is of great historical value as a window to early expeditions and voyages of discovery. It is also taxonomically significant, containing about 20,000 of the 28,000 species of fishes worldwide.
- Mauna Loa Carbon Dioxide Record (1958–present): is the longest continuous record of atmospheric concentrations of carbon dioxide, the chief greenhouse gas responsible for global climate warming. It is often called the most important geophysical record on Earth.
- Mussel Watch (1960s–present): is the longest continuous contaminant monitoring program in U.S. coastal waters. Its data set includes contaminant concentrations in sediments, oysters, and mussels monitored at 300 sites around the country for over 100 organic and inorganic pollutants.
- National Spatial Reference System (1816–present): is the complete set of survey marks or reference points that surveyors use as starting points to ensure accurate and consistent surveys across the nation.
- Nautical Charts (data collection: 1816–present; chart production: 1844-present): are a suite of over 1,100 charts that depict coastlines, islands, rivers, harbors, and features of navigational interest such as water depth, hazards, and aids to navigation. Charts are constructed by combining information from shoreline mapping, tide observations, depth soundings, and geodetic positioning.
- NOAA Weather Radio (1950s–present): is the primary and official source of weather data, forecasts, and life-threatening weather warnings for the United States.
- Regional Fisheries Data Sets (California Cooperative Oceanic Fisheries Investigations, 1949–present; Biostatistical Menhaden Surveys, 1952–present; Northeast Bottom Trawl Surveys, 1963–present): are the backbone of NOAA Fisheries scientific research and conservation decisions.
- Tropical Atmosphere Ocean Array (1985–present): is a network of deep-ocean buoys at 67 sites in the equatorial Pacific Ocean that collect ocean and atmospheric data to predict the global climate phenomenon known as El Niño.
- Weather Observations (1890–present): are daily reports on air temperature, precipitation, and other weather factors such as snow depth, river levels, and soil temperature from volunteers around the nation in NOAA's Cooperative Observer Network.
- World Ocean Database (1961–present): is the world's largest collection of vertical profile data of ocean characteristics available internationally without restriction. It contains data for 28 ocean variables in 11 distinct data sets.

Producing nautical charts relies not just on hydrographic surveys and onshore positioning. It also requires observations of water levels made by tide measuring stations like the one shown here. *Credit: NOAA Central Library Photo Collection*



Launching an expendable bathythermograph (XBT) from the NOAA Ship *McArthur*. These instruments measure ocean temperature. An XBT data set is one of 11 data sets in the World Ocean Database. *Credit: NOAA Central Library Photo Collection, Capt. Robert A. Pawlowski, NOAA Corps, photographer*