U.S. DEPARTMENT OF COMMERCE ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION JULY 1969

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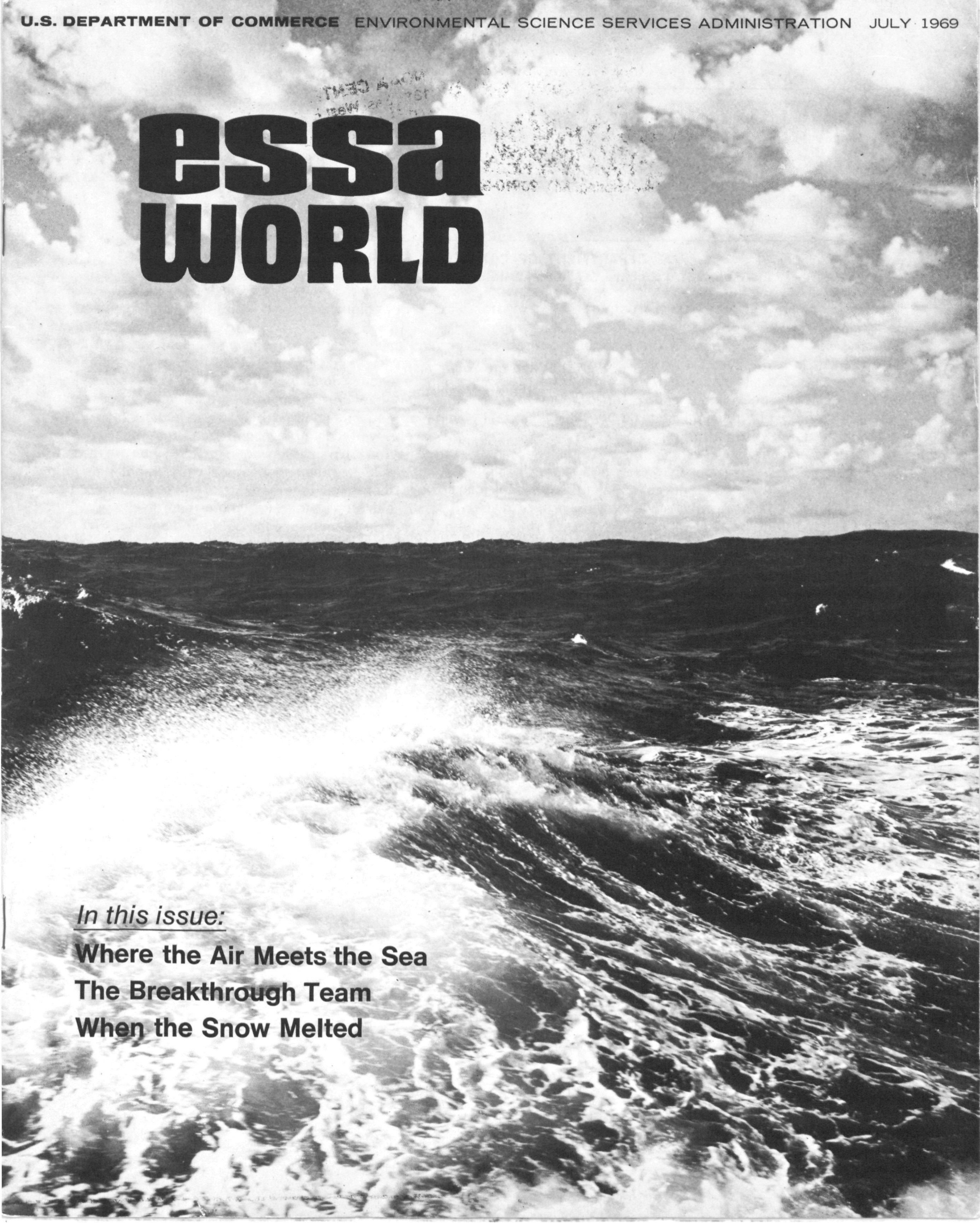

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National Oceanic and Atmospheric Administration

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U.S. DEPARTMENT OF COMMERCE, MAURICE H. STANS, Secretary
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION, Dr. Robert M. White, Administrator
Dr. John W. Townsend, Jr., Deputy Administrator

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COVER
Weather begins at the ocean surface, where energy from the sea joins the atmosphere in processes being studied intensively by the Barbados Oceanographic and Meteorological Experiment.

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RICHARD P. AUGULIS

ESSA and the Young Man*

Where is ESSA going in the years ahead? Is there a place in this organization for the young scientist or professional man? Will ESSA offer challenging job opportunities to its young employees?

These are just a few questions job-seeking college graduates or young ESSA employees may be asking themselves. The answers are very important to a young man or woman with a few years of job experience or starting his or her career. No organization can continue to grow, develop, and improve unless new ideas are introduced and present ones renovated to adjust to the changing times. New sources of talent must be tapped and instilled into the mainstream of an organization. In this way, growth and improvement are attainable goals.

The Environmental Science Services Administration is no exception to this and recognizes the importance of the young man in its organization. Last December one of ESSA's line components, the Weather Bureau, attempted to do something about tapping some of its young talent. Hazen H. Bedke, Director of the Weather Bureau Western Region, proposed that a Council of Young Meteorologists from the Region be formed with the purpose of examining and discussing the weaknesses and strong points of Weather Bureau operations. He wanted the Council to come up with some concrete suggestions and recommendations for improvement.

The Council meeting was held at the Regional Headquarters in Salt Lake City in early February. The Council itself was composed of nine meteorologists and a hydrologist from weather offices in the Western Region. These included offices in the larger cities of Los Angeles, San Francisco, and Seattle, as well as medium and smaller population centers like Salt Lake City; Las Vegas; Helena, Montana; and Medford, Oregon. This allowed for a representative cross-section of weather user requirements and Weather Bureau operations. The age range of the Council members was from 26 to 31 years, with an average of 28 years. All members had bachelor's degrees in meteorology, with three having received their master's degrees.

The closed-door sessions lasted for two days with no-holds-barred discussions, making the exchanges candid and stimulating. Topics discussed varied from training programs for prospective employees and experienced forecasters, to changes in the public service forecast program. The spirited exchanges of the members' experiences and ideas attested to the group's enthusiasm and its desire to improve the Weather Bureau. After completion of the sessions, the recommendations of the Council were presented to Mr. Bedke and his staff.

To many of the young meteorologists, this was the first opportunity to air their ideas and opinions about the organization for which they work, and to know someone was listening. Too often, this is not the situation in an organization. The young college graduate or employee is placed in the background and expected to find his own way. In due time, he'll have enough experience or seniority to have his chance. The fact that the young employee is not experienced enough to contribute to the group is a common complaint from senior employees. Why can't they see what he has to offer *now?* All too often, no organized career ladder is provided by the employing organization for the young employee's development and growth. Unfortunately, when this philosophy is adhered to, both the employer and employee suffer. The young worker feels rejected because of a lack of input, and either gives up, falls into a monotonous routine, or moves to more fertile and challenging employment. The employer loses potential talent to someone else and stunts the growth of his company or organization. The time for prevention is during the early years of a young person's employment. The vigor of youth comes once and should be tapped at this opportune moment. As time goes on, this becomes more difficult.

The Council of Young Meteorologists is an example of ESSA and the Weather Bureau using their young talent. No Council member expects all the recommendations to be implemented; however, the fact that his ideas and opinions were listened to imparts the feeling that he is an important part of the organization.

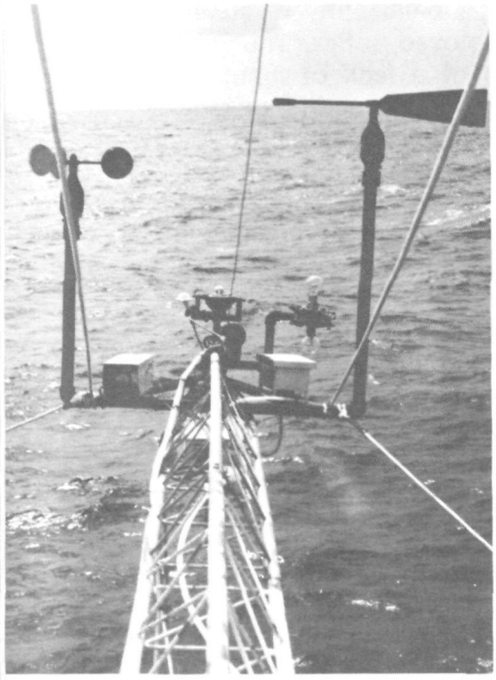
With such thinking and progressive leadership by ESSA's agencies, the future of the young man in ESSA is bright. Challenging job opportunities and an important place for the young man will be available in the future. The opportunity is there—it remains only for the young employee to express himself and take advantage of it. □

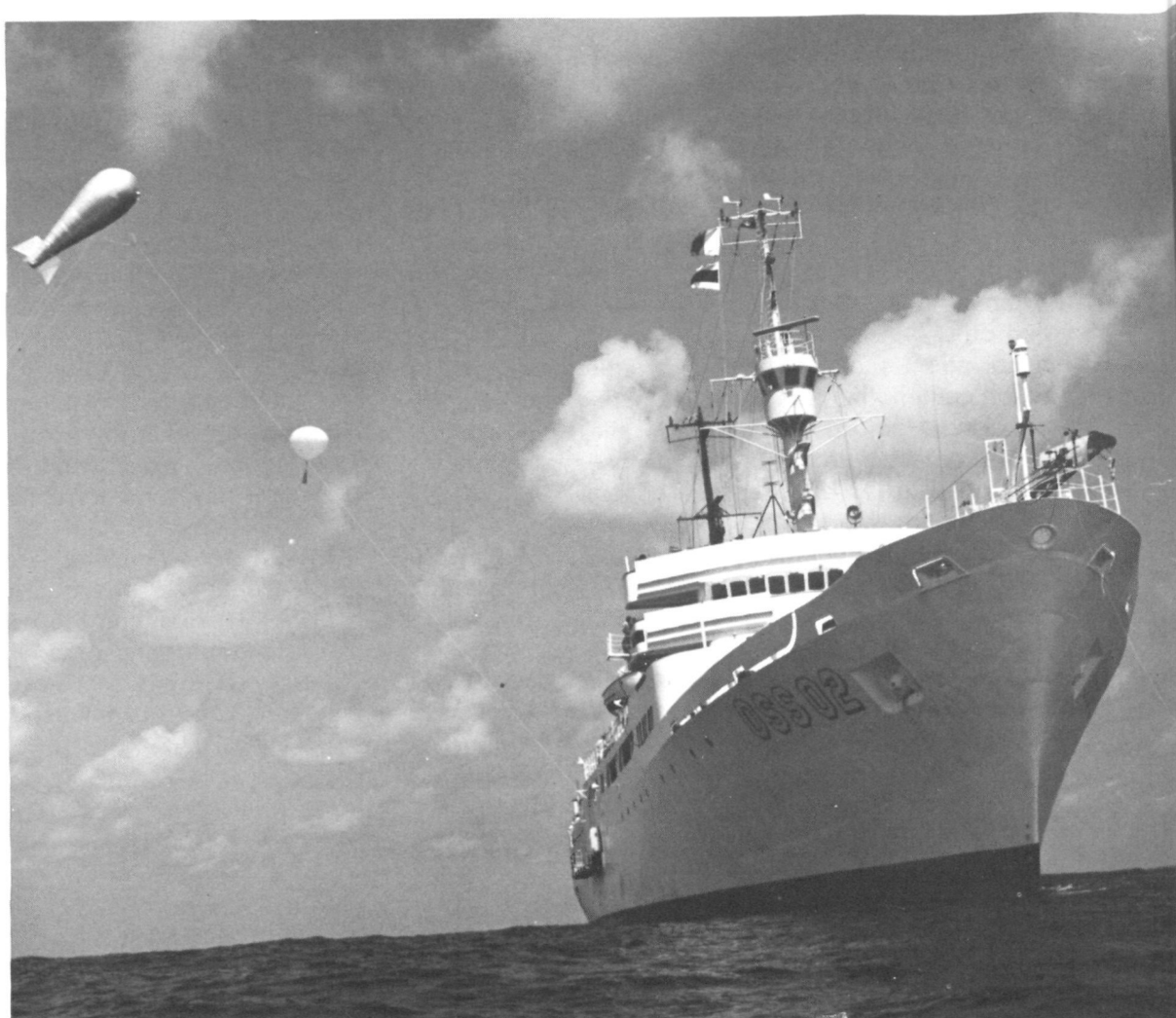
Richard P. Augulis

Richard P. Augulis
President
Council of Young Meteorologists
Western Region, Weather Bureau

** Recognizing the need for ESSA's younger men to have a voice in the direction of the agency, Hazen Bedke, Director of the Weather Bureau's Western Region, encouraged the formation of a Council of Young Meteorologists. At my suggestion, this issue's editorial was written by the President of the Council.*

Robert M. White, Administrator





(Top) RFF and Navy planes on a BOMEX mission. (Left above) A boom on the bow of each ship is instrumented to measure low-level weather conditions. (Right) The DISCOVERER flies a boundary layer instrument package, while a radiosonde rises from the deck to gather upper-air data.

A massive national effort is using science's newest techniques to learn what happens

WHERE THE AIR MEETS THE SEA

Where does weather begin?

Perhaps immediately above the oceans, where energy from the sea joins the atmosphere.

Scientists are confident that this sea-to-air swap is the first building block in the general circulation which envelops our earth and governs our lives.

Learning more about the turbulent journeys of water vapor from the sea to the top of the 6,000-foot layer of atmosphere in which the trade winds blow is one of the prime goals of the Barbados Oceanographic and Meteorological Experiment.

An armada of ships and planes, and 1500 scientists and technicians, converged on Barbados at the beginning of May to mount the most difficult and complex scientific effort ever conducted over a large ocean area.

The 166-square-mile island was selected as the base for the experiment because it is the easternmost of the West Indies, with no land between it and Africa to disturb the transatlantic course of the trade winds.

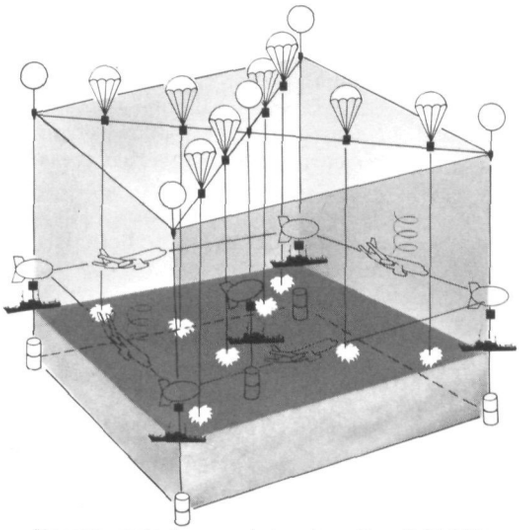
In the three-month experiment which ends July 28, 24 planes, 10 ships, several satellites, a dozen buoys, and a vessel that flips from horizontal to vertical position will have gathered data from a parcel of the atmosphere and ocean covering 90,000 square miles of the Atlantic. Vertically, the BOMEX "cube" stretches from the sea floor at a depth of 18,000 feet to an altitude of 100,000 feet above sea level.

During and after the experiment, scientists will take history's longest, hardest look at an area of air and sea and will attempt to relate thousands of findings to the grand schemes of global weather.

BOMEX is a national program, with participation by seven federal departments and independent agencies, twenty universities, and six industrial laboratories, and with the cooperation of the Government of Barbados. It is the first of a series of large-scale research projects planned by the nations of the world under the Global Atmospheric Research Program (GARP) and directed toward the development of the World Weather Watch.

BOMEX

BARBADOS OCEANOGRAPHIC AND METEOROLOGICAL EXPERIMENT



Energy entering and leaving the BOMEX cube is being measured by instrumented aircraft and by the four ships at the corners.

U. S. Government participants are: Department of Commerce (Environmental Science Services Administration); Department of Defense (U. S. Air Force, U. S. Army, U. S. Navy, and the National Guard Bureau); Department of the Interior (Bureau of Commercial Fisheries); Department of Transportation (U. S. Coast Guard); Atomic Energy Commission; National Aeronautics and Space Administration; and the National Science Foundation. Universities and independent research laboratories in the United States, Canada, and Barbados are taking part.

They came to Barbados to study the links between sea and air. The mechanism of sea-air interaction is almost unknown, yet it is the primary process which drives the atmosphere's circulation and its weather systems. Until this process is understood, it will be impossible to extend weather prediction to more than a few days.

Explaining the objectives of the BOMEX experiment, its Director, Dr. Joachim P. Kuettner, described the air-sea interface as the scene of a complex and continuous exchange of energy, water, gases, and particulates.

"Most of the heat received from the sun," Dr. Kuettner said, "is stored in the tropical oceans between the latitudes of 30 degrees North and 30 degrees South, a region representing half the earth's surface.

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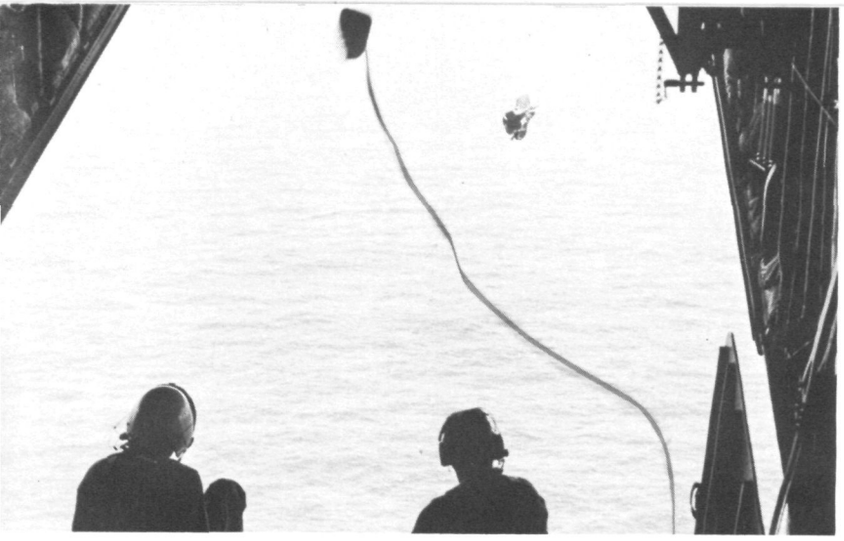


Collecting data capsules from the ships, the Air Force C-130 strikes the line and the balloon bursts and falls away.

The data package, aerodynamically shaped to fly with a minimum of oscillation, starts its journey planeward from the DISCOVERER.

"In contrast, the earth loses heat by radiation almost uniformly at all latitudes, so heat has to be transported from equatorial regions to higher latitudes. Strangely enough, this transport is not done by the ocean, but primarily by the atmosphere. This process, of which relatively little is known, seems to occur in three stages. First, the energy in the ocean transfers to the atmosphere in a turbulent boundary layer about 6,000 feet thick. Most of this energy moves from ocean to air as latent heat in the form of water vapor. Next, the energy finds its way from the boundary layer to the upper layers of the troposphere. Finally, it is transported to higher latitudes by fast-moving air currents, sometimes in the nature of jet streams."

The Barbados Oceanographic and Meteorological Experiment is exploring the first two steps in this process, examining in detail the exchange of energy between ocean and atmosphere and the vertical and horizontal spreading of these energies within each fluid.

ESSA—as the lead agency for BOMEX—is coordinating and directing the experiment through the BOMEX project office and the control center on Barbados.

The BOMEX array is a square bounded by four Coast and Geodetic Survey ships—the OCEANOGRAPHER, DISCOVERER, MT MITCHELL, and RAINIER—with the Coast Guard Cutter ROCKAWAY stationed in the center.

In a staging period during March and April, special instrumentation and supplies were placed aboard these five vessels at Gulfport, Mississippi, where port facilities were provided by the State of Mississippi. Equipment installed included signal conditioning and recording devices, sensor equipment, meteorological booms, boundary layer instrument packages, and free-fall mooring systems.

The free-fall mooring systems were designed to permit the ships to anchor at their stations in 18,000 feet of water, and thereby eliminate the need for continuous maneuvering. The systems were the first production models of the size required, and their use in BOMEX was the first time that ships of such size attempted to anchor for so long at such great depths. When the mooring systems were dropped as BOMEX began, those on the MT MITCHELL and the RAINIER failed, but the ships were able to operate satisfactorily in a station-keeping mode by using their bow thrusters and variable pitch screws.

Also installed at Gulfport, aboard the OCEANOGRAPHER, RAINIER, and MT MITCHELL, were newly developed windfinding-at-sea systems which provide a capability for making winds aloft and upper-air soundings from a moving ship. The windfinding system had been developed over the past few years for the Weather Bureau's merchant ship weather program, and the Bureau made the operational prototypes available for the BOMEX project.

A 30-foot boom was fixed to the bow of each of the five ships to measure near-surface environmental conditions. On the boom, an array of meteorological instruments senses dry bulb, wet bulb, and sea surface temperatures, relative humidity, wind speed and direction, and net, incident, and reflected radiation.

Tethered, dirigible-like balloons—26 feet long and 10 feet in diameter—flown from the five vessels carry instruments that measure temperature, humidity, and wind at three levels close to the sea surface. These systems are called BLIP—for Boundary Layer Instrument Package.

A special multipurpose meteorological radar aboard the USC&GSS DISCOVERER makes upper-air wind observations, shows the location and extent of precipitation areas, and permits estimates of the duration and rate of precipitation from individual rain cells.

Signal conditioning and recording devices, designed and developed by NASA's Mississippi Test Facility and its contractors, were installed on the ships at Gulfport. These systems tape record the basic data taken by the shipboard meteorological and oceanographic instruments.

After each experimental period, the data tapes are flown from Barbados to the Mississippi Test Facility for processing. The Facility—a component of NASA's Marshall Space Flight Center—is operating the data-management system for the basic BOMEX experiments.

The first data was retrieved from the five ships on May 7, in a 1396-mile airlift operation executed by a C-130 of the 54th Squadron, Aerospace Rescue and Recovery Command.

The initial pickup was made from the OCEANOGRAPHER, the farthest ship from land. Millions of bits of data accumulated on magnetic tape were waiting aboard the ship in a red-and-white-striped, 120-pound capsule.

The data snatch was an ingenious process. The package to be recovered was attached to a 500-foot line and tethered to a balloon. Three bits of red paper were spaced on the line, and the recovery plane, going 140 miles an hour, aimed for the center piece, a few feet below the balloon. A yoke, 16 feet wide when extended, was on the nose of the plane. When the plane hit the line, the yoke captured it.

After the line was caught, the few feet at the top whipped back over the plane; at this point, the pilot, copilot, or flight engineer opened a window or hatch, attached a stout string to it, and fed it to the rear of the plane. There, through the cavernous open doors of the plane, loadmasters retrieved and secured the line and winched in the package flying below.

In succession, data capsules were snatched from the RAINIER, ROCKAWAY, DISCOVERER, and MT MITCHELL. Nearly three billion bits of data were retrieved in the operation.

After a quick scanning at BOMEX headquarters, the data tapes were flown to NASA's Mississippi Test Facility, for data processing and reduction. Without the sea-to-air operation, the first data could not have been inspected before the third period of the three-month experiment.

In addition to the vessels at the corners and the center of the array, other ships have

Standing at the cavernous open doors of the C-130, an Air Force loadmaster makes ready to winch in the data-filled capsule.

It's aboard. The Aerospace Rescue and Recovery Command, which retrieved the data, last year saved over 2000 men in Vietnam.

participated in the project at various times. They are the Coast Guard Cutters LAUREL and COURAGEOUS, the U. S. Navy Ship GILLISS, the Cape Fear Technical Institute's ADVANCE II, and the Bureau of Commercial Fisheries Research Vessel UNDAUNTED.

A Floating Laboratory Instrument Platform — FLIP — made available to BOMEX by the Navy and Scripps Institution of Oceanography is the last word in sophistication in this esoteric field. An unpowered, 355-foot platform resembling part of a ship at the end of a 300-foot tube, she is flipped when the tube is filled with water. Upended, she presents a stable platform for scientific study. A network of instrumented booms extends outward, upward and downward from the small portion above water.

Twelve buoys positioned in the BOMEX array measure ocean currents and temperatures, sea surface temperatures, and meteorological conditions close to the surface.

Information at levels up to 60,000 feet is being gathered by a fleet of aircraft that includes the four planes from ESSA's Research Flight Facility, weather reconnaissance and research aircraft from the Air Weather Service and the U. S. Navy, and other planes from the National Center for Atmospheric Research, the National Aeronautics and Space Administration, Woods Hole Oceanographic Institution, Colorado State University, and the University of California.

A special aircraft control center, with Barbadian flight controllers supervised by a Federal Aviation Administration representative, guides all aircraft passing over the BOMEX ocean areas.

During the first three BOMEX data-gathering periods—May 3-15, May 24-June 10, and June 19-July 2—the principal emphasis of the project has been on interactions between the ocean and the atmosphere.

According to Dr. Joshua Holland, Chief Scientist for the Sea-Air Interaction Program, the study was designed to examine in detail the transfer to the atmosphere of heat received by the ocean from solar radiation.

"Two independent methods have been used in the study," Dr. Holland explains. "One, called the point method, measures the upward and downward flow of energy in both air and sea at specific points on the sea surface.

"The second or volume method treats the BOMEX area as a cube. Instrumented aircraft flying around the large cube of air measure the inward and outward flow—just as a museum guard counts people going in and people coming out. Between aircraft flights, the ships at the corners of the array record this flow."

In concentrated four-day observation periods, the BOMEX area was measured by instrumented balloon, by instruments dropped from aircraft, ships at the corners of the array, and by day and night flights around the cube's outer perimeter. During these intensive data-gathering periods, serial rawinsonde observations and dropsonde observations were taken on all four days, special flights were made on three nights and two days, and shipboard observations were scheduled to coincide with the aircraft observations.

These measurements will be used to calculate the net gains or losses in heat, moisture, and wind energy in the volume of air overlying the BOMEX square, and the amount of heat and moisture that the atmosphere over the area receives from the sea.

One of several approaches to the measurement of the transport of water vapor from the ocean is the gust probe used by a variety of BOMEX aircraft. A sophisticated version of this instrumentation system has been installed by the Research Flight Facility, ESSA's aerial fleet, to measure water vapor transport at varying heights above the ocean. All the planes' noses are equipped with needle-like red-and-white-striped booms, the world's most sophisticated weathervanes.

The five ships in the BOMEX array and the Floating Laboratory Instrument Platform also are measuring water vapor transport, among other things, but in ways different from those used by the RFF.

During the fourth data-gathering period —July 11-28—the BOMEX project will concentrate on exploring large convective systems over the tropical Atlantic. It is in these systems that most of the energy contained in the atmospheric boundary layer is transported to higher levels and distributed throughout the troposphere. A fleet of aircraft will explore the tropical disturbances, with the specific objective of gaining the information needed for improved mathematical models of the global atmosphere.

Convection over the tropical oceans takes place in large cloud clusters, easily seen in satellite pictures, which form and die in a surprisingly short time in the general neighborhood of the intertropical convergence zone—the region where the southeast trades of the Southern Hemisphere meet the northeast trade winds of the Northern Hemisphere. These cloud clusters may attain diameters of 300 to 500 miles.

Another tropical system to be studied during July is the so-called "inverted V," a disturbance of about 1000 miles in length, with the characteristic V-shaped cloud pattern for which it is named. Traveling westward out of Africa, the inverted V sometimes blows up into a very large cloud cluster over the tropical Atlantic, and occasionally develops into a hurricane.

Dr. Jule Charney of the Massachusetts Institute of Technology is Scientific Director for the exploration of tropical convection systems, in which eleven aircraft will gather some preliminary scientific information and gain experience in highly flexible scientific flight operations based on satellite pictures. For this phase of the project, NASA's ATS-III (Applications Technology Satellite) has been moved eastward, and a satellite ground station has been installed on Barbados to receive continuous daylight pictures of the BOMEX area from the earth-synchronous spacecraft.

To increase the chances of intercepting tropical disturbances, the ship array will be flipped south on July 11, by moving the Coast Survey ships RAINIER and OCEANOGRAPHER to positions near seven degrees North, while the other vessels remain at their former stations. In this way, the latitudinal spread will be extended to incorpo-

continued

rate the intertropical convergence zone.

If a sufficient number of convective disturbances does not pass through this extended array, flights will be staged from advanced bases in Brazil and Africa. At least six of the project's long-range aircraft are capable of reaching any point over the tropical Atlantic between Africa and Barbados with an operational capability of two hours over the target area.

The more than 80 independent research projects within BOMEX have been grouped into five major program areas, which include oceanographic, radiation, and satellite studies in addition to the sea-air program and the exploration of tropical convection systems.

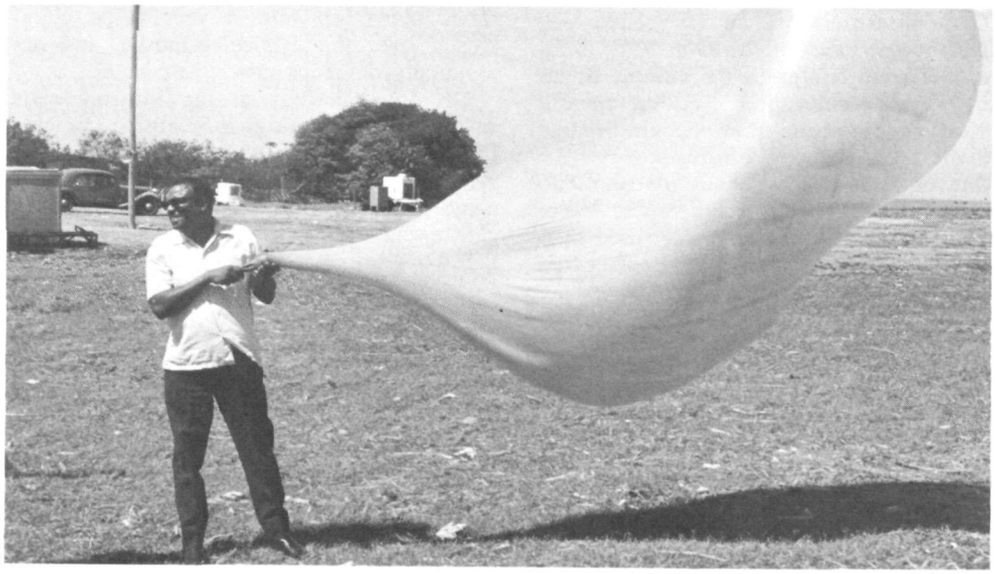
The oceanographic program encompasses various objectives related primarily to processes in the upper ocean and at the sea-air interface. The experiments range from studies of the temperature structure in the ocean and of the behavior of surface and internal waves and ocean currents, to mathematical modeling of the ocean-atmosphere as a single system.

In the radiation program, scientists are attempting to determine the radiation budget over the entire BOMEX area from the ocean surface to the top of the atmosphere. This analysis is linked closely with the total energy budget of the sea-air interface. The four experiments measure radiation moving upward and downward at the sea-air interface, at various levels above the sea, at the top of the BOMEX cube, and along the lateral boundaries of the array.

The BOMEX satellite program has many facets, some operational and others of a research nature. Throughout the three-month experimental period, excellent day and night weather coverage is afforded by direct readout of photographs from the ESSA Automatic Picture Transmission satellites and from Nimbus III. The weather facsimile (WEFAX) experiment on ATS-III relays other material from the National Environmental Satellite Center at Suitland, Md., to the BOMEX control center at Barbados. By this method, the Satellite Center sends a special mosaic of an area of a million square miles, centered over Barbados, to the BOMEX control center every evening. ATS-III's communications capability has also been used for experimental communications between the BOMEX ships and aircraft.

Satellite coverage will become a vital factor in flight planning during the July exploration of tropical disturbances. The ATS-III synchronous satellite has been moved to 47 degrees West, where it will provide continuous high-resolution views of the cloud cover over the "flipped" BOMEX array. The pictures received at the special Barbados ground station will be used to select tropical convection systems for investigation. Satellite data from all these sources provides scientific background information for many of the BOMEX experiments. In the field of satellite meteorology, advanced techniques for deriving winds and other parameters from satellite pictures will be checked against the measurements taken from other platforms. The satellite program also supports the development of new spacecraft instrumentation by permitting comparison of remotely sensed data with direct measurements from ships and aircraft.

When all the results are in, and the data collected by ships, planes, buoys, satellites, and land stations has been analyzed, man will have vastly increased his store of knowledge about the mysterious beginnings of the awesome phenomena we call weather. □

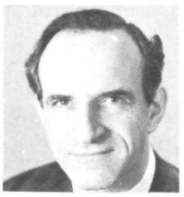


Barbados Prime Minister Errol Barrow released one of the first weather balloons to be used in the three-month study. The Prime Minister, a World War II pilot, has had a lifelong interest in meteorology. An upper-air station on the island is manned by the Air Weather Service 6th Weather Squadron (Mobile).

Dr. Joachim P. Kuettner, Director of the Barbados Oceanographic and Meteorological Experiment, was director of NASA's Mercury-Redstone Project, which resulted in the space flights of Alan Shepard and Virgil Grissom. Later, he was deputy director of the Saturn-Apollo Systems Office in the manned lunar landing project. Dr. Kuettner joined ESSA in 1965, and is Director of Advanced Research Projects with the ESSA Research Laboratories.

Dr. Jule G. Charney, Alfred P. Sloan, Professor of Meteorology at the Massachusetts Institute of Technology, is serving as Scientific Director for the BOMEX exploration of tropical convection systems. A world leader in dynamical meteorology and oceanography, Dr. Charney pioneered in the field of numerical weather prediction. He is chairman of the National Academy of Sciences' Committee on the Global Atmospheric Research Program (GARP).

William S. Barney, Project Manager for BOMEX, is the man responsible for the planning, procurement, operations, training, and administration required to ensure that all the platforms, personnel, and equipment needed for this massive undertaking are in the right place at the right time. He joined ESSA's BOMEX Project Office in October 1967, immediately after his retirement as vice commander of the Air Weather Service.



Dr. Joshua Z. Holland, Chief Scientist for the BOMEX Sea-Air Interaction Program, is chief of the Atomic Energy Commission's Fallout Studies Branch. He helped to organize the branch in 1959 and has directed its nuclear fallout and atmospheric sciences research program since then. From 1948 through 1955, Dr. Holland was with the Weather Bureau, conducting a research program on air pollution meteorology at Oak Ridge National Laboratory.

Arnold H. Glaser is consultant to the BOMEX Director, coordinating university and research laboratory experiments, and advising on techniques for reducing and analyzing BOMEX data. He is a former vice president of Allied Research Associates, where he performed contract research for the government in the fields of satellite meteorology, radar meteorology, oceanography, earth resources, electronics, aeronautics, and computer programming.

OILSPILL!

IT WAS January 31, 1969. Two men, one in Washington and one in Los Angeles, spoke urgently over the telephone. An oilspill off Santa Barbara, California, was menacing miles of coastline. The problem was serious, and there was no way of knowing how much worse it might become.

Quickly, Max W. Mull, chief of the Weather Bureau's marine group, and George W. Kalstrom, meteorologist in charge of the Los Angeles forecast office, made their decision: The Weather Bureau should move without delay to offer active help to agencies fighting the mass crawling toward shore.

The situation then was four days old. On January 28, normal drilling had been underway on the Union Oil Company's Platform A, in 190 feet of water 5½ miles southeast of Santa Barbara Harbor. During a routine withdrawal of the drill string from the well hole, a series of mud and natural gas bubbles broke the ocean's surface only 200 yards from the platform.

In the coming hours and days, those bubbles would grow into a massive crude-oil boil fated to contaminate 800 square miles of ocean, cover Santa Barbara Harbor, deposit a tarry layer on approximately 50 miles of beaches, and arouse the concern of the Nation.

On the second day, crude oil had begun bubbling to the surface in five separate plumes which, by evening, had consolidated into one huge bubble. On the third, the plume continued to grow near the platform. Federal and State officials assessed the situation as a serious one, and began mobilizing to fight it.

As Mull and Kalstrom talked on the fourth day, the first reports were being made of oil on the beaches.

How did it happen? Standard procedure in offshore oil drilling is to extend a concrete and steel casing to a depth of between 500 and 1000 feet. Beyond that depth, drilling mud and drilled materials form the sides of the hole. Many times during drilling of an oil well, the drill string is withdrawn from the hole to permit measurements and for drill inspection or replacement.

In this case, in order to develop a shallow oil-bearing sand stratum, the casing for Well Number Five off Platform A had been terminated at a depth of 239 feet. Drilling had been continued toward a much larger and richer oil stratum known to be at about 3000 feet.

continued

Looking east along breakwater with heavy oil on water and rock.

Work crews spreading straw on water to soak up oil.

Vacuum trucks being filled with heavy oil layer.

Suction pipe drawing in oil in harbor. Oil estimated up to one inch thick.

Geologists knew the hole would penetrate two fault lines, but there was no evidence that either fault would—or could—vent to the ocean floor. It was anticipated that the great pressure of the deep stratum would be transmitted upward to pressurize the shallow upper layer and permit economical oil extraction from this reservoir.

During removal of a drill string, enough drilling mud (a mixture of clay, water, and chemicals weighing approximately 80 pounds per cubic foot) is pumped into the well to counterbalance natural pressure of the oil-bearing strata. It may never be determined just what went wrong on Platform A, but the 1472-pounds-per-square-inch pressure of the deep oil-bearing layer was much greater than that applied by the weight of the capping mud.

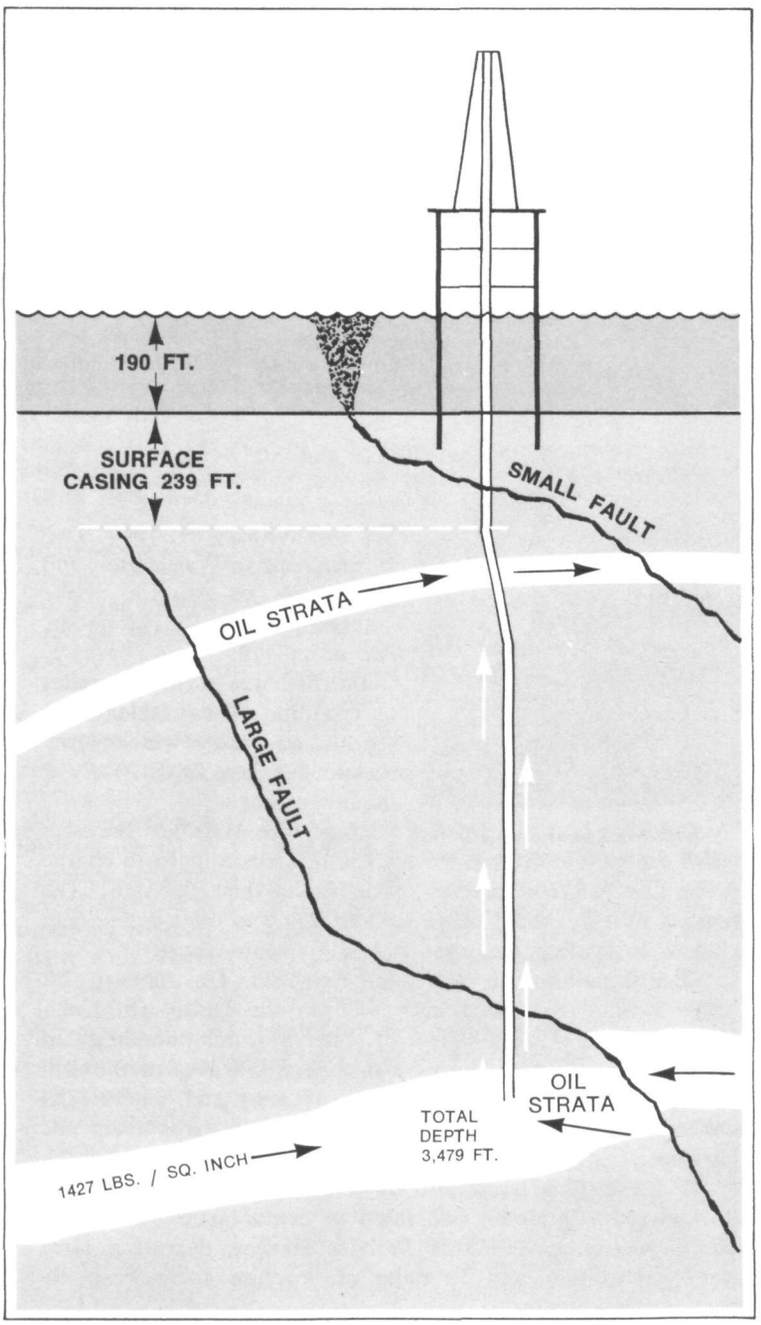
Despite the best efforts of the drilling crew, this pressure forced oil up the shaft. Driven upward by tremendous forces, surging oil eroded the sides of the drill hole and pushed on past the drill string, which by then had been dropped back in an attempt to block the rising oil.

The upward-driven oil soon reached and pressurized the more shallow oil-bearing sandy layer. Increasing forces in this stratum quickly forced oil into a small geological fault line—and the fault line then vented to the ocean floor.

The cycle was complete. A path was open for the free escape of oil to the surface.

The Federal establishment, on July 31, 1968, had issued a National Multi-Agency Oil and Hazardous Materials Pollution Contingency Plan, and it went into action as quickly as the facts of the Santa Barbara spill became known. Kalstrom, with final authorization from Rex Warner, Western Region Operations Chief, volunteered a mobile fire-weather unit to the Eleventh Coast Guard District and other agencies involved. The offer was quickly accepted. The unit was assigned to Lt. George H. Brown III, commander of the Coast Guard's Santa Barbara group, and was made available to assist everybody who needed its services.

The ensuing days saw an unending battle of men against wind, wave, and oil. Manned by Marine Meteorologist Gordon C. Shields and Fire Weather Meteorologists George R. Ellis and Donald V. Lust, the small unit gave virtually round-the-clock weather support.



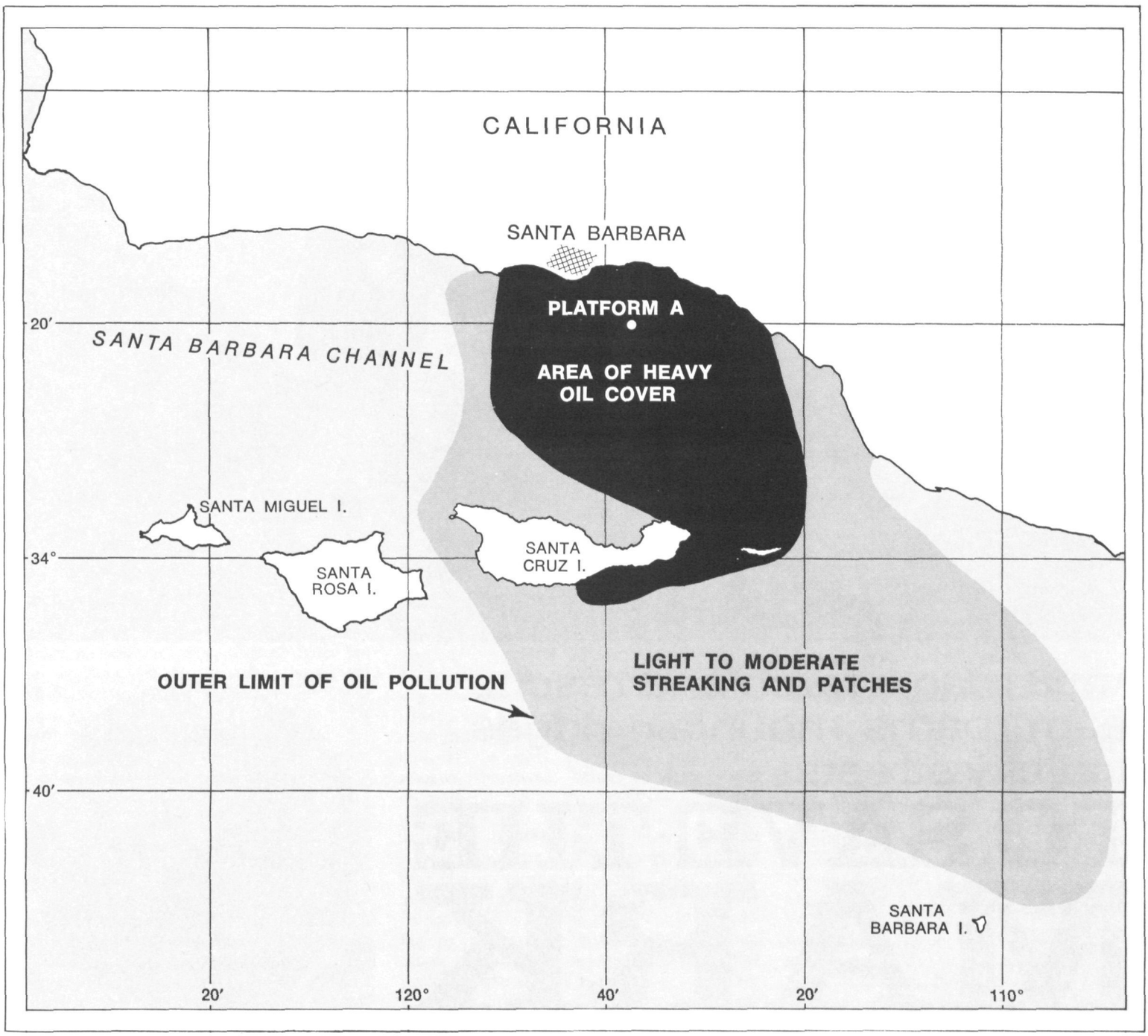
Pressures in the shallow oil strata forced oil into the small geological fault, which offered a path to the ocean floor.

An instrumented fire-weather mobile unit was sent to the scene to aid the battle against spreading oil.

A constant flow of weather observations, forecasts, and charts was available to the field unit. Equipment was also available for local observations. Fire Weather Supervisor Leo A. Sergius provided forecast office support throughout by collecting and transmitting data, monitoring facsimile transmissions, and coordinating forecast discussions between field and office units.

Weather was a prime factor in the fight against the oil. Every wind shift, every action of wave might have meaning for the thousands whose shores were threatened.

For ten days, three written forecasts were prepared daily from the mobile unit. Weather briefings were integral to the twice-daily command staff meetings. At almost any hour of the day or evening, impromptu advice was urgently and informally sought from any number of sources. It was a tense, tiring time.



It began with a few bubbles and eventually contaminated 800 square miles of ocean.

For the first several days, light, variable winds shifting from westerly by day to easterly at night kept the heavy oil concentration near the platform. During this time, several experimental methods of oil containment through floating booms were attempted, and wind forecasts were vital to the planning of boom placement and operation.

Ocean current data also was supplied, but it soon became apparent that, in the very weak eddy currents of the Santa Barbara Channel, wind forces were of much greater importance than water current transport in forecasting oil slick drift.

On February 4, the polluted area was buffeted by gusty southerly winds that churned up 8-to-12-foot seas, driving huge masses of oil into Santa Barbara Harbor and onto nearby beaches. Now wind, weather, and sea-state forecasts were of paramount importance in logistical programming of men, ships, supplies, and equipment into the best system for fighting oil-spread and planning the cleanup.

Forecasts of bad weather for February 5 were a major factor in a command decision to curtail much nighttime activity, allowing more rest for overworked crews. Additional telephone-pole booms were built for later use at sea, while great quantities of drilling mud were stockpiled for a massive onslaught on the renegade well when weather abated.

With rested crews and improving weather, a fresh assault was launched on the morning of February 7. Thousands of barrels of extra-heavy mud and cement were forced into the well. By late on the 8th, the runaway flow had been reduced to a trickle. Careful observations over the next 48 hours indicated that the well had at last been brought under control.

After the final forecast and weather briefing on the morning of February 10, Ellis dismantled the observational equipment and packed to go home to Los Angeles. It had been a hectic ten days. But it had been ten days well spent in the Nation's service. □

BY DAVID STUART
Coast and Geodetic Survey

An 18-man search and rescue team roams mountain ridges and city streets

TO SAVE THE MARK

Embedded in the fields, deserts, mountain tops, and city streets of the United States are more than 617,000 saucer-shaped bronze discs.

They are variously known as marks, markers, monuments, control stations, triangulation stations, azimuth marks, bench marks, and reference marks, the particular name sometimes denoting their purpose.

The bronze discs, about four inches in diameter, are set in concrete to pinpoint the geographic location of a site, its elevation from sea level, its azimuth (the directional angle which enables surveyors and engineers to connect or align their surveys), or to reference the location of a principal marker.

Each disc bears the message: "$250 fine or imprisonment for disturbing this mark." But in spite of the warning, destruction of marks continues. Most are demolished during construction work, some are carried off by souvenir hunters, and others are victims of natural disasters such as floods and earthquakes.

To ensure the survival of the markers and the geodetic networks they comprise, 18 men, each working alone, constantly rove the United States from the east coast to Hawaii, from the Canadian to the Mexican border, and throughout Alaska.

The 18 men are mark maintenance engineers. Their task is to maintain the horizontal and vertical control networks that form the surveying backbone of the nation. In doing so, they travel some 360,000 miles a year.

The geodetic markers are part of the two networks of monuments laid out during the past 153 years by the Coast and Geodetic Survey. The networks provide engineers and surveyors with the basic starting data they require for conducting surveys, whether they involve laying out the nation's highways, marking out a new housing or commercial development, determining a state's boundaries, or even settling a dispute between neighbors over their property lines. About 33,000 registered engineers and surveyors in this country are dependent on the networks for a large percentage of their work. The networks also play an important role in the maintenance of tax and real estate records, in surveys for transportation and communications systems, and in routing urban utilities.

The mark maintenance engineers must systematically inspect the markers of these networks for damage caused by man and nature, and take whatever remedial action may be necessary. This may include re-

pairing the marker, relocating it to a new position, or updating the written description that enables engineers to find the markers. The written description is kept on file at the Geodesy Division of the Coast Survey, at the agency's Rockville, Md., headquarters.

The mark maintenance program was established in 1949. Prior to that, the work was performed by geodetic field parties in conjunction with their normal surveying activities.

Initially, the program was designed to provide a systematic check of all geodetic markers to ensure that they had not been moved, deteriorated, or otherwise lost their usefulness. Maintenance was performed as needed, and the descriptive report for each marker was updated to denote changes in the landscape and other adjacent areas. As time passed, however, this phase of the operation was pushed to the rear as the nation's growth and development necessitated repair and relocation of more and more marks, leaving little time for the original mission.

Each of the 18 men presently assigned to the program is responsible for approximately 200,000 square miles and 33,000 geodetic markers. Working over such a large area, he lives a somewhat nomadic life. If the marker he seeks is some distance from the road, you may see him trudging the terrain with his surveying instruments on his back. This lonely task keeps him away from his family about 75 percent of the time.

Each engineer performs the same duties. Among the more pressing duties in which they are involved are "rescue operations." When a marker is threatened with destructions, they hasten to the rescue.

If the station has to be moved (as, for example, when a structure is being erected on the site), the saving to the taxpayer is considerable if it can be relocated before it has been destroyed. The cost of relocating a horizontal control mark is about one-eighteenth of the cost of re-establishing it once it has been destroyed. A vertical mark can be relocated for approximately one-fourth the cost of reestablishing the mark.

The tasks of the mark maintenance engineer are many and varied. The responsibility of each engineer is to check the accuracy of existing marks. The smallest lateral movement of a horizontal marker would destroy its usefulness, as would any up or down movement of a vertical marker. Precision is essential if the networks are to fulfill their functions.

Once the maintenance engineer has established that a marker has not moved from its original position, he will take any other remedial steps that may be needed. He will either leave the marker, as is, at its original location; make repairs, if necessary; or relocate the marker nearby, if such action seems warranted. Relocation requires precise measurements to integrate the relocated marker into the network. He will then prepare a report outlining the work he has done and describing how the marker can be found. To retain the position of a triangulation marker, a disc is also buried several feet in the ground beneath the surface marker which might possibly be displaced. Mark maintenance engineers are trained to relocate both vertical and horizontal control markers.

In addition to the normal maintenance work, the engineers must maintain close liaison with state highway and surveying officials. These officials furnish vital and timely information regarding the condition of the markers and give the maintenance engineer advance notice of markers threatened with destruction. The liaison also enables the maintenance engineer to keep abreast of highway construction and other programs which might endanger the markers. In addition, when his work requires assistance, the state often provides it.

Sometimes two or more maintenance engineers will combine their efforts when triangulation or level projects are needed locally, but are not of sufficient magnitude to warrant a geodetic party being moved into the area.

Occasionally, a county surveyor may call on a maintenance engineer for assistance when he lacks the technical experience needed to perform the work to standards acceptable to the Coast and Geodetic Survey. The Coast Survey official explains the procedures to be followed, furnishes technical training to the surveyors as needed and, as the work progresses, periodically reviews the work being performed and recommends technical modification to the procedures and network as they are required. In these instances, the end product is a documented and monumented survey that can be accepted by the Coast Survey as part of the national network. Highway personnel who become proficient in relocating or maintaining geodetic markers are often permitted to relocate Coast Survey station markers. This is especially important in remote areas, where a Coast Survey engineer is unable to reach a marker in time to relocate it.

Mark maintenance engineers frequently represent the Coast Survey at engineering meetings attended by public and private engineers and surveyors involved in geodetic control surveys. His counseling at these meetings often plays an important role in the development of future control survey programs.

Each mark maintenance engineer must stay abreast of what happens in the large area to which he is assigned. He must establish contacts with public and other government organizations whose aid he can solicit in the protection and relocation of markers before they are destroyed. This cooperation is a critical aspect of the program.

Thus, it might well be said that the Coast Survey mark maintenance man is not only an engineer and a surveyor, but a teacher, diplomat, and public relations man.

The mark maintenance engineer not only leads a lonely life; sometimes, it's dangerous. Mountainous and desert areas always pose a hazard, especially in Alaska and some western states where distances are vast and help cannot be easily summoned. Normally, he must rely on his own resources. The engineer must be on constant alert against sudden storms, slides, earthquakes, floods, and other natural hazards, including poisonous snakes and wild animals.

Some areas have their own peculiar hazards. In Hawaii, for example, the mark maintenance engineer has to traverse the knife-like ridges of Oahu and Kauai mountain ranges, where a slip over the side could be fatal. On the island of Hawaii, dense vegetation grows over old lava flows and camouflages many crevasses and pitfalls.

The mark maintenance program is coordinated from six offices of the Coast and Geodetic Survey in Norfolk, Va., Kansas City, Mo., San Francisco, Calif., Seattle, Wash., Anchorage, Alaska, and Honolulu, Hawaii.

East coast markers are watched over by four men, under the supervision of the Norfolk, Va., office: Nelson C. Sampson, who covers the New England states in the summer and North and South Carolina in the winter; Martin E. Zimmer, North Carolina, Virginia, West Virginia, and Maryland; John S. Rindal, Florida, Georgia, and South Carolina; and William F. Rexrode, New York and Pennsylvania.

The Kansas City, Mo., office controls the maintenance in 22 states with the work divided among seven men: Charles L. Novak, Raymond L. Wright, Alton K. Hansen, Marvin A. Randall, Floyd K. Stuart, Wilson A. Ziegler, and Leon F. Smith. The seven men have about 200,000 markers to maintain in Missouri, Kansas, Nebraska, Iowa, Minnesota, North and South Dakota, Colorado, Wyoming, Alabama, Arkansas, Louisiana, Mississippi, Texas, Oklahoma, Indiana, Illinois, Michigan, Ohio, Wisconsin, Kentucky, and Tennessee.

The west coast is handled jointly by the San Francisco and Seattle offices. James T. Stapleton is responsible for Washington and Montana, Floyd A. Martin for Oregon and Idaho, and Leo A. Critchlow and Jay L. Gummow for California, Nevada, Utah, Arizona, and New Mexico.

From Honolulu, Richard F. Hanson services 1200 markers in the Hawaiian Islands. Based at Anchorage, Sidney Henderson, Jr., is responsible for Alaska's 17,000 markers.

The entire program's technical guidance is coordinated from Coast Survey headquarters in Rockville, Md., by Carl F. Kelley, Chief of the National Network Maintenance Section in the Geodesy Division. □

Accurate early warnings alerted the nation to the floods that came

When the Snow Melted

BY HERBERT S. LIEB

Nature tested man, and man won the battle over what was "the flood of the century" for huge sections of the nation.

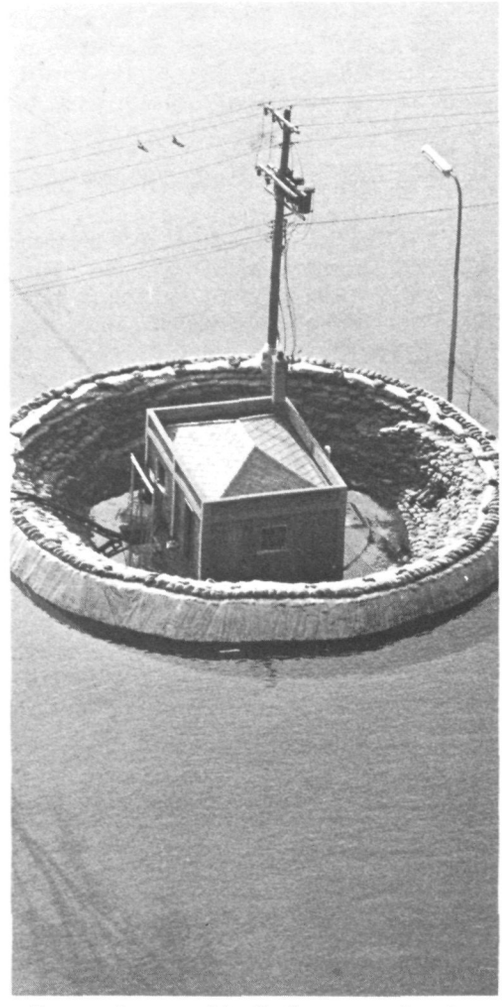
This spring, floods in the midwestern states caused a hundred million dollars' damage, killed eight people, and forced 25,000 to leave their homes, as massive snowpacks melted and turned usually tranquil rivers and streams into torrents of destruction. Particularly hard hit were parts of North and South Dakota, Minnesota, Wisconsin, Iowa, Nebraska, and Illinois.

Bad as it was, it might have been worse. Precise flood forecasting permitted advance action that prevented an estimated $250 million in damage, saved lives, and reduced human suffering to a minimum.

Secretary of Commerce Maurice H. Stans has commended the Weather Bureau for "outstanding" performance in forecasting widespread flooding in the Midwest, and for moving vigorously to alert the nation to the critical situation.

Singled out by the Secretary as having served the nation "in the highest traditions of the Commerce Department," were: Dr. George P. Cressman, Weather Bureau Director; William E. Hiatt, Associate Director for Hydrology; Roy L. Fox, Central Region Director; Verne Alexander, Regional Hydrologist; Ray E. Johnson, Hydrologist in Charge, and the staff of the Kansas City River Forecast Center in Kansas City, Mo.

As early as January, ESSA hydrologists were alert to the possibility of severe to record-breaking floods. Their warnings triggered an unparalleled federal-state-local effort of preparedness.



Preparedness paid off. Pumps and a fortress of sandbags kept this Fargo, N. Dak., power station dry and operating. Photo by the Fargo Forum.

Well before the flood, states on the northern border of the Midwest had a severe emergency on their hands. More snow than ever experienced—more than 100 inches in some areas—plagued the area. Many communities and some of the states exhausted their emergency funds fighting the snow. Continued heavy snows and low temperatures in December gave the first indication to Weather Bureau forecasters that flooding might assume serious proportions when the snowpack melted in the spring.

On January 9, representatives of the U. S. Army Corps of Engineers, Minnesota Civil Defense, and the Minnesota Department of Military Affairs were alerted by the Weather Bureau Forecast Office in Minneapolis to the possibility of serious and widespread flooding. This concern was echoed by Weather Bureau offices throughout the Midwest area.

A four-state survey of snow and ice conditions in Iowa, Minnesota, Wisconsin, and South Dakota—a cooperative project of the Weather Bureau, the Corps of Engineers, and the Geological Survey—showed a large water equivalent lying on the ground in the form of snow. The extent of flooding would depend on temperatures, precipitation, river stages, and ground conditions in the coming weeks and months.

One fact was clear: regardless of any other factors, when that snow melted it would pour into the fields, creeks, and drainage ditches and then into the streams, whose banks would not hold it.

After an analysis of the snow survey, the Weather Bureau's River Forecast Center at Kansas City on February 11 issued its first

flood outlook. Local Weather Bureau stations tailored the outlook for their areas of concern. Meetings were held in large cities and small communities where there was a threat of flooding.

The planning began.

At the Weather Bureau, arrangements were made for special and frequent observations. Staffs of the River Forecast Center and River District Offices would be augmented. The National Meteorological Center would make special temperature and precipitation forecasts. Emergency communication links were established. The Army provided helicopters so that ESSA technicians could take special snow-depth and water-equivalent measurements in otherwise inaccessible places. ESSA's Satellite Center furnished special enlarged satellite photos of the snow-covered regions.

On February 20, the staff at the River Forecast Center began issuing weekly flood summaries that were distributed widely to members of Congress, Governors and State authorities, the national news media, and to all of the affected communities through Weather Bureau offices.

The threat of flooding became a certainty.

"The nation is facing a major natural disaster," ESSA officials told the Secretary of Commerce on February 20. The President was notified. On February 28, the Weather Bureau Associate Director for Hydrology, William E. Hiatt, briefed federal officials on the extent of the threat at a special White House meeting.

The next day, March 1, President Nixon ordered a major effort by federal agencies, to undertake all feasible preparations to reduce or alleviate the threatened flood damage. The Office of Emergency Preparedness was instructed to coordinate "an extraordinary federal planning and operational effort to supplement state and local resources."

The Secretary of the Army was requested to make full use of the Corps of Engineers' capability for advance preparations and operations relating to the flood emergency.

Other resources and participation were marshalled in the departments of Defense, Interior, Agriculture, Transportation, Commerce, and Housing and Urban Development, the Small Business Administration, Interstate Commerce Commission, Bureau of the Budget, and the American Red Cross.

Never before had such an effort been mounted in so short a time to combat a natural disaster—before it happened. The all-out effort was called Operation Foresight.

"Never before had such an effort been mounted to combat a natural disaster before it happened."

On March 13, the Weather Bureau River Forecast Center issued a complete, detailed snowmelt flood outlook for the area. This outlook consisted of two crest stage values —one for no further precipitation and one for normal precipitation—to be expected at some 225 points in the states of Montana, North Dakota, South Dakota, Minnesota, Wisconsin, Iowa, Nebraska, Kansas, Illinois, and Missouri. Record or near-record stages were predicted for over half of these points, and major flooding for most of the remaining points. In general, the streams with the most serious flood potential were the Big Sioux, Little Sioux, James, Red (of the North), Minnesota, Upper Mississippi, and Upper Des Moines rivers. Among the metropolitan areas threatened were the Minnesota cities of Minneapolis, St. Paul, and Mankato; the quad cities of Moline and Rock Island, Illinois, and Bettendorf and Davenport, Iowa; Des Moines and Sioux City, Iowa; Sioux Falls, South Dakota; Fargo and Grand Forks in North Dakota. Directly or indirectly more than a million people would be affected.

Thirty days after this comprehensive outlook was issued by the Weather Bureau, an estimated 3,700 lineal miles of the rivers mentioned were simultaneously above flood stage. Crests had been passed at some points and stages were rising at others, but flood waters were overflowing the banks. By April 16, most of the tributaries were receding.

The early outlooks and the crest forecasts of March 13 showed remarkable accuracy for all points. Considerable refinement in forecasts was possible as the weeks passed and the floods progressed to the peaks. Most of the revised key forecasts had a lead time of from one day to one week and verified within tenths of a foot, even though some of these rivers rose as much as 35 feet.

The long lead time gave river forecasters at the Center pain as well as pleasure. With the warnings out, residents and officials looked in disbelief at their quiescent, ice-covered rivers and streams. Pressure began to mount on the forecasters to change their minds—to lower their crest forecasts. They stuck by their guns.

The Corps of Engineers, chief flood-control agency of the federal government, spent about $19 million to construct and reinforce levees. They said it was about four times less than the amount that would have been needed if Operation Foresight had not been in effect. Some 400 communities throughout the nation were aided in the flood-fighting effort. Another 400 communities received technical advice and did their own work.

More than 200 miles of emergency dikes were built, and 10 million sandbags emplaced. The American Red Cross served 250,000 meals to the homeless and to workers. More than 2,000 servicemen and National Guardsmen battled the floods, shoulder to shoulder with the townspeople. Five million bushels of grain were hustled out of flood zones under the supervision of the Interstate Commerce Commission.

At one point on the Big Sioux River, levees protected the left bank, while the unguarded right bank suffered extensive flooding. Photo by U.S. Army Corps of Engineers.

1. In Minot, N. Dak., as elsewhere, students filled sandbags. 2. The Red Cross served 250,000 meals to the homeless and to workers. 3. At Windom, Minn., where a dike was built in the middle of a street, one side was wet, the other relatively dry. 4. (L. to r.) Roy L. Fox, Director, Weather Bureau Central Region; Ray E. Johnson, Hydrologist in Charge of the Kansas City River Forecast Center; Verne Alexander, Regional Hydrologist, were among those cited by the Secretary of Commerce for outstanding performance in forecasting widespread flooding in the Midwest. 5. William E. Hiatt, Weather Bureau Associate Director for Hydrology, was also commended by the Secretary.

At the local and state levels, they said: "We are ready this time as never before." More than 11,000 residents were evacuated from homes in Minot, North Dakota, before the Souris (Mouse) River inundated large parts of the city. The sleepy Mouse River became known as "Mighty Mouse" and, before it was all over, was called the "Dirty Rat." For Minot, it was the worst flood in history. Not since 1904 had Minot witnessed a serious flood on the river that winds for 27 miles through the four-mile-wide city.

Spurred by the flood advisories, communities took action.

Sioux City, Iowa, mobilized for the fight and won. As in most communities, Civil Defense had the key role. At Sioux City, CD Director Tom Elliott drew up a plan for what was later to be called the Natural Disaster Task Force. On February 26, two weeks after being alerted to the possibility of high water in the Floyd, Big Sioux, and Missouri rivers, city officials met to organize. On March 3, they met with the city council. On March 5, officials of the city, state, and federal government exchanged plans and information. Working under Operation Foresight, the Corps of Engineers let contracts for emergency dikes and maintained an around-the-clock emergency center.

The Weather Bureau set up close communications with flood fighters to report and predict flood stages. The Iowa state government organized under the state civil defense office and made National Guard and other resources available to help local communities.

Meanwhile, Elliott, as chief of staff and logistics, took over the day-to-day command function. He served with a member of the city council, the city manager, the city engineer, and the public service director. They appointed people to take care of communications, damage assessment, procurement and supply, a representative to list volunteer and city personnel engaged in disaster operations. A public information officer kept news media informed through special hot-line connections. And then, of course, there were fire and rescue, traffic control, security, health and welfare services, and public works functions. There was a transportation pool to move workers where they were needed, and a manpower manager to get the volunteers.

By March 7, they had stockpiled sand and sandbags, checked pumps and floodgates, and made arrangements for other equipment. When the Weather Bureau issued its March 13 crest forecast for the Big Sioux at Sioux City, it was apparent that the dikes would have to be raised. Work was started the next day.

The crest reached Sioux City on April 10 setting a new record of 11.73 feet above flood level. It was three feet below prediction, because the Corps of Engineers, operating the discharge at Gavins Point Dam, kept the Missouri River much lower than had been thought possible. The damage would have been disastrous, however, if nothing had been done to the original dike.

Nerve center of the flood battle in Sioux City was its emergency operations center. It went on 24-hour duty April 3, and remained operational for the next 10 days. A "hot-line" was installed to the Weather Bureau, where Paul Holcomb and his staff at the River District Office kept the center informed of the latest developments. Information was relayed quickly through the news media to the public. Ivory Rennels, former MIC at Sioux City, was "brought out of retirement" to help provide up-to-the-minute weather and crest information at all hours of the day and night.

That was one city in one state. The scene was repeated in community after community, at one Weather Bureau station after another.

It was best summed up in the Fargo (N.D.) *Forum*, April 16, 1969:

"Without these precautions the losses would have staggered the imagination.

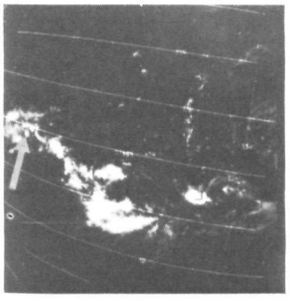
"And without the compassionate response from human beings in unlikely ranks, the job wouldn't have been done.

" 'The kids—they're dynamite!' exclaimed the mayor of Valley City after the fire siren blasted its signal for emergency help to raise the dikes. Young people of all ages turned out by the hundreds to work through the night filling and tossing sandbags.

"Kid power joined with man power in many beleaguered communities. The youth drew from their elders a new assessment of the coming generation.

"As the waters ebbed and the aftermath of flood debris became the immediate chore people were not too preoccupied to reflect upon their situation.

"In a land often bereft of water for farms and industry, man must resolve to harness the powers of nature. During the flood of 1969 the people showed they have the resourcefulness to accept that challenge." □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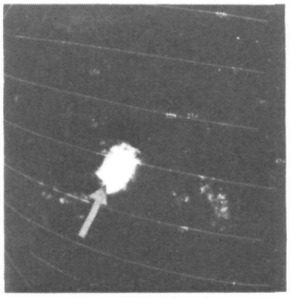
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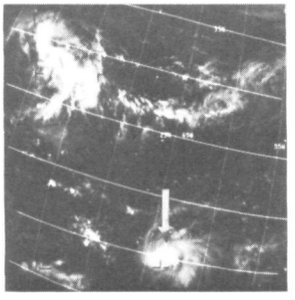
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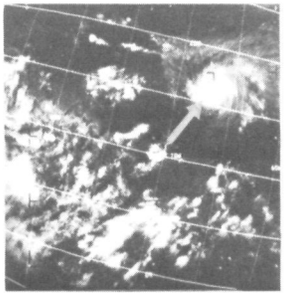
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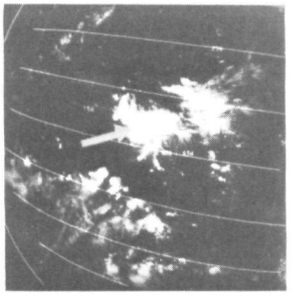
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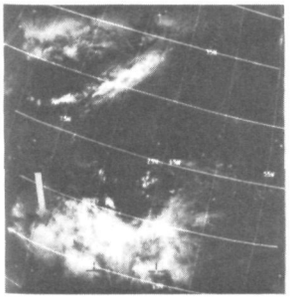
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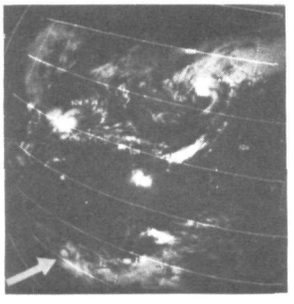
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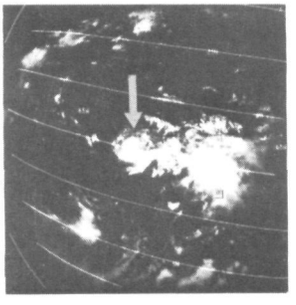
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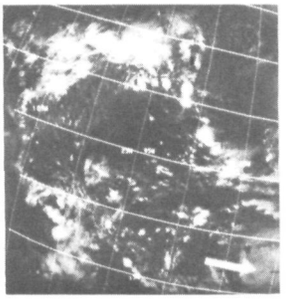
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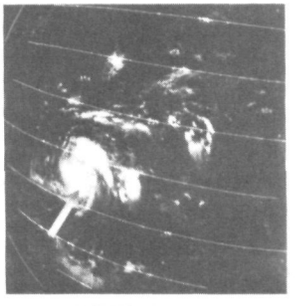
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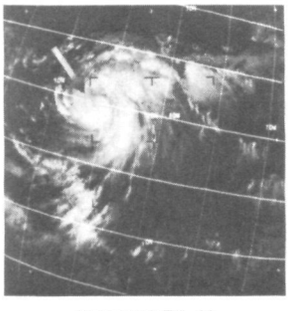
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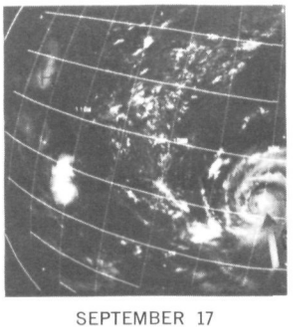
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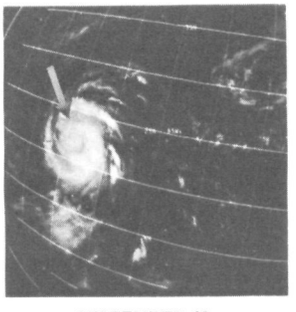
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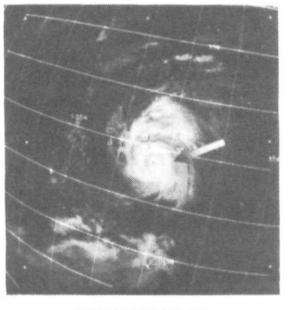
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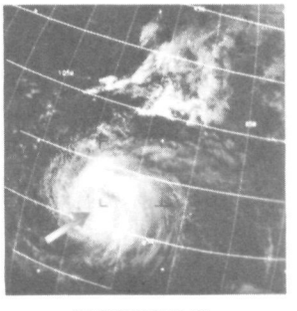
SEPTEMBER 20

ESSA 3 track of hurricane Beulah September 6-September 20, 1967

Every tropical storm leaves fingerprints for scientists seeking

A MODEL HURRICANE

BY JOANN TEMPLE
ESSA Research Laboratories

From her beginnings as a weak tropical depression east of the Windward Islands on September 5, 1967, to her death over Texas 16 days later, Hurricane Beulah posed a threat to millions of people.

The killer storm moved through the Caribbean, across Yucatan to the Gulf of Mexico and on to southern Texas, leaving 41 persons dead, thousands homeless, and more than one billion dollars in property and crop damage.

The Texas coast was the hardest hit but, long before that, while Beulah was still far at sea, Weather Bureau forecasters were estimating her next landfall.

Until half a decade ago, a basic hurricane forecast was the subjective judgment of an experienced hurricane forecaster—from all the data accumulated around the tropical zones of the Caribbean or Gulf, from all the map discussions at the Weather Bureau, from all the information gathered by aircraft in the storm—one man's opinion emerged as the final word to the waiting public.

In the final analysis, the hurricane forecast is always the end result of one man's opinion, that of the responsible hurricane forecaster. But two decades ago he was on his own, and his judgment was conditioned mainly by the length of his experience in dealing with hurricanes and tropical storms. Today, this man's opinion is bolstered by a variety of objective techniques which assist him in the decision-making processes.

The first semi-objective techniques for predicting hurricane movement were developed in the early 1950's, the original work being done by Professor Herbert Riehl, then of the University of Chicago. During the middle and latter fifties, the Weather Bureau's National Hurricane Research Project (which later was to become ESSA's National Hurricane Research Laboratory) sponsored an all-out effort to develop completely objective prediction techniques, together with a continuing program of basic research on theoretical hurricane models.

The most successful fully objective techniques were developed by Dr. Banner I. Miller of the National Hurricane Research Laboratory, working with his colleagues in the laboratory and in the National Hurricane Center and later with scientists at the National Meteorological Center. These techniques produced a first approximation of a storm's motion for the next 24, 48, and 72 hours, based on a machine analysis of the large-scale circulation at the time of the forecast. Since 1964, these forecast guides—

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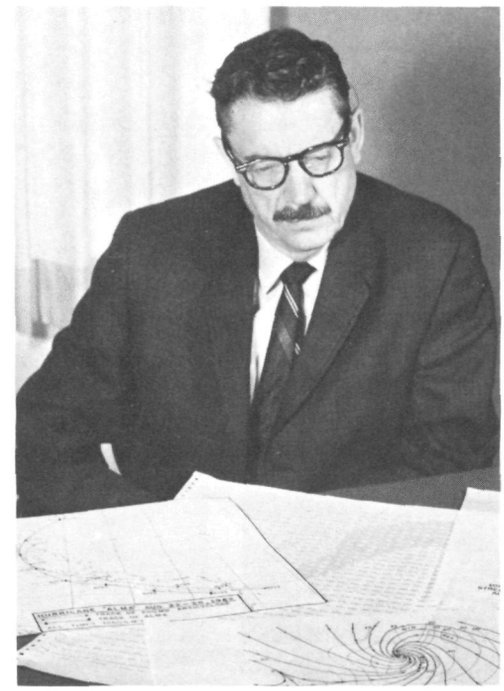
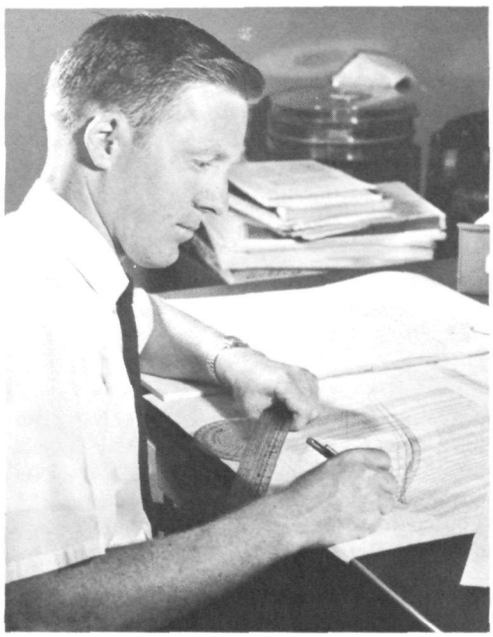


(Above) Dr. Banner I. Miller, working with the National Hurricane Center, developed a new prediction program that is being tested during the 1969 season. (Left) Laboratory scientists spend a great deal of time on airborne research missions. (Left below) Robert C. Sheets uses statistical methods to define the mean characteristics of hurricanes and to study potential modification methods.



NHC-64 and its updated cousin NHC-67 —have been the principal objective tools used by forecasters at the National Hurricane Center in reaching decisions on hurricane movement.

During 1969, NHC-67 will be run on the National Meteorological Center's computers, using information on initial conditions provided four times a day by the National Hurricane Center.

A new prediction program being tested this season stems from a collaboration between NHRL's Dr. Miller and the NHC Director, Dr. Robert H. Simpson. This program also provides an estimate of the 24- and 48-hour movement of hurricanes.

The main difference between the two methods is that NHC-67 bases its decision upon presently existing conditions in the large circulation environment of the hurricane, including the trends of the preceding 24 hours, and considers the movement of past hurricanes under similar conditions. The new prediction program takes environmental conditions as they presently exist, predicts the changes in these conditions, and steers the hurricane in the direction implied by the changes.

In addition to studying new forecast techniques, the National Hurricane Research Laboratory, located only one flight of stairs away from its operational Weather Bureau counterpart in Miami, conducts observational, analytical, and theoretical research on hurricanes and associated tropical weather systems.

Dr. R. Cecil Gentry, director of the laboratory, explains: "Our research work is broad, but can basically be divided into two general areas—that dealing with actual storms, and diagnostic treatments attempting to 'model' the hurricane in a computer."

Robert C. Sheets is one of the NHRL researchers charged with sorting out various identifying "fingerprints" in hurricanes and the environment around them. He relies heavily on statistical methods to do this. For example, Sheets recently attempted to define the mean conditions inside a hurricane. He collected radiosonde data from 100 different launchings of these meteorological measuring packages in various hurricanes. All the soundings were within 115 miles of the eye. Some of the storms, such as Inez in '66 and Cleo in '64, were small and concentrated whirls of destructive energy. Others, including Beulah in '67 and Dora in '64, were widespread but still quite strong.

As with much of the laboratory's work, some of the results of Sheets' statistical research spilled over from basic to applied research and STORMFURY, the ESSA-Navy hurricane-modification study.

After defining his "mean hurricane," Sheets used a cloud model developed by Dr. Joanne Simpson of ERL's Experimental Meteorology Branch, to see how rain bands might be affected by seeding. From his mean values, Sheets calculated how much heat energy was available in various cloud lines. Then, assuming that this heat could be released by seeding, he calculated probable cloud growth after seeding. In general, he determined that the clouds most affected by seeding were those farthest from the eye. Clouds closer to the eye were already so huge that there was little room left for them to grow before reaching the tropopause.

This statistical finding that clouds are higher near the eye has been verified by

measurements from Air Force U-2 aircraft. Getting a bird's-eye view of the storm from 60,000 feet, these aircraft records indicate that the clouds in a really strong storm center reach to about 55,000 feet. In a weaker storm, they may top off at about 35,000 feet.

Other statistical work is underway at NHRL to develop a way to measure vertical motions of air in a storm. This measurement system is based on the displacement of an aircraft in the storm and will be flight-tested this year. Any aircraft that records true air speed, pitch angle, and radar altitude every three seconds provides the basic data from which to deduce vertical air motions. Although the laboratory's prime motive for developing this capability was for hurricane research, it may also be useful in describing the severity of turbulence encountered on routine flights.

Statistical studies have revealed a number of physical features that are common to most hurricanes. For example, every hurricane has a warm core. Every hurricane has an eye or central area of relatively weak winds, although it is not necessarily a closed eye. Eye diameter seems to be somewhat related to latitude, with the eye getting larger as the storm moves northward. Winds normally peak in the eye wall, but Dora was an example of a storm whose strongest winds were elsewhere.

NHRL scientists spend a great deal of time on airborne research missions. The structure and energetics of hurricanes have been studied from painstaking analyses of the data gathered on flights into hurricanes. From the thousands of observations recorded on magnetic tape, they reconstruct details of the cloud structure, mean mass motion, and budgets of moisture, energy, and momentum. In this manner, they have established the basic features of the storm which must be incorporated in numerical models.

Another approach used by the laboratory to find out what is going on in tropical weather systems is to subject the carefully analyzed data to a set of diagnostic equations. If the appropriate equations are used and the pertinent processes are expressed reasonably well in these equations, they provide answers to many questions about tropical storms. How large are the centers of vertical motion and where are they located? At what level is the maximum heating occurring? Which process is most important in effecting local vorticity changes? A seven-level diagnostic model, programmed for the computer by Mr. Hawkins, should help to answer these and other questions and lead to the development of more accurate theoretical models.

In addition to "routine" data-collection flights in, around, and through hurricane-force storms, the scientists participate in study projects such as the Eastern Caribbean Cooperative Reconnaissance Operation and the Barbados Oceanographic and Meteorological Experiment.

The Eastern Caribbean study, conducted in October 1965, involved numerous aircraft flights at varying altitudes and special radiosonde launches to gather meteorological data in the subtropics. Observations of temperature, moisture, geopotential heights, and cloudiness provided a dense network of information about the synoptic and mesoscales of motions which trigger the growth of large-scale atmospheric disturbances.

During the study, a cold, high-level low broke off from the westerly winds in the mid-latitudes and drifted down to the tropics. The data gathered on the scene was used with an NHRL computer model to determine the vertical motions and energy conversions which went on in this cold low. The computer calculations showed energy rising for the first three days and falling for the last three. This conformed well to the actual measurements.

Indirect circulation was also studied in the model, since field observations indicated a strong northwesterly current in the western side of the region, with a lot of convection. The model indicated that there existed a state of warm air sinking and cold air rising, while the necessary energy to perform this backwards process was being absorbed from the surrounding environment.

The hurricane laboratory and some of its university collaborators are participating in the BOMEX project, particularly the July investigation of tropical convection systems.

They are especially interested in attempting to investigate a synoptic entity that can be traced to an origin over the African deserts. So-called tropical waves appear to roll off the African coast near Dakar every three to four days during the late summer months. During August and September, a significant fraction of easterly waves develops into tropical storms or hurricanes.

To improve forecasts and increase understanding of hurricane processes, NHRL is working on modeling from two separate approaches. Dr. Banner I. Miller and his group are developing a primitive equation baroclinic model to forecast the movement of storms. This model of a hurricane includes such seemingly subtle, but nonetheless quite significant, factors as ocean-to-atmosphere evaporation, release of latent heat, and various heat sources in and around the storm.

Dr. Miller used this model with real data from Alma in 1962 and found that his computer model did successfully generate a hurricane. The computer predicted the deepening of Alma from a full easterly wave to a storm with winds increasing from 25 to 60 knots, while the pressure dropped and the low-level inflow and high-level outflow developed. These essential features of a hurricane were forecast by the computer with approximately the correct intensity and time scale. The model also accurately forecast the actual motions of Alma as the storm moved from Jacksonville to Cape Hatteras.

This is not an operational forecast model because of its time factor. It takes the computer used by the laboratory almost 24 hours to run a 24-hour forecast. Thus, it is currently useful only for research.

Theoretical studies of hurricanes are completely different. In these, researchers are not so much interested in forecasting the motion of existing hurricanes as they are striving to create a correct physical model of a storm in the computer. Dr. Stanley L. Rosenthal explains: "In forecasting, if you find something that works, you use it. You don't have to know why it works or be able to detail the physical principles behind it. In diagnostic work, we insist on knowing why. If we can't explain something in physical principles, it does not go into our model.

"First we want to have a model that is correct. Then we can take real data from the atmosphere, put it into our model and determine whether a hurricane will form. Once we have a true-to-life model of the storm we want to be able to simulate its whole life cycle so that we can also simulate and study the effects of modification attempts."

The theoretical model now being developed at NHRL is an idealized storm. Mathematical equations describing the storm have been built to include a 600-mile-wide section of the atmosphere extending upward from the ocean surface to an altitude of 55,000 feet. This model successfully follows the life cycle of an idealized hurricane. It begins with a very weak circulation which intensifies in three to five days into a hurricane. The system then organizes and grows rapidly to a full-blown storm before it begins to degenerate. With this model, NHRL researchers can study the physical processes inside the storm from beginning to end.

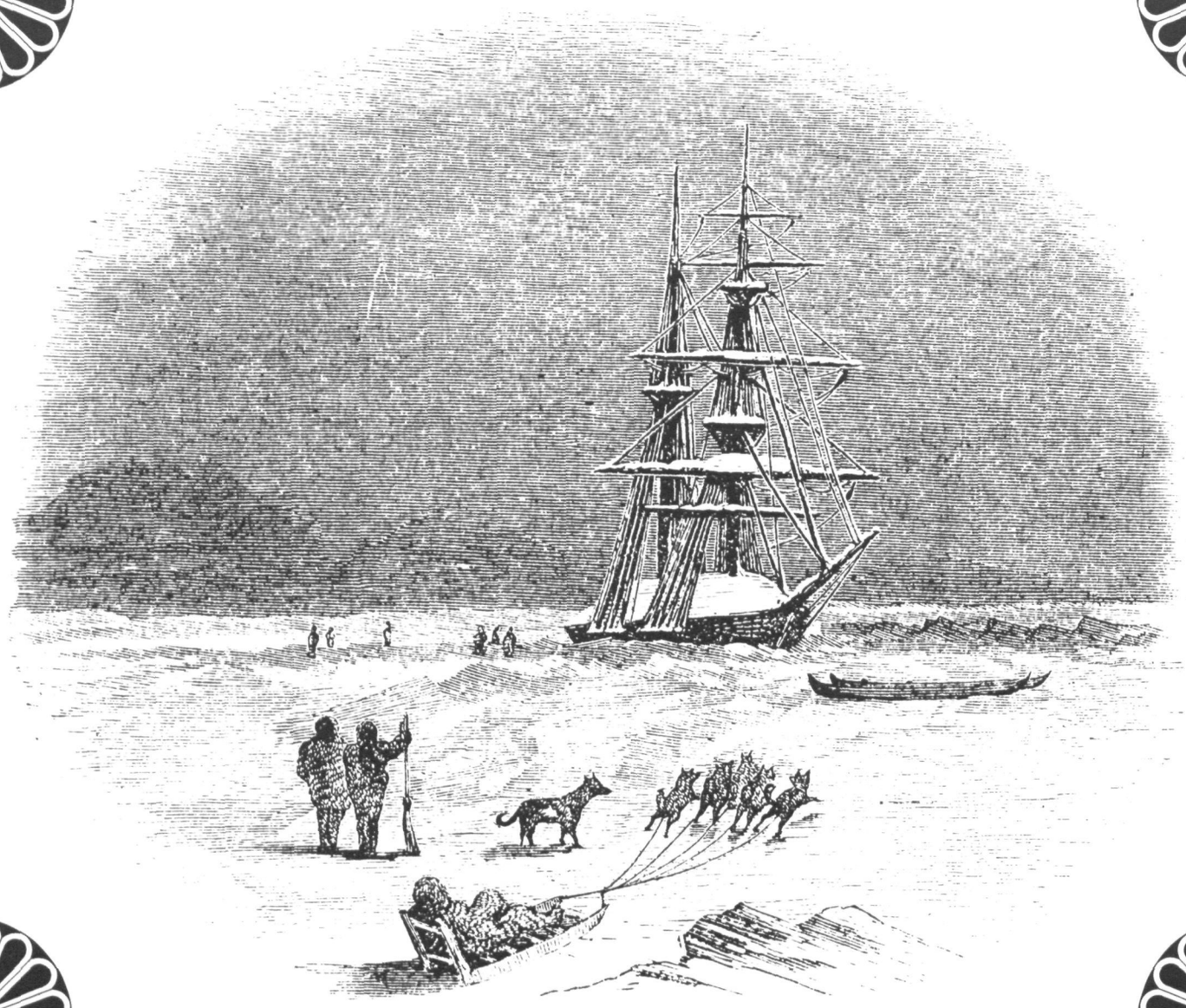
Rosenthal has used his model in an initial test of the STORMFURY hypothesis. He mathematically seeded the eye wall. That is, he introduced heat into the eye wall. The resulting small changes in wind and central pressure did weaken the storm for a while. Repeated computer "seedings" at different times and places in the storm's life produced the same results.

The next major advance will be to move from the idealized storm closer to reality. To do this, the first step will be to drop the features of the present model which assume that the storm is perfectly symmetrical.

Dr. Gentry concludes: "Great progress has been made in the general field of hurricane research in the last few years. This is especially true with increased understanding of the energetics and structure of hurricanes, in our ability to simulate hurricanes by numerical models, and in developing improved techniques for forecasting hurricane motion. Future plans call for extensive use of all our observing tools, both old and new, to collect the data needed to gain further understanding of the energy processes in hurricanes at all stages of maturity." □

KANE'S ARCTIC GATEWAY

BY ALBERT STANLEY Coast and Geodetic Survey



RENSSELAER HARBOR

When men essay great adventure, glory and tragedy often visit them in almost ironic proportions.

So it was when Elisha Kent Kane, a frail young doctor, set out to rescue a British expedition lost in a search for the Northwest Passage. His party did not find Sir John Franklin and his ill-fated 136 seamen. It found, instead, the passage for which Franklin and his men gave their lives.

Kane was a physician and naval officer who had been assigned to the Coast and Geodetic Survey in 1850 for ship duty in Mobile Bay. He failed almost spectacularly to fit the stereotype of the adventurer. He was small, with little physical strength, and he died at 37. His nature was essentially poetic: He wrote of Mobile Bay, "the breeze comes to me purple-stained with the sunset, rippling over the bay with an eloquent crescendo of wavelets and a cadenza of tiny surf."

But he was a Renaissance man—doctor, officer, scientist, explorer, administrator, author, and above all a leader.

At that time, many learned men believed that an ice-free passage existed beyond the ice barrier along the Greenland coast. Since the 17th century, many nations had sought without success, on various expeditions, a northern route around North America.

England had been in the forefront of these efforts. In 1845, the last of her great Northwest Passage expeditions sailed under Franklin, the uncle of Alfred Lord Tennyson. The expedition of 136 men in the two small ships, the EREBUS and TERROR, never returned. Public sympathy for the lost explorers was intense, both in Great Britain and the United States. Many believed they might still be alive in the Arctic wastes.

Lady Jane Franklin, wife of Sir John, worked tirelessly to foster expeditions to rescue her husband and his crew. She wrote several times to President Zachary Taylor and through the resulting publicity Henry Grinnell, the noted New England shipbuilder and philanthropist, reacted immediately to the plea. His offer of two brigs, the ADVANCE and RESCUE, was accepted for the first expedition which had Congressional support, permitting the U.S. Navy to outfit and man the two small vessels.

At Mobile Bay, Dr. Kane heard of the rescue plan, and immediately volunteered for it. The ship departed in May 1850, with Lt. Edwin DeHaven, USN, in command and Dr. Kane aboard as physician and surgeon. The undertaking proved fruitless and after returning to New York in 1851, Dr. Kane laid plans for another expedition, one which he would command personally.

He wrote a popular account of his experiences in the northland and started immediately to plan for the second trek, with ascertaining Sir John's fate as his primary goal and seeking an ice-free passage in the polar sea as his second. Joseph Henry of the

Elisha Kent Kane, M.D., USN

Smithsonian Institution, Matthew Fontaine Maury of the National Observatory, and Alexander Dallas Bache of the Coast and Geodetic Survey, all stellar figures of American science, were among his strongest supporters.

The second expedition was conceived as a private undertaking. The Secretary of the Navy authorized special duty for Dr. Kane and 10 American seamen who volunteered. Henry Grinnell again contributed the ADVANCE, a brig about 100 feet in length. The party also included nine civilians.

The men Dr. Kane selected for his expedition had the qualities necessary to survive in a hostile environment. There was never a question of maintaining discipline or yielding to authority. He had utmost confidence in his associates, and they trusted their leader with a devotion and dedication seldom recorded under like circumstances.

The ADVANCE sailed from New York May 30, 1853, as an independent and privately financed expedition with Dr. Kane in command. By midsummer, the small vessel and its 20 hardy pioneers had sailed along the Greenland coast, through Smith Sound, and into a large ice-packed expanse later known as Kane Basin. Open water existed only in a narrow belt along the Greenland coast and, as winter set in, the brig returned to Rensselaer Harbor, the farthest north a vessel had ever wintered.

Scientific work was accomplished during the winter with equipment furnished by the Coast Survey and the Smithsonian Institution. These included a small magnetic observatory, a miniature astronomic observatory, and tide observing equipment. The Arctic winter of 1853-54, in all its howling fury, soon set in with the brig almost lost in a sea of ice and snow. Dr. Kane organized a series of sledging forays into the frozen wastes, in search of Sir John's party. One group of six nearly perished from exposure in the vicinity of Humboldt Bay. Through superhuman effort Dr. Kane was able to find and rescue four of the party, but the other two died of exposure.

Sledging parties mapped a good portion of Kane Basin, and two noteworthy discoveries were made. Dr. Isaac I. Hayes, physician of the expedition, crossed Kane Basin in May 1854 and discovered Ellesmere Island after touching Cape Sabine. Another party under William Morton, steward of the expedition and an Irish immigrant, departed base camp in May 1854; with one of his party, Morton reached Cape Constitution late in June. This point is north of the 80th parallel and the northernmost latitude ever reached at that time. Climbing to a height of 500 feet above the shoreline at Cape Constitution, Morton saw ice-free open water in the distance. Thus, Kennedy Channel was discovered and a part of Ellesmere Island could be seen on the opposite side of the channel. Upon reporting the open water to Dr. Kane, they were certain that the ice-free Arctic passage for which they had searched was found at last.

Preparation was started in August 1854 for a second Arctic winter. The astronomer of the party, August Sonntag, formerly of the Royal Observatory of Vienna, Austria, with Dr. Hayes and several others, considered it useless to spend another winter there and asked Dr. Kane for permission to withdraw and return home by way of the nearest settlement, far to the south. Dr. Kane gave his permission, and provided them with a 26-foot whaleboat in which nine men set out on August 28, 1854. Winter howled in once more, and Dr. Kane and the remaining eight men stayed near the ice-packed brig, with the doctor administering to their illnesses and injuries. On December 12, 1854, the Hayes party returned to the brig, sick and beaten, not having made one-third their way to Upernavik, the nearest settlement, about 1300 miles to the south.

The winter of 1854-55 was even more intense and devastating than the previous year. Disaster was averted by Dr. Kane's resolve to maintain systematic action, including his routine of scientific observations. He refused to have his party demoralized by foregoing the approved and habitual ways of life, even under the most trying circumstances. He was careful to maintain an hourly schedule, regular assignment of duties, religious observances, table formalities at mealtime, maintenance of fires, lights, and regular watches—even scientific observations and tidal records were conducted on a regular basis.

The most important single factor in their survival was the good fortune of making contact with the Eskimos at Etah, Greenland. Much time was spent on studying and practicing the lessons to be learned from the

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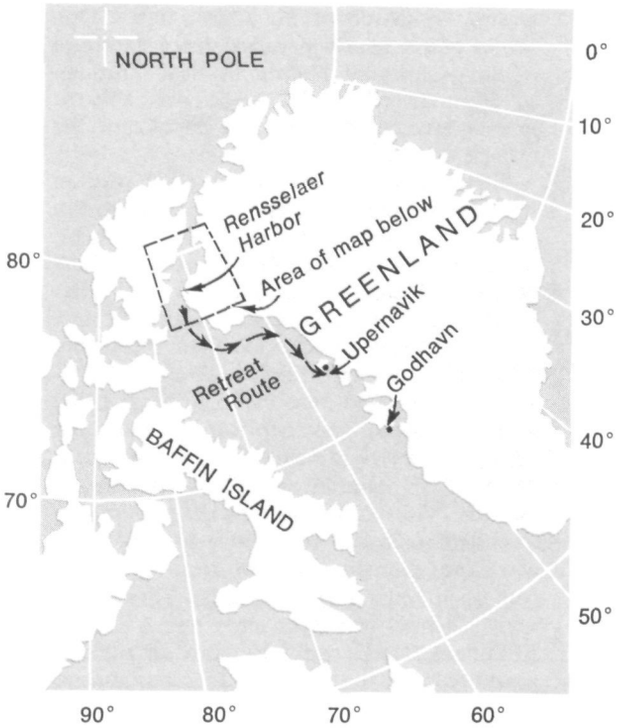
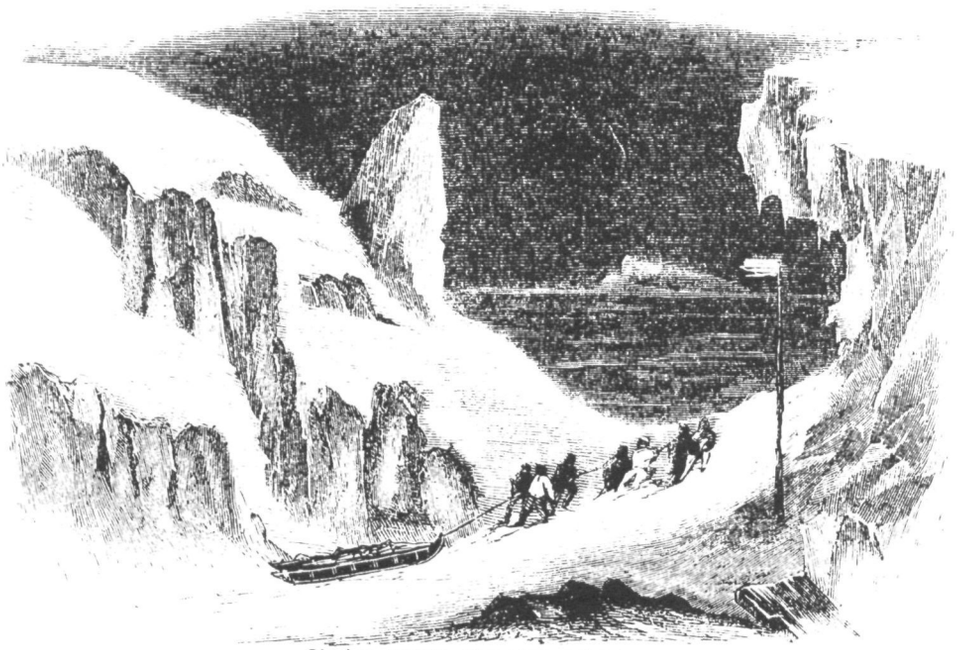
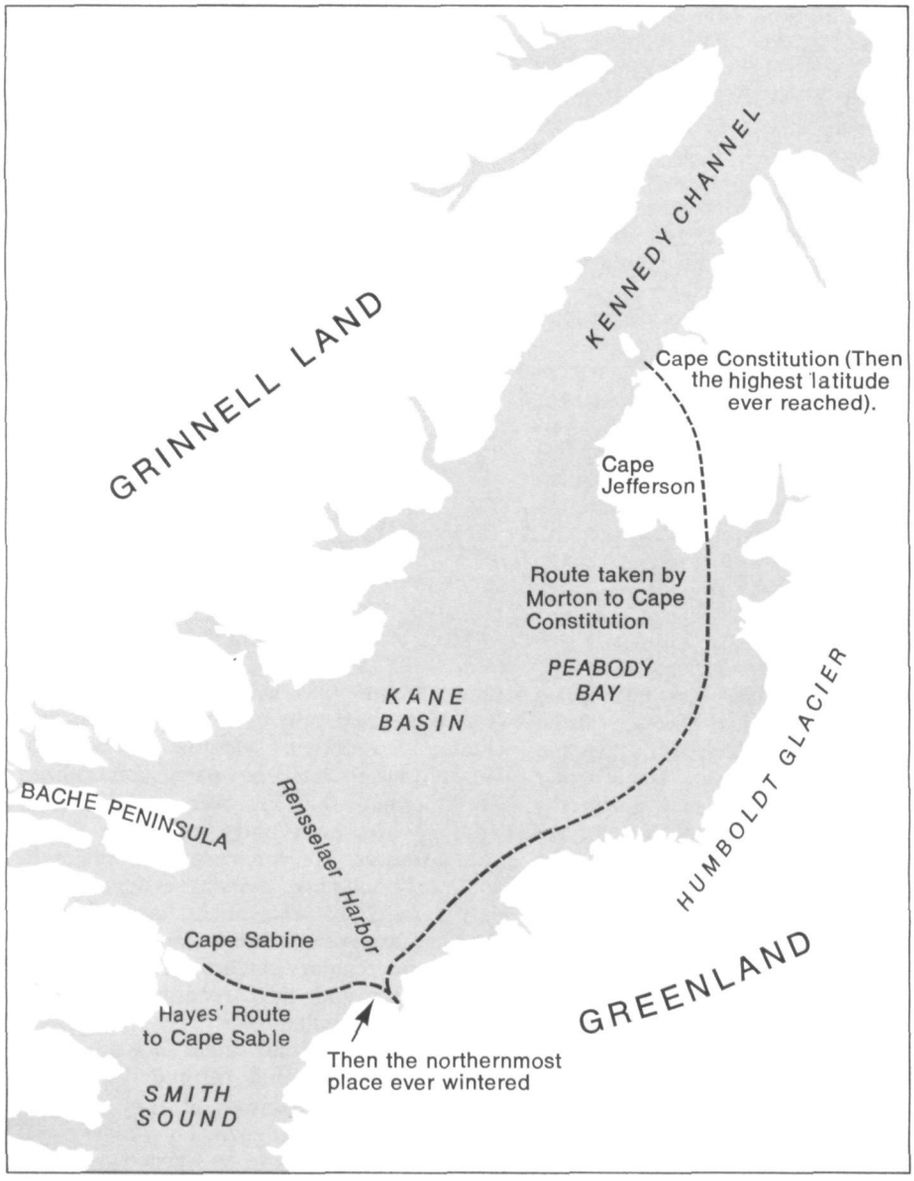
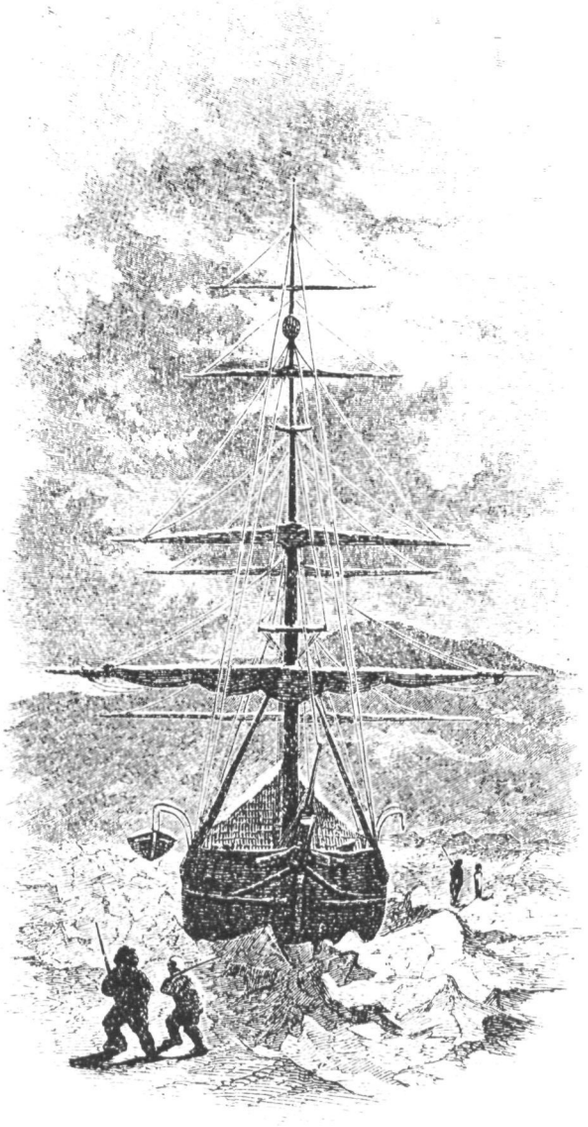


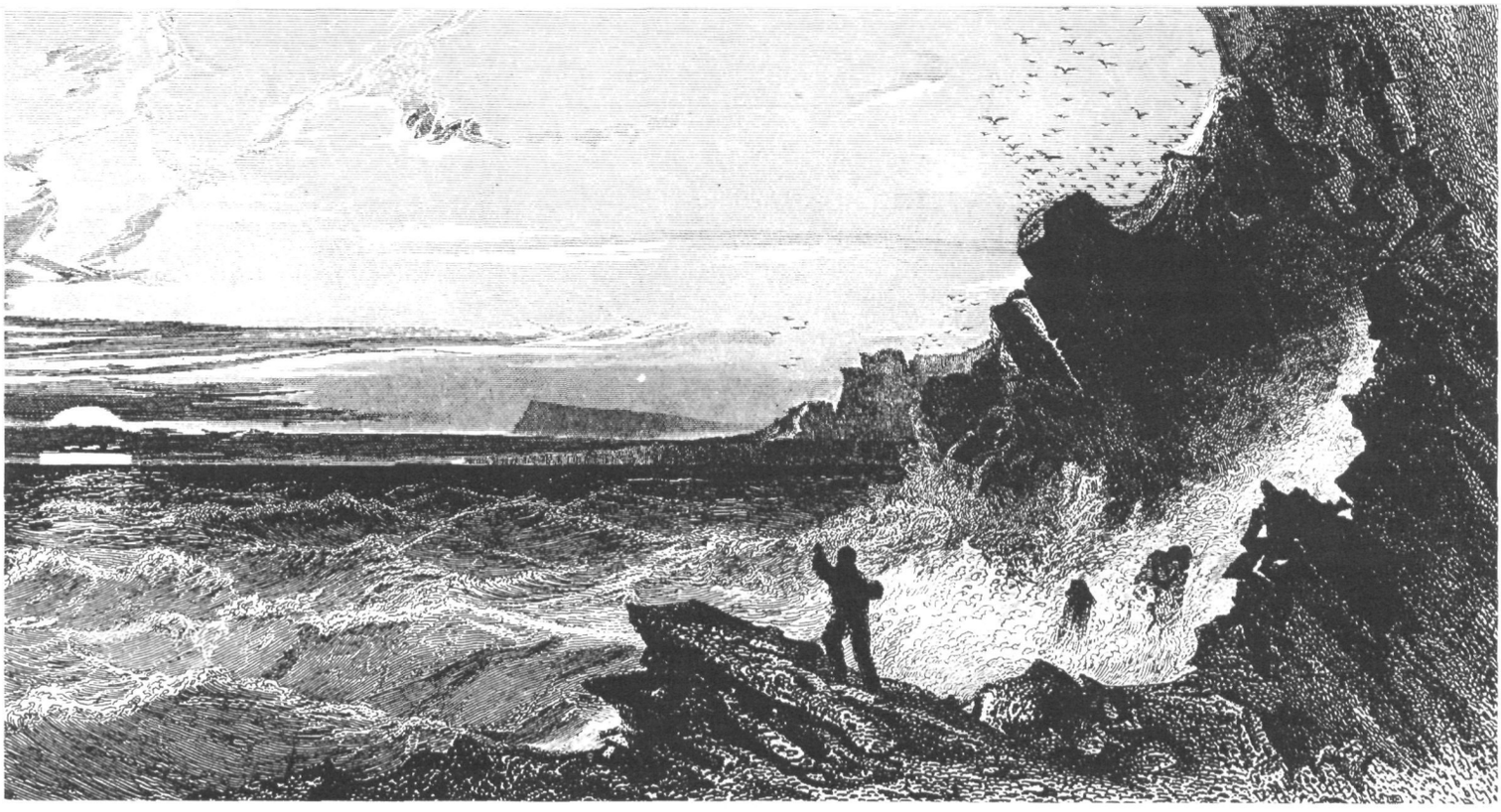


Sledge rescue of an injured man.





The ADVANCE was hopelessly icebound in Rensselaer Harbor.



The open water from Cape Jefferson. *(Except for this engraving, the sketches were the work of the talented Dr. Kane.)*

natives of the far northland. To make the brig liveable for the long Arctic winter, he took a lesson from the Eskimos in igloo building. The able-bodied members of the party spent many days gathering moss and turf wherever it could be scraped. The sides of the brig and the quarterdeck were well padded. An inner space, just large enough to accommodate his party, was similarly enclosed and packed. An entrance was made into the hold through a low moss-lined tunnel.

From the Eskimo was also learned the secret of obtaining food from the walrus, seal, bear, and Arctic birds. A treaty was agreed upon with the Eskimos and solemnly ratified, although not in writing. The natives agreed not to steal, to bring fresh meat, to lend dogs, and to show the explorers where to find food. The white men promised not to "visit them with death or sorcery, nor do them any hurt or mischief whatsoever." The explorers were to shoot for the Eskimos in the hunt, to make them welcome aboard ship, to give presents of needles, pins, knives, wool, fat, an awl, and sewing thread, and to trade honestly for walrus and seal meat of the first quality. The contracting parties pledged themselves, then and forever, brothers and friends.

With supplies low, and realizing the impossibility of enduring another Arctic winter, Dr. Kane began a systematic plan for their retreat from Rensselaer Harbor to Upernavik. He knew the 1300-mile journey would take most of the summer. In keeping with his concept of Arctic logistics, he sent out sledge teams to cache supplies as far down the coast as possible. All through the late winter and early spring they made preparations, packing supplies and equipment into three 26-foot whaleboats, since most of their journey would be by water, and the brig, hopelessly frozen in, would have to be left behind. On May 20, 1855, the party left Rensselaer Harbor and traveled by land for about 40 miles, carrying the boats to a point where they could put them in open water.

The rest of the 1300-mile trip to the Danish settlement was made largely via the three boats, but not without excruciating difficulties. Open water was spotty, and frequently the boats had to be pulled out of the water and carried over rugged and dangerous ice packs. One man died, leaving now only 17 to carry the boats and supplies.

Finally, in early August 1855, 84 days after they left the brig, they reached Upernavik. Here, they were greeted warmly by the Danes, and learned of an Eskimo report that Sir John and his party had perished 1000 miles from where the Kane group had been searching. They learned also that the U. S. Navy had sent a ship out to rescue them under the command of Lt. H. J. Harstene, USN. Some weeks later, after Harstene had been sent a message advising him of Kane's safety, Kane and his 16 remaining men set out in a whaleboat to meet the rescue party, which they did in the vicinity of Godhavn.

Late in the morning on a clear day in early September, the captain of the Navy steamer, sent out to find the lost explorers, saw a weatherbeaten whaleboat with 17 unkempt voyagers. The leader was a small man in a ragged flannel shirt standing in the bow. The whaleboat drew alongside, and the weary men were taken aboard the Navy ship. The ship arrived in New York harbor on October 11, 1855, ending one of America's most historic voyages.

Dr. Kane had pioneered a route that was followed later by other American explorers, including Admiral Robert E. Peary, discoverer of the North Pole, more than 50 years later. Dr. Kane was responsible for the initial mapping of a large portion of the route he followed, including Kane Basin. He designed a system of logistics for Arctic exploration—involving the use of cached supplies—to be followed by all subsequent Arctic explorers. Also, he established friendly relations with the Etah Eskimos in northern Greenland, to the great advantage of those who followed his pathway to the Arctic. In addition, he and his party conducted significant scientific investigations to gather meteorological, geomagnetic, geological, tidal, astronomical, and biological data of the area.

Lasting benefit to American science resulted from the long, hard sojourn in the Arctic. Professor Bache accepted for the Coast Survey the wealth of astronomic, meteorological, tidal, and magnetic data which Dr. Kane brought back on his return to civilization. They were processed and evaluated by one of the Survey's leading scientists, Charles A. Schott. Professor Bache personally presented the findings to the American Association for the Advancement of Science.

After Dr. Kane's death in 1857, Professor Bache paid him the following tribute in addressing the American Philosophical Society: "The labor in physical observation of Dr. Elisha Kent Kane and his associates had few parallels when the difficulties to be surmounted and the results produced are considered."

The Weather Bureau Director discusses money, manpower, and meteorology, as they affect the outlook for

The Weather Bureau: Today and Tomorrow

"I have never seen a more dedicated, harder-working group of public servants."

In a special interview for ESSA WORLD, the Director of the Weather Bureau, Dr. George P. Cressman, sees real progress in weather and river services despite hard times.

Q. *It is now a little over a year since you announced plans for a reorganization of the Weather Bureau forecast system. What is its current status, and is it going according to plan?*

A. The Weather Bureau forecast reorganization is off to a good start. New Weather Bureau Forecast Offices have been established at Portland, Oregon; Detroit, Michigan; Pittsburgh, Pennsylvania; Raleigh, North Carolina; Columbia, South Carolina; and a partial start made at Oklahoma City. We hope to follow soon with Birmingham, Alabama. The FY 1970 budget request to Congress contains funds for Boise, Idaho; Indianapolis, Indiana; Philadelphia, Pennsylvania; and for bringing Oklahoma City up to full Weather Bureau Forecast Office status. This is pretty much according to plan.

Q. *The combination of the creation of forecast centers, the trend to automation, and the use of recorded answering devices would seem to indicate a stripping of responsibilities at the local Weather Bureau level. Is this the case?*

A. That is a ridiculous idea. On the contrary, completion of the forecast reorganization will result in over 50 stations preparing public and aviation forecasts directly from facsimile for issuance to users, instead of the previous 26 offices. We should not confuse this with the trend to automation and the use of recorded answering devices. These are intended to help lighten the excessive workload found at most Weather Bureau offices. I have personally looked into the problem of "telephonitis" at a large number of field stations. We are all very concerned about it. The use of recorded answering devices is a method we are counting on to relieve our personnel of much useless work. We will expand the use of these as fast as we can find the necessary funds.

Q. *Who will issue what kinds of forecasts in the future?*

A. As explained in policy letters issued last year, meteorologists will be issuing forecasts of all types, and meteorological technicians will be preparing local forecasts and warnings for short time periods.

Q. *Which of the Weather Bureau services have the biggest payoffs?*

A. The figures we have indicate that public weather, agricultural weather, fire weather, and river and flood forecasting have the biggest economic payoff per dollar invested. The hur-

"Public weather, agricultural weather, fire weather and river and flood forecasting have the biggest economic payoff per dollar invested. The hurricane and tornado warning services are effective in saving of life, which is hard to evaluate in a coldblooded cost-benefit ratio."

ricane and tornado warning services are effective in saving of life, which is hard to evaluate in a coldblooded cost-benefit ratio.

Q. *Why are we faced with continual retrenchments year after year, especially when there is such an obvious benefit to the economy from our services?*

A. As you know, we don't print the money we use. Our requests for funds to the Congress have to be made within the national policies which are set by the Executive Branch of the Government. We then are voted funds by Congress to use. Additionally, we fall under those other restrictions set by the Congress to keep the total Government employment and the total Government spending under control. As far as I know, we're not faring any worse than other comparable civil agencies of the Government during these times, which are austere for practically all of the old line agencies of the Government.

Q. *There has been criticism that the field stations suffer at the expense of disproportionate central and regional headquarters staffs. Do you wish to comment?*

A. During a period of retrenchment, it is natural to think that the other fellow is getting off too easily. However, we are making every effort to associate personnel reductions with workload reductions at field stations, but not at headquarters offices. Vacancies are being held without explicit workload reductions at both central and regional headquarters. In addition, all relief on the position restrictions has been applied directly to field stations and none to headquarters.

Q. *Why are you moving ahead with the reorganization at a time when you are forced to close stations and reduce staff? Why not wait for better times?*

A. If we wait for better times, then we may wait too long. Austerity is no excuse for not correcting inequities or failing to make progress.

Q. *Is progress in Weather Bureau programs and services possible during these austere periods?*

A. Yes. It is more difficult, but not impossible. For example, the weather radar network has been substantially extended during the last few years, through budget action and cooperative arrangements with the Federal Aviation Administration and the Department of Defense. Air Report (AIREP) coverage has increased by a factor of ten. Real progress has been made in the accuracy and extent of numerical forecasts. To some extent, we can document the improvement that this effects in the public forecasts.

Q. *What is the Weather Bureau's relationship with the Federal Aviation Administration (FAA)?*

A. The FAA is working with us in three areas particularly. They take observations at a large number of locations around the country, and in this way, enable us to get enough information to make our forecasts. The FAA is also handling the large increase in dissemination of weather information to pilots. For many years, they have operated the domestic weather communications. On our part, we are trying to concentrate on those activities which

continued

are appropriate to a meteorological organization—namely, the collection of the data, the processing of the data, the interpretation of it, and the preparation of the forecast material. The FAA is a tremendous help in dissemination of prepared forecast material to the pilots. Without the help of the FAA, I'm afraid that we simply would not be able to handle the tremendous increase in demand for our own products.

Q. *Where do you think the Weather Bureau is heading in the next few years?*

A. The most important thing we have to do in the next few years is to cure the staffing shortage. We intend to do this using as a framework the reorganized forecast structure.

Q. *At most field stations, there are many instances in which forecasters and briefers must devote much of their time to communications and other duties. Are there plans to alleviate this situation?*

A. We are very concerned about this type of situation. Basically, it stems from staffing shortages. If the staffing shortages could be alleviated, we'd be able to be much more successful in having the meteorologists and meteorological technicians work at their proper grade level. In the long range, automation may be of some help, but doesn't present much hope in the near future.

Q. *What are the prospects for increasing the number of day jobs, especially for senior employees?*

A. To begin with, a number of OIC jobs are being created in connection with the redefinition of duties of meteorologists and meteorological technicians and in connection with the forecast reorganization. The forecast reorganization will add a large number of day-shift jobs for meteorologists, principally at Regional Weather Centers. The service program expansion in special areas, such as air pollution and fire weather, will help increase the proportion of day-shift jobs by adding positions which are mainly day-shift positions. Our longer-range plans for easing the staffing shortages will help with this problem further, since study and training shifts will have to be added during the daytime hours.

Q. *How do you feel about unions in the Weather Bureau?*

A. I think that the Weather Bureau unions give us a very good opportunity because they are a valuable channel of communication. I think they have a function to serve.

Q. *What lies ahead in forecasting? What new developments do you foresee in the next five years?*

A. I see developments leading to improved forecasting in the five-day range and in the periods under twelve hours. Within the next five years, increased computer capacity will enable us to use higher-resolution numerical grids, and at the same time the general improvement to be expected in numerical models should lead to significant increases in accuracy of forecasts in the two- to five-day range. At the shorter ranges, completion of the radar network, together with the prospect of pictures at 20-minute intervals from a synchronous satellite, should lead to a distinct advance.

Q. *What, in your opinion, is the value and the potential of the weather satellite program?*

A. The present weather satellite program, with its photographs of cloud distribution, has proven to be practically indispensable for hurricane and typhoon forecasting and for general forecasting along the edge of sparse data areas. Our west coast forecasters are particularly enthusiastic about the value of satellite pictures. The potential of satellites exceeds the present value, in that there are indications that technology is capable of giving us extensive wind data and vertical sounding data from future sensor development in satellites. This could go a long way toward solving the problem of prediction when we have to deal with large areas of no data.

Q. *Is the World Meteorological Organization (WMO) important to the Weather Bureau and to our national weather service?*

A. The WMO is absolutely essential. We couldn't solve the forecast problem without data from the high seas and from other countries—for example, Canada and Mexico. The WMO is the coordinating body which sees to it that we obtain the data from the rest of the world on a timely schedule and in a coordinated manner.

Q. *Are you sold on probability forecasting, and are there any plans to reevaluate its use?*

A. The atmosphere itself is not completely predictable at any scale. The smaller the scale, the shorter is its predictability. I think that, in view of this basic fact of meteorology, probability forecasting is the only way we can honestly express the forecast. Of course, we are constantly reevaluating this to see if there isn't a better way to express probabilities.

Q. *Is there enough value to the five-day forecast, the thirty-day outlook, and even a seasonal forecast to warrant the attention and resources to try to improve them?*

A. There is considerable information from agricultural and other commercial activities to indicate a very high potential value of thirty-day and seasonal forecasts, if significant skill could be demonstrated. However, we have to admit that methods of attaining satisfactory skill have yet to be developed. There is much more promise in the five-day forecast activity. All that is preventing us from increasing our operational five-day forecasts to daily issuance is the lack of sufficient funds. We hope to find a way to do this.

Q. *What changes in service activities are apparent to you at this time?*

A. Three types of activities are especially apparent as needing increased emphasis. These are:

- ☐ Marine forecast needs, especially in coastal waters where high surf, storm surge, etc., can be disastrous.
- ☐ Air pollution control. Air pollution has assumed the status of a large-scale national problem, and the movements and properties of the atmosphere are the key to its control.
- ☐ Dissemination of weather information both to the public and to aviation. We are still using the methods of the 1930's for our main dissemination systems and are reach-

ing only a fraction of the potential users. Mass dissemination done as automatically as possible is the only way to handle this problem.

Q. *Is there enough applied meteorological research being done in ESSA?*

A. Of course, there is not. However, the balance of applied meteorological research, as compared to other ESSA activities, seems reasonably sound.

Q. *Where is the greatest emphasis on applied research needed in the next few years?*

A. I would say that several areas need applied research emphasis in the next few years. First, of course, we need to continue our emphasis on numerical prediction models. Also, a substantially greater emphasis is required in development of equipment for observing and for relaying observations to a collection point. Techniques of marine forecasting for high seas and for coastal and inland waters as well are very badly needed. Development of techniques for forecasting tornadoes is also lagging and should be pushed.

Q. *What are the career opportunities for the meteorologist and the meteorological technician today?*

A. There is no limit to the career opportunities for the meteorologists. We have also enhanced the career opportunities for the meteorological technicians with widespread application of the new concept of the OIC.

Q. *What kind of training and education is needed to get ahead, and what kind of help is the Weather Bureau providing?*

A. The best education is a broad one in the physical sciences with plenty of meteorology or hydrology. Oceanography is assuming increasing importance. By and large, the man with graduate degrees will go farther. The Weather Bureau cannot substitute for the university in providing education. However, we hope to be able to build up our practical training in forecast techniques and practices and to make a significant start in training in weather briefing and interpretation.

Regardless of how bad the times are, we will have to get started on a Weather Bureau-conducted course in adaptive forecasting, interpretation, and briefing for meteorological technicians, within the next year. As a longer-range program, we are giving high priority to an attempt to budget for a comprehensive training program for technicians and entering meteorologists and hydrologists.

Q. *Where, in your opinion, are the best jobs in the Weather Bureau now?*

A. To my liking, they are found mostly in the Weather Bureau Forecast Offices. I would single out especially meteorologist in charge, hydrologist in charge, or official in charge jobs. As you say, it's a matter of opinion.

Q. *How does the Weather Bureau and the caliber of its people stack up in your opinion, and why should a young man or woman want to get into the weather and river services?*

A. I have never seen a more dedicated, harder-working group of public servants. I would list two reasons for entering the weather and river services: The work is exciting and interesting, and it is a vital public service. □

George P. Cressman

became Director of the Weather Bureau on September 1, 1965. Before the formation of ESSA, he headed the Bureau's Office of National Meteorological Services, providing policy guidance and direction of Weather Bureau field offices.

Born in West Chester, Pennsylvania, October 7, 1919, Dr. Cressman received his bachelor's degree from Pennsylvania State University, his master's from New York University, and his doctorate from the University of Chicago. He served in the U.S. Army as a meteorologist from 1941 to 1946. After leaving the Army, Dr. Cressman served as a research assistant at the University of Chicago. From 1949 to 1954, he was a civilian consultant with the Air Weather Service at Andrews Air Force Base.

In 1954, he played a key role in the establishment of the Joint Numerical Weather Prediction Unit, the NMC predecessor operated by the Weather Bureau, Air Force, and Navy. While with the unit, he pioneered in the field of operational forecasting procedures by numerical weather prediction techniques.

Dr. Cressman transferred to the Weather Bureau in 1958 as Director of the newly formed National Meteorological Center. Three years later, he received the Department of Commerce Gold Medal for his outstanding accomplishments, distinguished authorship, and leadership of NMC.

He was president of the World Meteorological Organization's Commission for Aerology from 1961 to 1965 and served on the WMO Advisory Committee from 1963 to 1968. He is a member of the American Meteorological Society, the Washington Academy of Sciences, and the American Association for the Advancement of Science.

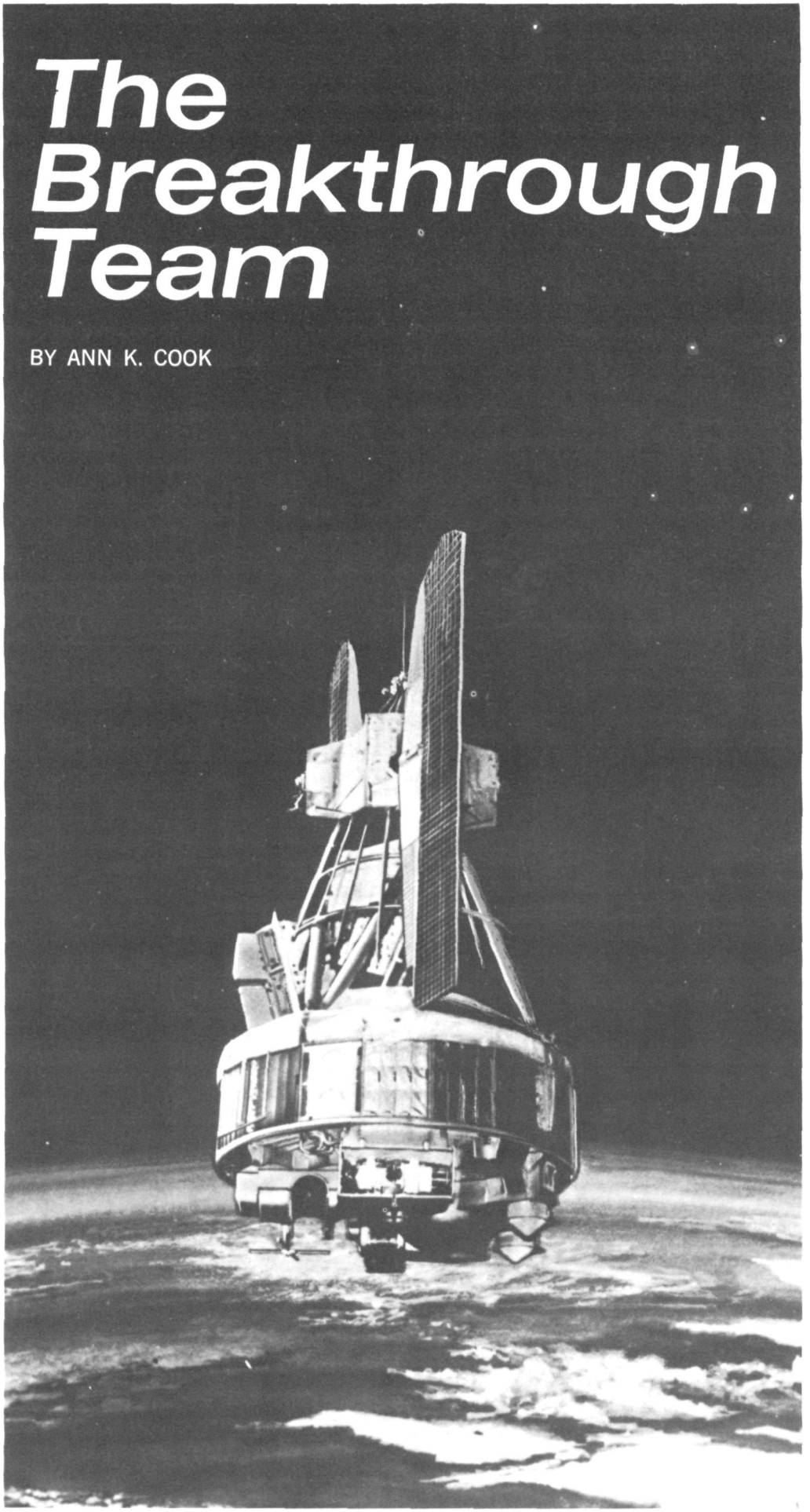
Dr. Cressman is married to the former Nelia Hazard. They have four children: Ruth (25), George (23), Catherine (19), and Florence (17).

Camping, hunting, fishing, archery, and hiking are some of the things Dr. Cressman likes to do when he gets the chance —and when the weather cooperates. □

Swearing-in ceremony. (L. to r.) Dr. Cressman, Guy Dorsey, and Dr. White.

The Breakthrough Team

BY ANN K. COOK



EXCITEMENT and elation were evident throughout ESSA's Satellite Experiment Laboratory in April, as data began to come in from the Satellite Infrared Spectrometer aboard Nimbus III.

Called SIRS A, the instrument was built by the Laboratory to provide a profile of temperatures from the satellite to the ground or to the top of a cloud layer.

The April 14 launch of NASA's latest research and development weather spacecraft climaxed a decade of work for this group of scientists and technicians in the National Environmental Satellite Center.

SIRS is the first product of the Laboratory to be flown on an unmanned satellite although its development began in 1959 before any weather satellite had been orbited. An identical instrument was aboard the Nimbus spacecraft which was destroyed during launch in May 1968.

Within a week of the successful Nimbus III launch, SIRS A was being hailed as a "breakthrough," an accolade rarely bestowed by meteorologists.

The Nimbus Project Manager at NASA's Goddard Space Flight Center, Harry Press, called SIRS "a major breakthrough in every respect. This device has performed well beyond our fondest expectation. . . . We get a three-dimensional view of the earth's temperature right down to the ground or cloud tops. . . . It is really a fantastic device. It is working beautifully, and the data is stupendous."

David S. Johnson, Director of ESSA's Satellite Center, said that "the successful launch of experiments to measure temperatures in the atmosphere is as significant to the advancement of meteorology as the launching of the first satellite.

"The first satellite showed that one could have an observing platform. But it did not show what could be done to meet a very urgent need in weather prediction, namely providing the quantitative atmospheric measurements that are needed for weather prediction for any length of time in the future. Nimbus III has clearly showed that this can be done."

He pointed out that SIRS A is providing 5000 temperature soundings per day in the Southern Hemisphere alone, whereas the National Meteorological Center receives only about 70 upper-air soundings daily from that half of the globe.

Mr. Johnson anticipates that sounders based on the principles of SIRS will be incorporated in ESSA operational satellites during the early 1970's.

SIRS is a 91-pound instrument which measures the infrared energy radiated by the atmosphere at seven wavelengths in the 15-micron absorption band of carbon dioxide. Temperatures at various levels can be derived from these measurements, using techniques developed in the Laboratory. The spectrometer also senses the temperatures of the cloud tops, when they are present, by means of a measurement at an eighth

wavelength in the water vapor "window" (at 11 microns). In the absence of clouds, this measurement can be used to determine, within a few degrees, the surface temperature.

Harold Yates, Director of the Satellite Experiment Laboratory, calls the SIRS project "an outstanding team effort," citing in particular Dr. David Q. Wark, who led the theoretical work, and Don T. Hilleary, who supervised the instrument's development.

"Our calculations from the SIRS data have confirmed our theoretical studies," Dr. Wark says. "They have demonstrated that atmospheric temperature data which meets the accuracy requirements of meteorologists can be obtained from a satellite by an instrument that meets rigid standards of quality."

The accuracy of the temperatures derived from SIRS data is close to one degree Celsius above 500 millibars and about 2 degrees at lower levels, depending on cloud conditions. Analyses of circulation patterns based on the satellite data are in good agreement with circulation patterns based on conventional observations, especially for regions where large numbers of upper-air soundings are made. Discrepancies appear over areas where few weather observations are taken, indicating that the conventional analyses for these areas are incorrect. The National Meteorological Center is using the SIRS data in a test program to determine whether it will improve weather analyses and forecasts. The computer time required for the calculation of a single SIRS sounding is less than one-tenth of a second, and 24 hours of soundings can be derived in about three minutes.

Computerized weather forecasting demands dense observation of weather elements all over the globe and at many levels in the atmosphere. Today such information is available from only 20 percent of the earth, and the remaining 80 percent—mostly over the oceans—remains inadequately observed. ESSA satellites have been providing daily pictures of the earth's cloud cover since the operational system began early in 1966, but the photographs do not fill the need for quantitative information on temperature, humidity, and wind. Satellites present a practical method of gathering such data.

The staff of the Satellite Experiment Laboratory combines scientific knowledge, ingenuity, and the craftsmanship of expert instrument makers to develop new techniques for remote sensing of the environment from spacecraft.

As the history of SIRS A demonstrates, the Laboratory's projects are a long time in coming to fruition. After the original idea is conceived, a project begins with the design of sensors and electronics, and the construction of an initial experimental or "breadboard" model, which is tested and, if necessary, adjusted or changed. When this phase has been completed, instruments are built for flight-testing, usually on balloons or aircraft. Results of these tests are then studied to determine whether the project is feasible and to check the accuracy of the sensors' measurements. Finally, if the instrument is accepted by NASA for incorporation in a satellite such as Nimbus, flight models compatible with the spacecraft environment must be built.

In the case of SIRS, the initial idea for using radiometric measurements from satellites to sound the atmosphere was put forward in 1969 by Dr. L. D. Kaplan of the Massachusetts Institute of Technology. A project to develop such an instrument was proposed by the Weather Bureau, and NASA agreed to support the first phase of the effort. In this phase, a breadboard instrument was developed to check the engineering feasibility of the experiment and to develop a basic optical and detector system.

About six months were devoted to laboratory testing of the prototype instrument, to check its performance and stability from an engineering standpoint.

Larry Heacock and Lee Johnson recall the laboratory tests as a chilling experience for the staff. In the initial attempts to use the SIRS model to measure temperatures, the instrument was aimed out of a window. The staff worked at night, because the only time good measurements can be obtained near the ground by the SIRS technique is just before dawn, when a temperature inversion occurs in the lower atmosphere. To

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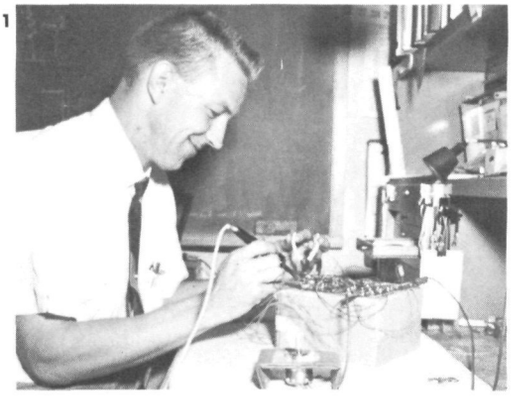

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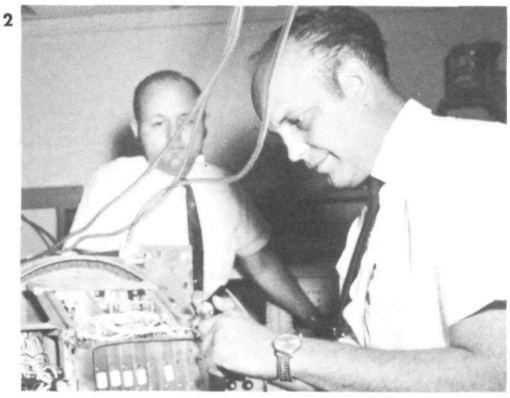

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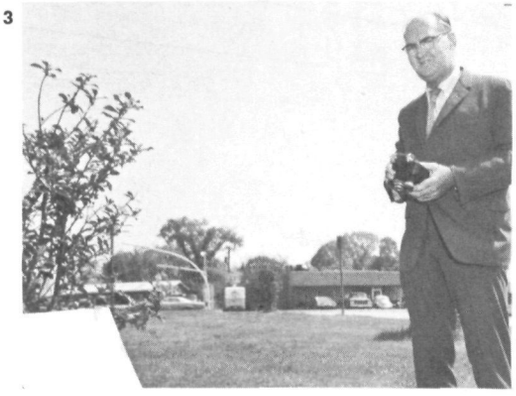

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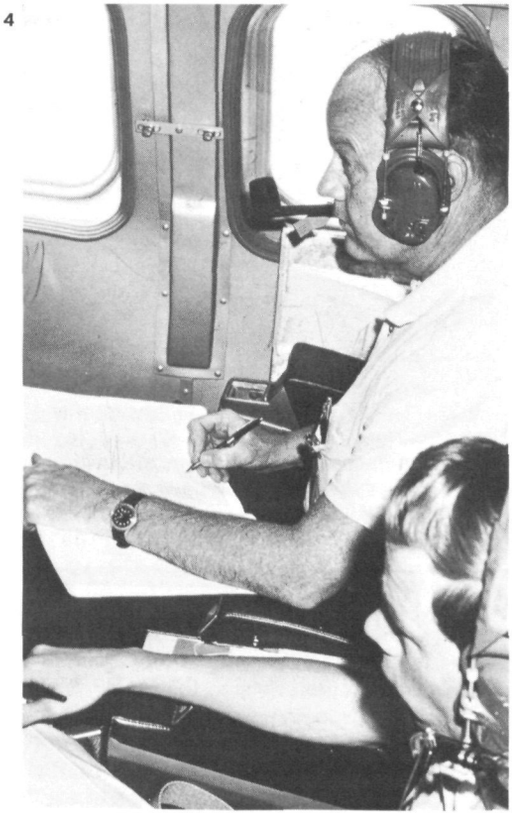

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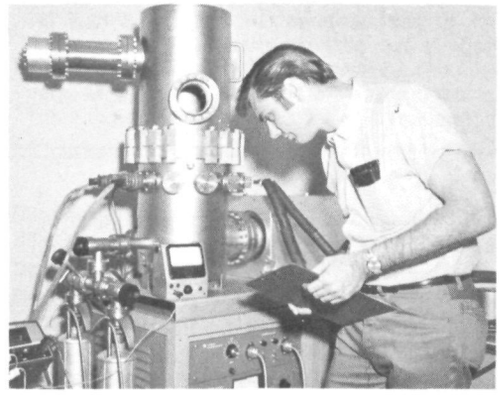
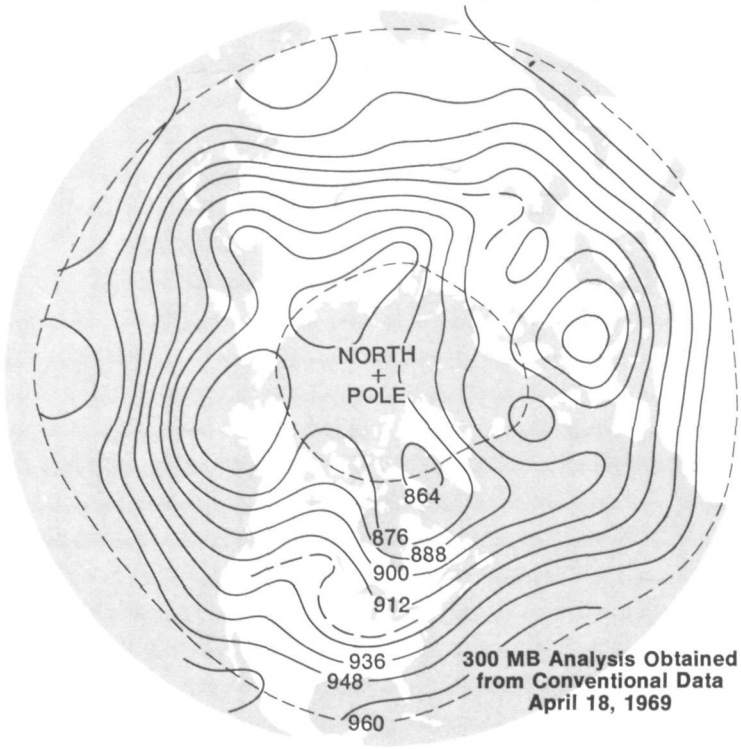
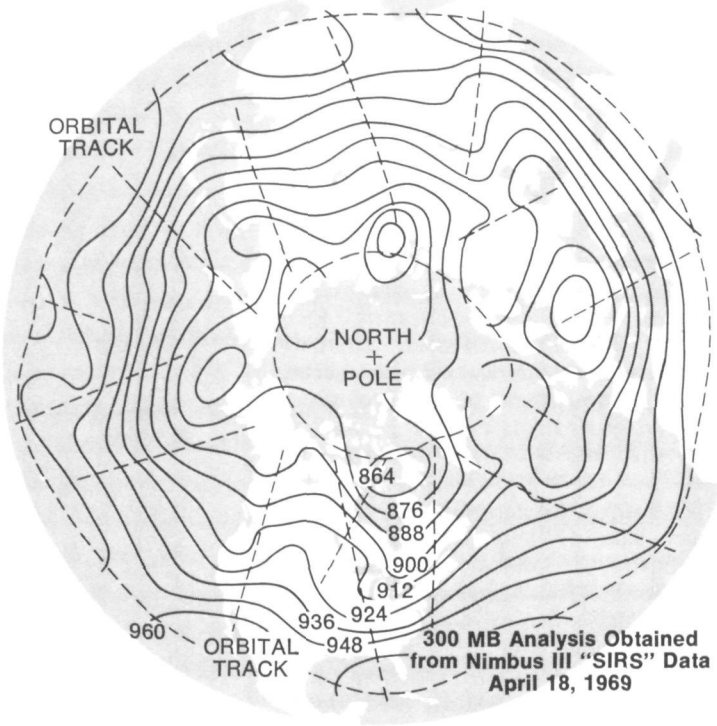


1. Eugene Henry performs a test as part of the Laboratory's search for a reliable motor for space use. 2. Joseph Kapsch (right) connects an amplifier to SIRS A with the help of Larry Heacock. 3. William Morgan calibrates the handheld spectrograph tested by Gemini astronauts. 4. David Wark and Lee Johnson (foreground) aboard NASA's Convair 990 check the performance of the Cloudtop Altitude Radiometer. 5. James Wydick subjects satellite subassemblies to environmental thermal vacuum tests.



300 MB Analysis Obtained from Conventional Data April 18, 1969



300 MB Analysis Obtained from Nimbus III "SIRS" Data April 18, 1969

These two charts illustrate a comparison of the height contours of the 300-mb. pressure surface derived from Nimbus III infrared radiance observations with the height contours obtained from conventional data. The contour patterns are closely related to the circulation of the atmosphere at an altitude of 30,000 feet. The atmosphere at this altitude tends to move in a direction parallel to the contours and with a speed inversely proportional to the contour spacing; that is, contour lines which are relatively close together indicate relatively high wind velocities.

Good agreement between the satellite-derived circulation patterns and conventionally derived circulation patterns is apparent in regions where large numbers of conventional observations are available. Discrepancies can be seen where conventional upper-air observations are sparse.

increase the temperature range, they used air conditioning to cool the room to about 10 degrees, and then opened the window.

After some modification, the instrument was performing according to specifications, and the Weather Bureau proceeded to the development of an advanced system, incorporating many of the electronic and mechanical design features of the eventual satellite instrument. Three of these advanced systems were delivered by the contractor early in 1964 for performance tests from high-altitude balloons.

The SIRS was tested on two balloon flights: one from Palestine, Texas, on September 11, 1964, and one from Sioux Falls, South Dakota, March 10, 1965. The spectrometer measurements were compared with readings taken by conventional radiosondes and by stations beneath the balloons' trajectories, and were found to approximate the temperature measurements taken by conventional radiosondes within 1 or 2 degrees Celsius.

Heacock and Johnson drove the balloon flight model to Palestine, Texas. On the road, they thought of a modification that would improve the instrument. When they stopped for the night, they bought parts in a radio store and built the modification in their motel.

The Texas test was the occasion of another memorable event for Lee Johnson. Technicians suspected that the transmitter sending SIRS data to the ground was affecting the instrument's readings. They wanted to check the readings with the transmitter off. Being the smallest member of the group, Johnson was placed in the gondola with the SIRS and hoisted 100 feet into the air on a crane, where he could record the measurements that were not being transmitted to the ground receiver.

Finally, the actual instruments for the Nimbus spacecraft were assembled in the Satellite Laboratory, using major components manufactured by contractors and within the Laboratory. Gil Smith, who put the components together, is known to his co-workers as "the man with the golden hands."

For everyone involved so deeply and for so long in the project, "a little bit of us went into the ocean with Nimbus B."

Long before SIRS A was orbiting the earth, the Laboratory was working on future generations of SIRS' descendants.

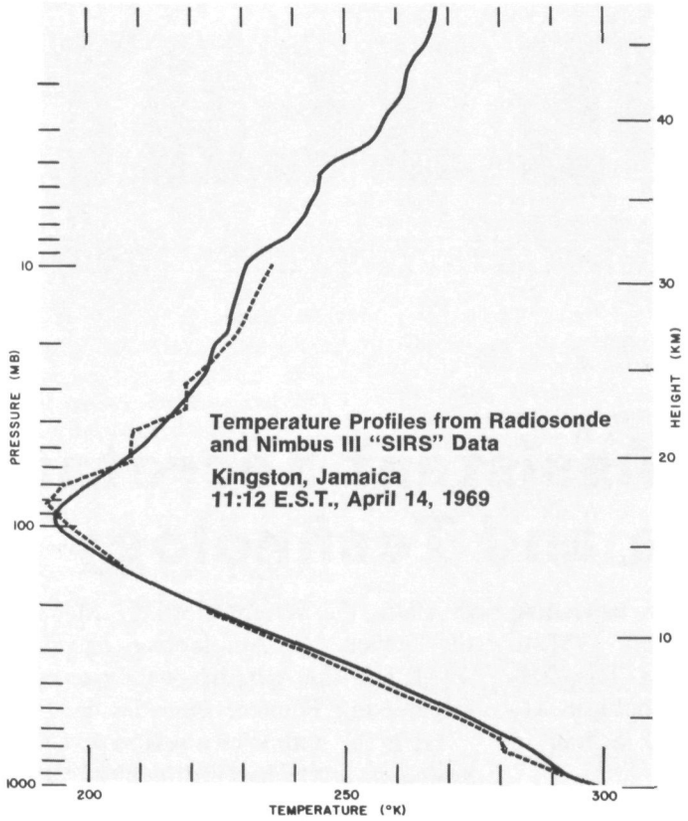
In 1966, the Laboratory began development of an improved SIRS, or SIRS B. The new instrument, now scheduled to be flown on Nimbus D in 1970, measures water vapor concentration as well as temperatures in the atmosphere. Its measurements of vertical temperature distribution, combined with measurements at several wavelengths in the water vapor band, can be used to deduce the humidity profile.

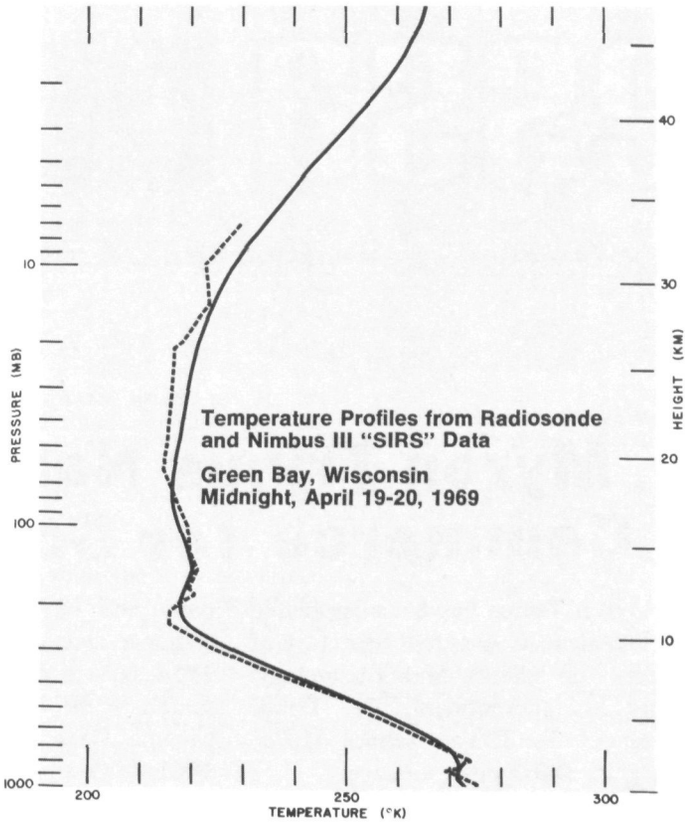
Moreover, SIRS B will provide more complete geographic sampling than the spectrometer on Nimbus III. The Nimbus III SIRS points straight downward, providing a large number of temperature profiles along the track beneath the spacecraft, but no data for the areas between successive orbital paths which are about 1600 nautical miles apart at the Equator. SIRS B will have three fields of view—directly beneath the spacecraft and to the east and west of the orbital path to provide increased geographical sampling. Flight models of SIRS B are now being built by contractors.

Still another SIRS offspring, an Infrared Temperature Profile Radiometer, has been accepted by NASA for Nimbus E, and construction of the first model will soon be underway in the Laboratory. The ITPR is designed to provide atmospheric temperature and moisture profiles and to overcome the problem of interpreting observations over partly cloudy areas.

One product of the laboratory—a hand-held spectrograph—was used by Gemini 5 astronauts Gordon Cooper and Charles Conrad, Jr., to test the feasibility of measuring cloud-top altitudes from a satellite.

This camera-like instrument records, on





These two figures show the temperature of the atmosphere over the Caribbean near Kingston, Jamaica, and over Green Bay, Wisconsin, obtained by conventional radiosondes (dashed lines) and from the SIRS data (solid lines). Temperature is in degrees Kelvin (above absolute zero Celsius), and the height is shown in millibars of pressure and kilometers of height. The Kingston sounding was the first indirect temperature sounding obtained from satellite data. The Green Bay sounding is an example from the intercomparison program, in which special radiosondes are released to coincide with the passage of Nimbus.

high-speed infrared film, the spectrum of sunlight reflected from a cloud top in two narrow wavelength regions—one in an absorption band of oxygen and one in an adjacent clear region. The effect is to make a quantitative measurement of the amount of oxygen above the cloud which, with an accurate knowledge of the angle of illumination and observation, can be related to the position of the cloud top in the atmosphere.

In the Gemini 5 test, the astronauts pointed the spacecraft downward, aimed the spectrograph at a selected cloud, and took a "picture." Simultaneous observations by a Research Flight Facility aircraft showed that cloud-top altitudes could be derived successfully in this way.

The Laboratory then turned to the task of developing a more sophisticated instrument for measuring the solar beams reflected from clouds to provide cloud altitude measurements over the sunlit portions of the earth. The first model of CAR—Cloudtop Altitude Radiometer—was flight-tested in 1968 from NASA's Convair 990. These tests showed the instrument to be effective on all but thin cirrus clouds. Cirrus measurements are important, so an improved version will be evaluated before proceeding to spacecraft hardware.

The Satellite Experiment Laboratory is staffed and equipped to carry the development of such instruments through the entire development cycle. It not only devises new techniques for measuring the environment from space, but also develops and tests the instruments in its own shop. Often, the equipment to calibrate and test the instruments must be developed and built in the Laboratory's shops. In many cases, the Laboratory must perform basic research on the characteristics of the medium being sensed. In connection with SIRS, the staff is conducting basic studies of the absorption characteristics of carbon dioxide in the atmosphere.

The Physics Branch, headed by Walter G. Planet, constitutes the Laboratory's basic research activity, investigating ideas for new sensors, conducting theoretical and experimental investigations, and evaluating theoretical models of geophysical phenomena. The Physics Branch also carries out applied research in the areas of satellite sensor calibration, accurate measurement of infrared molecular absorption coefficients in support of SIRS, and studies of the physical characteristics of special materials used in spacecraft instruments.

The scientists' work is supported by the Electronics Branch under Larry Heacock, and by the General Engineering Branch, whose acting chief is Spencer P. Anderson.

The Electronics Branch designs and builds prototype instruments, and also maintains all the Laboratory's electronic equipment.

The General Engineering Branch contributes expertise in mechanical thermal engineering and vacuum technology, and performs environmental testing and calibration of instrument components. The Branch's extensive facilities for testing include vacuum chambers, a metal-lined room which cuts out electronic noise, and environmental chambers.

A unit called the Special Project Group, headed by Don T. Hilleary, is responsible for the actual development and production of field-test and spacecraft instruments. This group, under support from NASA, developed both the SIRS A and SIRS B instruments. The instruments they develop must be capable of providing quantitatively accurate data over an extended period—a performance not demanded of early research instruments in space. The stability of SIRS A attests to the success of the Special Project Group in meeting this crucial performance standard.

If the Laboratory's work sounds far out, take comfort from Don Hilleary's reaction when, as a new employee, he was asked whether he would be interested in working on a spectrometer.

His response, confirmed by reliable sources, was: "What's a spectrometer?" □

essa NEWS BEAT

U.S. DEPARTMENT OF COMMERCE ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

Dr. Myron Tribus Named Assistant Secretary Of Commerce for Science and Technology

Dr. Myron Tribus has been appointed by the President as Assistant Secretary of Commerce for Science and Technology.

Before his appointment, Dr. Tribus was Dean of the Thayer School of Engineering at Dartmouth College.

Born in San Francisco on October 30, 1921, Dr. Tribus attended the University of California at Berkeley and received a B.S. degree in chemistry in 1942. He received a Ph.D. in engineering in 1949 from the University of California at Los Angeles, where from 1946 to 1960 he taught engineering, rising from instructor to professor.

In 1950, he served as a consultant in heat transfer at the General Electric Company and has worked as a consulting engineer since that time. From 1951 to 1954, he was director, Aircraft Icing Research, at the University of Michigan. He became Dean of the Thayer School in 1961.

Dr. Tribus has been a member of the Department of Commerce Technical Advisory Board and a consultant to the Federal Office of Saline Water, Department of Interior. He served as an advisor to NATO in 1953, and has been a director of the Carpenter Technology Corporation, a major producer of specialty steels.

His awards for outstanding achievement include the Thurman H. Bane Award, Institute of Aerospace Sciences, in 1945; the Wright Brothers Medal of the Society of Automotive Engineers, 1945; and the Alfred Nobel Prize of the Engineering Founder Societies in 1952.

He is the author of a textbook, *"Thermostatics and Thermodynamics,"* 1961, and a new book, *"Rational Descriptions, Decisions and Designs,"* is now in press. He is a member of the American Society of Mechanical Engineers; the Institute of Electrical and Electronics Engineers; and the American Society for Engineering Education.

Dr. Tribus is married to the former Sue Davis of Ezel, Kentucky, who is the author of two cookbooks. They have two daughters, Louanne, 13, and Kamala, 9.

Dr. Benton, ERL Director, To Head University Department

Dr. George S. Benton, Director of the ESSA Research Laboratories for the past three years, will return to Johns Hopkins University, Baltimore, Md., in September to become Chairman of a new Department of Earth and Planetary Sciences.

He will continue as a senior consultant to Dr. Robert M. White, ESSA Administrator, particularly in major field scientific programs and in relationships between research and services to ESSA.

Commenting on the change, Dr. White said: "It is with keen regret that we announce Dr. Benton's decision. His leadership at ERL has been marked by vigor, dedication, and a high order of ability. We are, however, grateful that he will be able to continue his service to ESSA in a consulting capacity. I know all of his colleagues in Boulder and across the Nation join me in wishing him all success in his challenging new assignment."

(Left to right) Dr. Robert M. White, ESSA Administrator; Marshall Grace, Denver, Colo., Meteorologist in Charge; and Roy Fox, Weather Bureau Central Region Director, checked for rain and found none when the new Weather Bureau quarters at Denver were dedicated May 8. The ceremony followed a three-day rainstorm in the Denver area. (Photo by Denver Post)

C&GS, MIT Seek Data on Ocean's Planetary Waves

An extensive investigation is being made in the Pacific for unseen, elusive ocean waves which are thought to be about 1,000 miles in length and take two weeks to a month to complete one cycle.

The waves will be recorded by 15 tide gages on islands of the Caroline and Marshall groups on an east-west line stretching 2500 miles across the Pacific about 500 miles north of the Equator.

Known as planetary waves, they are believed to be caused by the gravitational attraction of the sun and moon on the earth and are therefore special tides. Once the waves have been initiated, however, they are apparently very largely governed by the depth of the water and by the effect of the earth's rotation on its axis.

The investigation is being conducted by three physical oceanographers, Professor Henry M. Stommel and Professor Carl I. Wunsch of the Massachusetts Institute of Technology, and Steacy Hicks of the Coast and Geodetic Survey. Data regarding the planetary waves will be gathered by the gages for four years and then subjected to analysis by high-speed electronic computers at ESSA and MIT.

The investigators hope to obtain the answers to such questions as: Do the waves move across the ocean or do they merely oscillate back and forth in a specific area, like water sloshing in a bathtub? How high are they? What is their significance?

The researchers will look for similarities with the well-known planetary waves of the atmosphere, discovered years ago by a noted MIT meteorologist, the late Carl-Gustaf Rossby.

The study will utilize existing Coast and Geodetic Survey gages at Guam, Truk, Eniwetok, and Kwajalein and others being established this year on Majuro, Koror, Yap, and Ponape. Next year, gages at Woleai, Satawal, Pulusuk, and Satawan in the Caroline Islands and at Pingelap, Jaluit, and Kusaie in the Marshalls will complete the observation network. Lt. Gerald M. Ward, Chief of the Coast and Geodetic Survey's Pacific Tide Party in Honolulu, is in charge of the installations.

all in the family PERSONNEL NOTES

Capt. Hubert W. Keith, USESSA, is the new commanding officer of the USC&GS Ship DISCOVERER. Capt. Keith, a 21-year veteran of the Coast Survey, has spent half of his duty at sea. His sea duty has included command of the SCOTT, GILBERT, HODGSON, and BOWIE. Also, he was chief of geodetic field parties and head of an airborne magnetic survey party to Alaska, Greenland, Iceland, Puerto Rico, and in several Atlantic coast states. Other assignments were in the Coast Survey's Geophysics Division, Washington, D. C.; Seattle, Wash.; acting head of the Anchorage, Alaska, field office; and liaison officer with the Army at Fort Sill, Oklahoma. Most recently, he was chief of ESSA's Miami Ships Base.

John P. McCallister has assumed the duties of Regional Hydrologist at Weather Bureau Southern Region headquarters, Fort Worth, Tex. Mr. McCallister entered the Bureau at the Atlanta Regional Office in 1946. In 1950, he transferred to the River Forecast Center in Kansas City, Mo., as principal assistant. He later became Hydrologist in Charge at Fort Worth.

Herbert S. Groper, former principal assistant at the WB's Baltimore office, has become meteorologist in charge of the Trenton, N. J., office. Mr. Groper began his career with the Bureau in 1942. He was awarded a bachelor's degree in meteorology from Pennsylvania State in 1965, after receiving a Weather Bureau scholarship to complete his studies.

Milton N. Schmitz has succeeded Fred Davis as meteorologist in charge of the Toledo, Ohio, Weather Bureau office. Mr. Schmitz joined the Bureau in 1946 at East Liverpool, Ohio, and subsequently served in assignments at LaCrosse and Green Bay, Wisc.

Eldon V. Jetton has been selected as meteorologist in charge of WBO El Paso. Mr. Jetton began his Weather Bureau career in 1942 at Cleveland, Ohio. He moved to El Paso in 1952 and was made principal assistant in 1963. Mr. Jetton holds a master's degree from Texas Western University.

Roger J. Nicholas and **Leo J. Waskey** have been named officials in charge of WBO Tanana, Alaska, and WBO Bettles, Alaska, respectively. Mr. Nicholas, previously stationed at WBO Unalakleet, and Mr. Waskey at WBO Talkeetna, are graduates of the Alaska Region's Native Training Classes for the WB/FAA backup program.

Richard S. Baker has been assigned as official in charge of the Weather Bureau's Winslow, Ariz., office. Mr. Baker's previous assignments have included stations on Yap and Truk, islands in the Pacific Trust Territory, at Grand Cayman Island of the British West Indies, and Soskatupu, Panama, on the Panama Interoceanic Canal Project. Most recently, he was assigned to the Reno, Nev., WB office.

Ronald L. Brooky has been selected official in charge of the Weather Bureau's Barter Island, Alaska, office. Mr. Brooky, a former member of the Air Force's Air Weather Service, entered the Bureau in 1966. All of his assignments have been in Alaska.

Kelly F. Anderson has been named official in charge of the Duluth, Minn., Weather Bureau office. Mr. Anderson, a 23-year WB veteran, replaced Kenneth A. Nicolson, who recently retired. His previous assignments were at LaCrosse, Wisc.; Goodland, Kans.; and International Falls and Rochester, Minn.

Dow E. Boykin is the new official in charge of the Waycross, Ga., Weather Bureau station. He entered the Bureau in 1956 and served tours of duty in the Antarctic and Arctic before moving to Jacksonville, Fla., in 1958.

Lt. Cdr. Charles H. Nixon has succeeded Lt. Joseph W. Dropp as Officer in Charge of the Officer Training Section at the Atlantic Marine Center, Norfolk, Va. Lt. Cdr. Nixon joined the Coast Survey in 1959, following graduation from the University of Massachusetts. His assignments since then have included service aboard ESSA vessels and with photogrammetric and geodetic field parties.

Richard E. Wilson has become the new official in charge of the Weather Bureau office at Johnston Island in the Pacific. Mr. Wilson served with the U. S. Army Air Corps during World War II. He began his Bureau career in 1955 at North Platte, Nebr., and subsequently served at weather stations in Canada, the West Indies, Montgomery, Ala., and Midland, Tex., before moving to the Pacific in 1963.

Donald L. Ocker, Memphis, Tenn., Weather Bureau Forecast Office, has been selected meteorologist in charge at WBO Key West, Fla. Mr. Ocker began his Weather Bureau career as a student trainee at Austin, Tex., in 1961. He worked at New Orleans, La., and Brownsville, Tex., prior to his transfer to Memphis, Tenn., in 1967.

Paul W. Dailey, Jr., is the new ESSA State Climatologist for Pennsylvania.

Nick Bardoulas, weather service specialist at the Rockford, Ill., Weather Bureau office, has been named official in charge of the LaCrosse, Wisc., weather station. Mr. Bardoulas replaces Kelly F. Anderson. A 22-year veteran of the Weather Bureau, he has served at Rochester, Minn., Chicago, and Springfield, Ill.

Stanley Holbrook has been named ESSA State Climatologist for Idaho.

Billy R. Curry has been selected ESSA State Climatologist for Oklahoma. Mr. Curry was formerly a forecaster at the National Severe Storms Forecast Center, Kansas City, Mo.

John R. Burke, principal assistant of the Cincinnati, Ohio, Weather Bureau office since 1964, has been chosen as the new meteorologist in charge of the Louisville, Ky., weather office. Mr. Burke entered the Bureau in 1941 at Louisville. He also served in Washington, D. C., before transferring to Cincinnati in 1952.

Clayton L. Benjamin, weather service specialist at WBO Bethel, Alaska, has been named official in charge at WBO Yakutat, Alaska. Mr. Benjamin joined the Weather Bureau in 1965, following his retirement from the Air Force. He transferred into the Alaska Region in 1968.

Leroy W. Borg is the new official in charge of the Lihue, Hawaii, Weather Bureau office. Mr. Borg joined the Bureau in 1952 and later transferred to Barrow, Alaska. During his 17 years in the Alaska Region, he served as an observer and as official in charge of the Bethel and Yakutat weather offices.

Norman Schuyler, aviation forecaster at the Los Angeles Weather Bureau Forecast Office, has received the outstanding achievement award of the American Meteorological Society's Los Angeles branch for his noteworthy contributions to popular understanding of meteorology and its applications. Mr. Schuyler, himself a private pilot, has continuously encouraged pilots to submit weather reports, and his efforts have improved the quantity and quality of pilot weather reports in the Los Angeles area. As part of his flight safety campaign, he has written several articles on weather and weather briefings for pilots' magazines.

Oklahoma Radar Provides Continuous Rainfall Data To Fort Worth, Texas, River Forecasters

ESSA radar specialists have turned their unique weather radar system to the problem of river and flood forecasting for Texas and Oklahoma.

In an operational field test which began in May, rainfall data is acquired by the WSR-57 radar at Oklahoma City, using techniques developed by the National Severe Storms Laboratory and is transmitted to the Fort Worth River Forecast Center. The program is a cooperative effort of the Weather Bureau Office of Hydrology, the NSSL, and the Oklahoma City Weather Bureau office.

Thunderstorms over the single state of Oklahoma can drop one billion gallons during their lifespan of a few hours. With the longest total lake shoreline of any state, Oklahoma might salvage all this rainwater. But, the sparse population of the area coupled with relatively few rain gages and even fewer weather observations means that much rain falls unnoticed. The first warning that precious rain has fallen in a district may be when the usually dry or low stream beds are suddenly filled with a wall of water—a wall of water which is not only potentially damaging but which also will ultimately be lost because the watershed was not prepared to receive it.

Thus, the first problem in conserving rainwater is actually the meteorological problem of locating storms and, ideally, forecasting into which watershed the storm's water will fall. The next step is better management. Given the meteorological information, hydrologists in the future may be able to reroute surface water systems so that most or all the water that falls is saved.

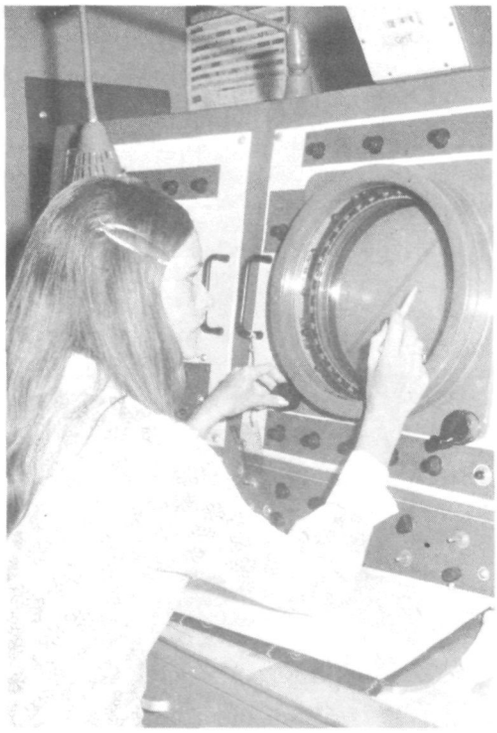
Weather surveillance radar, used for tracking and studying severe storms, does not measure the amount of rainfall with the accuracy of dense rain gage networks of the eastern seaboard, but it does provide estimates of the rainfall and its areal distribution. And it can do so on a continuous basis. A rain gage will only tell meteorologists and hydrologists how much total rain has fallen. Radar observations can determine how the rain is falling, and at what rate it is falling. This is important because the rate at which rain falls on the surface is a factor in river forecasting, in addition to playing a significant role in other water resource problems.

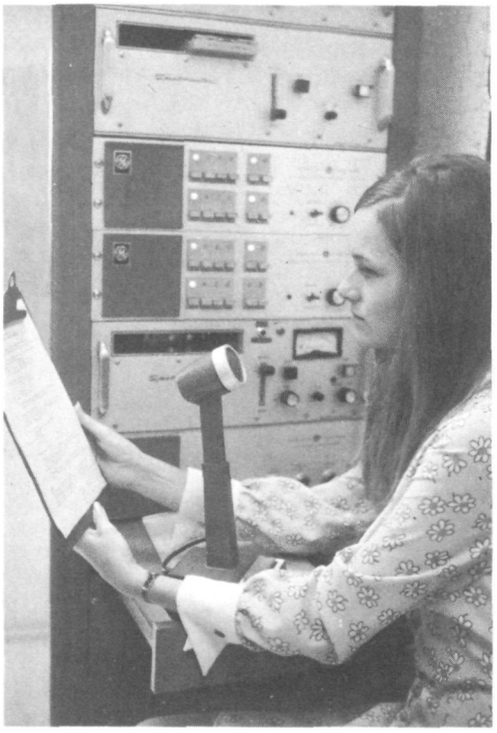
From complex frequency-distribution calculations based on digital radar data, the hydrologists can determine the probable amount and location of runoff. The tests mark the first time the radar system is being used under operational conditions. Storm data is acquired by the Oklahoma City radar, reduced to a form that can be transmitted over long-lines, and sent directly to the River Forecast Center in Fort Worth, Texas. There, hydrologists will use the radar data, combined with their computerized streamflow information, to make river forecasts for the Texas-Oklahoma area.

Operators of reservoirs, power plants, irrigation works, and water supply systems use these river forecasts to decide how to adjust their water management controls.

The rainfall input is provided via a unique, portable system, developed at the National Severe Storms Laboratory, that will operate with any WSR-57 radar. A digitizer takes radar information from the integrator and translates the radar echo received from 40,000 square miles into intensity values for 14,000 separate points on the radarscope. In essence, the radar picture is reduced to rows and columns of numbers. The higher the number, the greater the intensity of the radar echo and hence the precipitation. The intensity, a measure of areal rainfall, goes into a recorder, onto tape, and can then be transmitted immediately. In the test, an observation is made every 15 minutes. And, every 15 minutes, river forecasters in Texas can obtain digitized information on the distribution, intensity, location, and amount of rainfall at 14,000 points extending as far as 120 miles from the radar set.

Future Meteorologist Trains at National Hurricane Center





Diana Wells conducted a study project at the National Hurricane Center during her senior year at Coral Gables High School. Under the Dade County program, qualified students are authorized to perform off-campus laboratory research in government or private institutions. Diana's project, which she designed herself, was an investigation of certain aspects of tropical waves. Encouraged by her aviator father, Diana has long had an active interest in clouds and weather. While working at the Hurricane Center, she learned to grid ESSA satellite pictures, interpret the radarscope, operate a key punch, and tape record the ESSA VHF-FM broadcast, and acquitted herself well in an informal practice forecast program. A British subject born in Canada, Diana plans to attend London's Imperial College or Cambridge University, and hopes to work eventually as a meteorologist in Australia.

Dr. George S. Benton (standing left), director of the ESSA Research Laboratories, is shown presenting a plaque to Howard Mason, director of the Research Flight Facility and pilot of the plane whose crew was cited for its heroic efforts in effecting the rescue of the crew and passengers from a private plane that crashed while the RFF plane was preparing for take-off on a research mission in Flagstaff, Arizona. Seated left is Fred Werley, Aircraft Commander of the RFF plane. Seated right is Brad Patten, Flight Engineer of the RFF plane.

Weather Bureau Begins Air Pollution Forecast Services in 5 Cities

The Weather Bureau recently inaugurated special programs at stations in St. Louis, Chicago, New York, Philadelphia, and Washington, D.C., in support of air pollution control agencies.

Using radiosondes, the stations record temperature, pressure, humidity, and wind speed and direction from the earth's surface to about 10,000 feet. The information gathered is interpreted by specially trained air pollution meteorologists and transmitted to air pollution control agencies.

Initial funds to start these pilot stations have been provided by the Department of Health, Education and Welfare's National Air Pollution Control Administration. Each station will be supplemented later this year by a camper-type vehicle which will act as a mobile observatory.

A main meteorological concern in air pollution potential forecasting is stable atmospheric conditions. A temperature inversion is an extreme example of stability.

When a layer of warm air overrides cooler air near the earth's surface to create an inversion, a sort of lid is formed and normal up and down mixing (the rising of warm air and subsiding of cool air) is prevented. When this inversion is close to the ground and the surface winds are very light, it may be the first indication that pollutants will begin collecting near the surface. The longer such atmospheric conditions prevail, the longer an air pollution episode may last.

Warned by the Weather Bureau, air pollution control officials may take measures to control the amount of pollutants emitted from open dumps, smokestacks, and other pollution sources.

The new stations release two slow-rising radiosondes daily—one shortly after sunrise and the other around midday. Forecasts for up to 36 hours in advance are made by the air pollution meteorologists and provided to appropriate agencies.

U.S. Visit Opens Scientific Exchange With Soviet Union

Six U.S. atmospheric scientists toured weather modification laboratories and field sites in the Soviet Union during a four-week tour which began May 6.

A delegation from the Soviet Union is scheduled to make a similar tour in the United States later this year.

The Environmental Science Services Administration has been designated by the Department of State as sponsor of this scientific exchange, which is part of the 1968-1969 U.S.-U.S.S.R. Exchanges Agreement.

Members of the U.S. delegation to the U.S.S.R. were: Dr. George S. Benton, Director of the ESSA Research Laboratories, who headed the group; Dr. Archie M. Kahan, Bureau of Reclamation, Department of Interior; Dr. Fred D. White, National Science Foundation; Dr. Louis J. Battan, University of Arizona; Dr. Helmut K. Weickmann, ESSA Research Laboratories; and Morton J. Rubin, Environmental Science Services Administration.

NSSL Completes Spring Study

Seven aircraft, eight upper-air sounding stations, extensive ground facilities, and several types of radar were used in the 1969 spring study of severe storms, a cooperative effort of ESSA's National Severe Storms Laboratory and other government agencies and groups.

During the past five spring seasons, the National Severe Storms Laboratory in Norman, Oklahoma, has carried on extensive research and observational work on storms over the Oklahoma plains.

As the Laboratory's Director, Dr. Edwin Kessler, pointed out: "Each new set of data adds a little more to our understanding of the basic processes taking place in a storm. Better understanding on a research level eventually leads to better forecasting, as meteorologists learn which particular things to look for in the early stages of storm development."

The 1969 spring research was designed to continue basic studies of storms with added emphasis on observing them in urban areas. A surface network of 29 meteorological monitoring stations extended from Chickasha, Oklahoma, on the southwest corner of the network to a 1500-foot-high TV tower on the north edge of Oklahoma City.

While the surface network documented conditions near the ground, eight interspersed stations provided similar measurements upward through the atmosphere. Rawinsonde instruments were launched every 30 minutes during stormy periods. Balloons carried the instrument packages upward at a rate of more than 1000 feet per minute, and tracking equipment followed them and measured winds aloft. Records of pressure, temperature, and relative humidity at different altitudes were radioed back to ground-receiving stations. Other balloons were launched to provide tracking targets for the Laboratory's radars. The rawinsonde stations were operated for the project by Army and Air Force teams from Fort Sill and Tinker Air Force Base.

In addition to the vertical storm sampling provided by rawinsondes, NSSL gathered data on an almost continuous basis from the WKY television tower near Oklahoma City. This 1500-foot tower is instrumented at six different levels. Wind and temperature measurements can be made every two seconds from the tower at heights of 146, 296, 581, 1166, and 1458 feet.

Urban data such as this may be useful in improving predictions of hail, wind gusts, and heavy rain. According to Kenneth E. Wilk, Chief of Operations, the Laboratory is looking for short-term prediction techniques that could be used to improve airport warnings of hazardous weather. NSSL plans to experiment, in cooperation with the Federal Aviation Administration, with various computer techniques to generate short-term forecasts of hazardous flying and landing conditions.

The aircraft in this year's program were provided by the ESSA Research Flight Facility, the U.S. Air Force, the Canadian National Research Council, and the National Aeronautics and Space Administration.

Concerned with all storm characteristics, the Laboratory also measured transient bursts of lightning radiation from storms as far away as 115 miles and the voltage fluctuations of storms within a distance of 30 miles.

ESSA Publications Win FEA Awards

ESSA WORLD took first place in the house organ category of the Federal Editors Association competition for Government publications produced in 1968. Another ESSA publication, "Hurricane Information and Tracking Chart," was second in the leaflet class.

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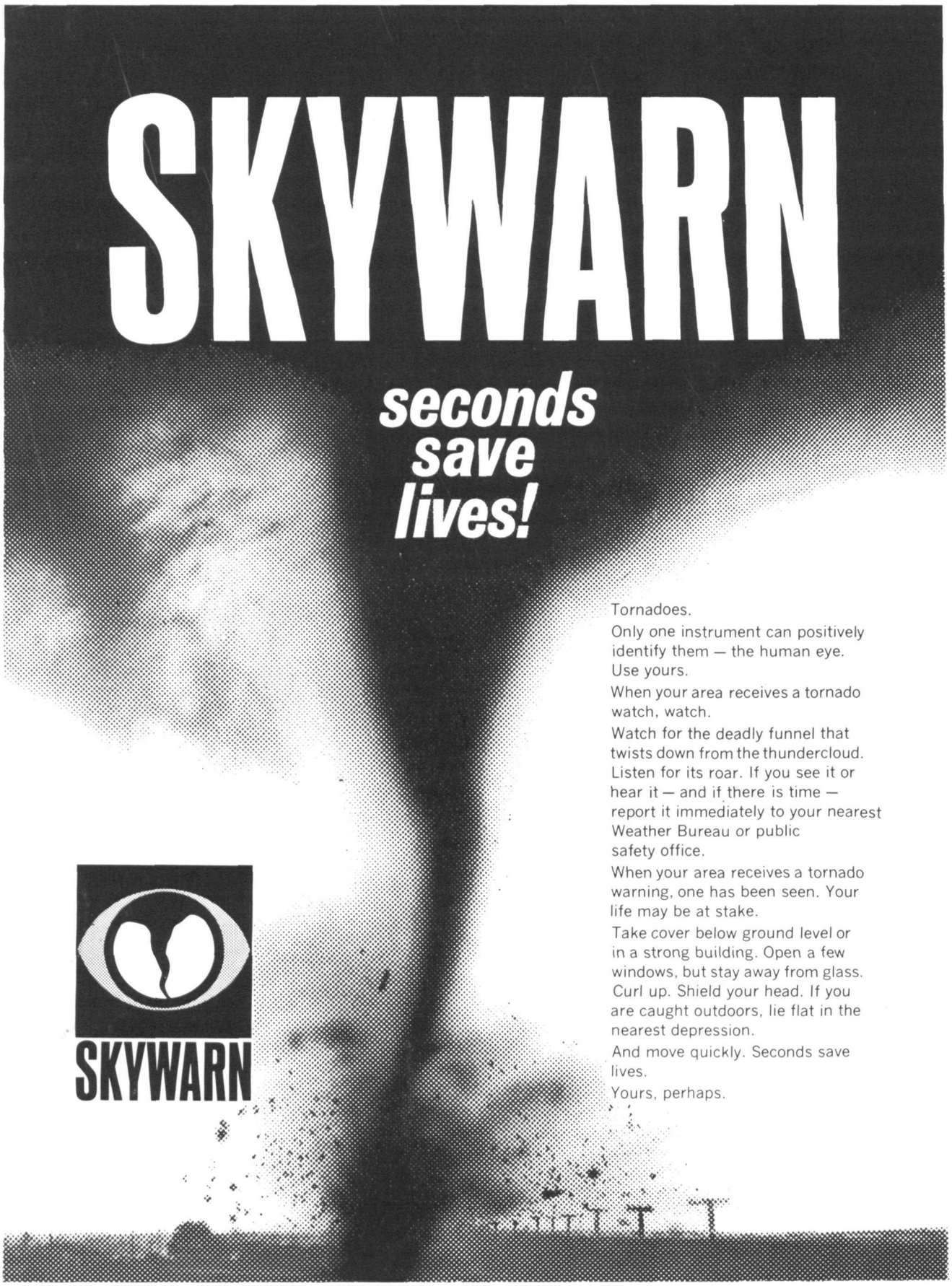

Tornadoes.

Only one instrument can positively identify them — the human eye. Use yours.

When your area receives a tornado watch, watch.

Watch for the deadly funnel that twists down from the thundercloud. Listen for its roar. If you see it or hear it — and if there is time — report it immediately to your nearest Weather Bureau or public safety office.

When your area receives a tornado warning, one has been seen. Your life may be at stake.

Take cover below ground level or in a strong building. Open a few windows, but stay away from glass. Curl up. Shield your head. If you are caught outdoors, lie flat in the nearest depression.

And move quickly. Seconds save lives.

Yours, perhaps.

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