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JANUARY 1970

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In this issue:

CENTENNIAL OF THE U.S. WEATHER SERVICE

National Oceanic and Atmospheric Administration

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U.S. DEPARTMENT OF COMMERCE
Maurice M. Stans, Secretary
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
Dr. Robert M. White, Administrator
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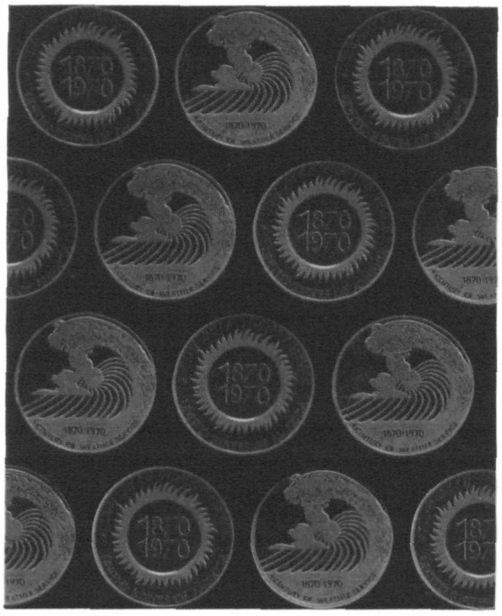

COVER
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A Message from the Administrator

This issue of *ESSA* (newly titled in the interest of cogency) is devoted largely to weather topics.

It is our salute to the centennial of the national weather services, whose first century goes into history on February 9, 1970. It has been a century of explosive development and growth, both in science and service, a century which has seen a remarkable record of progress written by men and women possessed of passionate dedication, talent, and ingenuity.

The centennial will be commemorated with a year-long series of events, highlighted by a distinguished symposium and a gala banquet at which weathermen from all parts of the Nation will gather next month in Washington, to hear Dr. Lee A. DuBridge, the President's science advisor. The weather service, and all the Federal agencies which have contributed so greatly to it, can take justifiable pride in the achievements of the period which is just passing. As it goes, we look with excitement toward the second century. The challenges and opportunities are staggering.

As populations grow and change, so do environmental problems. The weather service of the future must give ever-increasing support to the fight against air pollution. As town and city planning evolve toward whole-community concepts, the weather service must be prepared to help planners design their complexes with meteorology very much in mind. As our capacity for modifying the weather develops, we must learn to use it solely to help and never to harm; and in doing so we must surmount a host of thorny scientific, legal, and social problems.

In attacking these challenges, we shall not be alone. We have come to recognize, in common with our political leaders, that the atmosphere and its weather are part of the total physical environment. Looking ahead to the next hundred years of meteorology, the solution of our problems will require joining with the oceanographer, the aeronomist, and the solid earth scientist to expand our view to encompass the description and prediction of the behavior of many aspects of our planet, from its molten core through its oceans and atmosphere to the tenuous regions of nearby space. Only in this way will we gain the knowledge to begin to meet the weatherman's challenge for this next hundred years—to learn to modify and control the physical environment to meet man's needs.

One thing, however, will not change. No group of men and women, however capable, however dedicated, will be able to give more generously of themselves than those who have gone before us. Their example will guide and inspire us as we enter the second century.

R M White

The Nation's weather services have grown from kites to satellites in

*THE FIRST CENTURY**

THE NATIONAL WEATHER SERVICES of the United States will be 100 years old in 1970.

They enter their second century armed with a knowledge of the atmosphere, technology for observing and predicting weather, and a variety of services which could not have been dreamed of by the most visionary weatherman a hundred years ago.

On February 9, 1870, President Ulysses S. Grant signed a joint resolution of Congress authorizing the establishment of a national weather service. Later that year the first systematized, synchronous weather observations ever taken in the U. S. were made by "observer-sergeants" of the Army Signal Service at 24 stations and telegraphed to Washington.

Today thousands of observations are made daily by government agencies, volunteer citizen observers, ships, planes, automatic weather stations, and earth-orbiting satellites in an increasingly successful effort to answer the basic question, "What's the weather going to be?"

Where a century ago weathermen bent all of their scientific know-how on tracking a single storm, calculating the speed at which it moved, and warning "downstream" points of its approach, today meteorologists study global atmospheric circulations and many believe weather forecasts for a month or even a season may become possible. Although others disagree with this optimistic viewpoint, the fact that such matters are seriously discussed points up the strides taken in the field of meteorology and the U. S. weather services over the past hundred years.

When U. S. Grant put his signature to the 1870 resolution requiring the Secretary of War "to provide for taking meteorological observations at the military stations in the interior of the continent and at other points in the States and Territories . . . and for giving notice on the northern (Great) lakes and on the seacoast by magnetic telegraph and marine signals, of the approach and force of storms," weather observations and forecasts in the United States weren't turned on suddenly like an electric light. More than 200 years of weather observation and study in this country preceded the creation of "the Division of Telegrams and Reports for the Benefit of Commerce" (the earliest name for the national weather service).

Only 24 years after the Pilgrims landed at Plymouth Rock, the Reverend John Campanius Holm, chaplain for a settlement near the present site of Wilmington, Del., began making systematic weather records. His "diaries" for 1644 and 1645 form the first continuous weather records in what is now the United States.

Later, other men kept weather diaries from time to time, in many parts of the country. Thomas Jefferson and George Washington both had a more-than-casual interest in weather studies. Benjamin Franklin's kite-flying in a thunderstorm is widely reported, and Franklin was the first to deduce the progressive movement of a storm system as a whole.

In the 19th century, interest in weather and the possibility of coordinated observation and warning networks picked up a momentum which, in spite of several setbacks, has continued to the present. The appearance of the telegraph in 1845 made meteorology a practical science.

During the War of 1812, the Surgeon-General of the Army directed hospital surgeons to observe the weather and keep climatological records. This order initiated the first government collection of weather observations. In the 19th century and early in the 20th, there was tremendous interest in the effects of weather on health. This was the reason for the Surgeon-General's order. By 1853, 97 Army camps were keeping weather records; and many medical studies were based on these observations, including an investigation of the association of yellow fever with climate.

In the same period, other federal and state agencies set up observing networks. In 1817, Josiah Meigs, Commissioner-General of the Land Office, began a system of observations at land offices. From 1825 through the 1850's the New York State Board of Regents collected weather observations from a network of 30 stations. The States of Pennsylvania and Massachusetts had similar, smaller networks.

In 1849, Professor Joseph Henry of the Smithsonian Institution established an extensive observation network by supplying weather instruments to telegraph companies. Simultaneous observations were made by local telegraph operators and sent to the Smithsonian. Maps prepared from these observations were displayed in Washington, D.C.

By 1861, Professor Henry had 600 stations making regular weather reports, but the coming of the Civil War broke up his network.

In his annual report for 1865, Professor Henry advocated the reorganization of all meteorological observations in the United States under one agency as an effective means of predicting storms and warning coastal shipping.

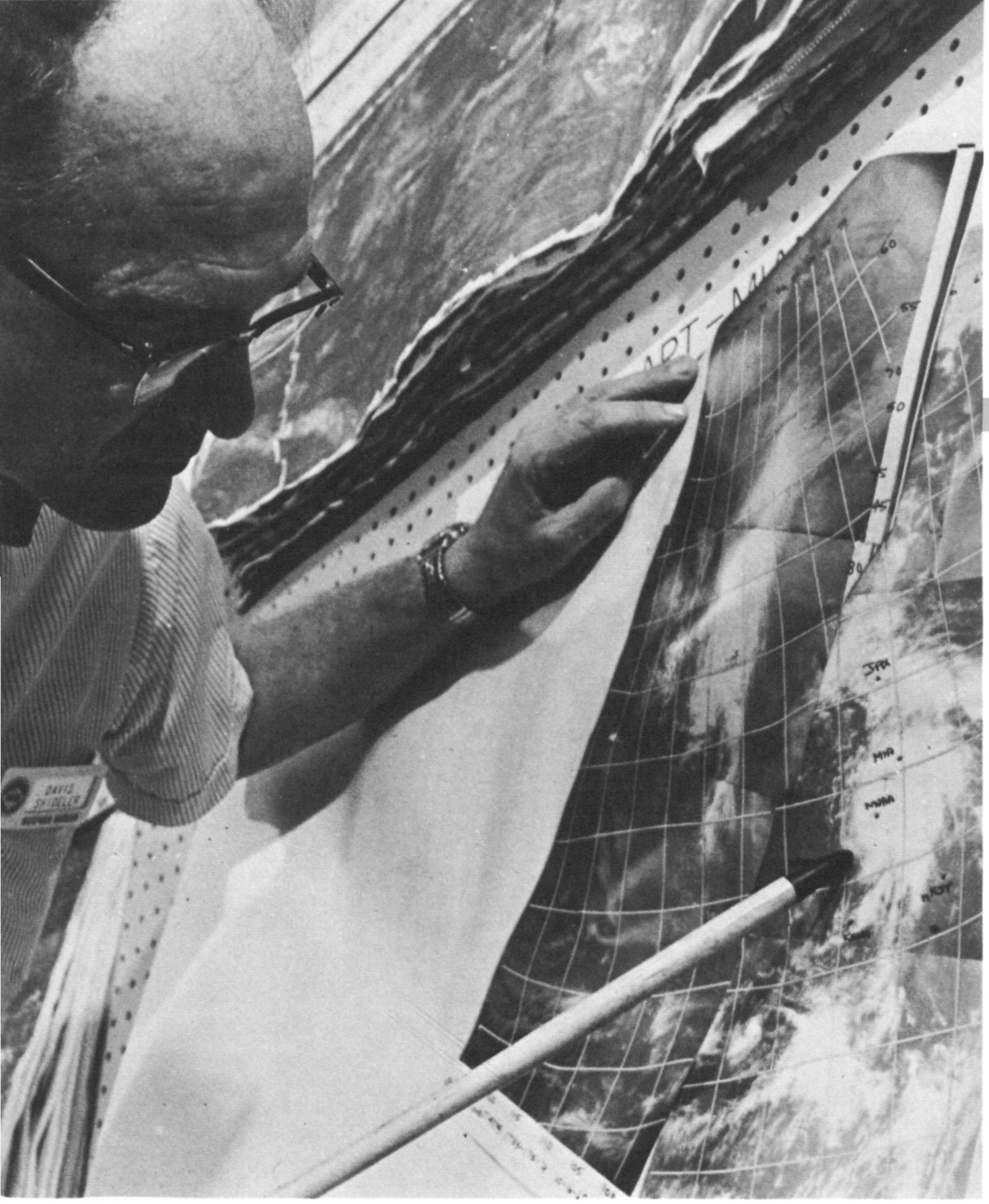
The director of the Cincinnati Observatory, Cleveland Abbe, created an observation network in 1869, using some of the former Smithsonian observers. He issued forecasts, which he called "probabilities."

Increase A. Lapham of Milwaukee was an observer for the Smithsonian and later for Professor Abbe. Lapham repeatedly urged the formation of a warning system for Great Lakes shipping. It was a friend and supporter of Lapham's, Congressman H. E. Paine of Wisconsin, who in 1869 introduced the bill establishing a national weather service under the Secretary of War. Lapham had convinced the Congressman that a weather warning system for the Great Lakes would save many lives and a vast amount of property. Paine saw that Lapham's suggestion, if valuable in the Great Lakes region, could be even more worthwhile for the nation as a whole.

Here, then, in February of 1870, was a beginning.

The period between 1870 and 1880 was one of rapidly expanding public services. In 1873, a river stage and flood warning service was started by the Signal Service. General weather services were extended throughout the United States by an appropriation act of 1872 providing for ". . . expenses of storm signals throughout the United States for the benefit of commerce and agriculture."

"The First Century" is based on the forthcoming book, "A Century of Weather Service," by Patrick Hughes, copyright 1970 by Gordon and Breach, Publishers, New York, N. Y.



As the first century comes to a close, meteorologists use pictures from satellites to track weather systems.

Soon, the 383 cooperative observers still remaining in the Smithsonian's network were transferred to the Signal Service. Weather services for producers of cotton and sugar were inaugurated in the early 1880's. Cooperating with the British Meteorological Office, the Signal Service (renamed the Signal Corps) in 1885 began issuing warnings of Atlantic storms. By 1886, 290 locations were equipped with cold-wave warning flags. Forecasts of cold waves were passed along by telegraph, telephone, and railroad in an effort to give a least 30 hours' warning.

Specific investigations undertaken during these years included studies of tornadoes, moisture in the air, atmospheric electricity, use of balloons, thermometer exposure, and wet-bulb temperature conversion tables.

The 1880's were stormy times for the fledgling national weather service. The War Department became concerned that should the military services of the Signal Corps be needed, its personnel (now almost entirely absorbed in the provision of weather services) could not be spared from their weather duties. A congressional commission investigating scientific agencies in government was of the unanimous opinion that the weather services should not be a military function. Several bills proposing the transfer of the civilian weather services to the Department of Agriculture were introduced in Congress and finally, in 1890, similar bills were introduced and passed in both Houses. On October 1, 1890, President Benjamin Harrison signed into law an act effecting the transfer. At noon on July 1, 1891, the Signal Corps weather stations, telegraphic lines, apparatus, and personnel (honorably discharged) were transferred to the Department of Agriculture. The agency was called, simply, "the Weather Bureau."

As the century turned, the emphasis of the Department of Agriculture's new agency, as Congress intended, was on greater service to the farmer. Climatological services, tailored to agriculture, came to the fore even as, in 1903, the Wright brothers' first flights presaged yet another shift in emphasis.

American aviation and the Weather Bureau grew to maturity together. Aviation, however, did not come into its own until the close of World War I. In the years preceding "The Great War," the weather service was attempting to keep up with a nation on the move—both in a technological sense as the Weather Bureau became the first U.S. Government agency to adopt a new and promising communications technique known as wireless telegraphy, and quite literally as Henry Ford's "Model T" put Americans on the road and created an extremely weather-sensitive industry.

The first two decades of the 20th century had a remarkable effect on the nation's meteorological services. In 1902, Weather Bureau forecasts were sent by wireless to ships at sea. In 1905, the first wireless weather report was received *from* a ship at sea. Two years later, the daily exchange of weather observations with Russia and eastern Asia was inaugurated. In 1910, the Weather Bureau began issuing weekly outlooks to aid agricultural planning. The U.S. Coast Guard began an International Ice Patrol in 1912 as a result of the *Titanic* disaster. In 1913, the first fire-weather forecast was issued. An aerological section was established in the Weather Bureau in 1914 to meet the growing needs of aviation.

As the United States entered World War I, the need for weather services specifically geared for military use was met by a special meteorological section in the Army Signal Corps. The new section was charged with providing the American Expeditionary force in Europe—as well as Army aviation, artillery, ordnance, and gas warfare activities in the U.S.—with all the meteorological information needed. The Navy, too, took the first steps in the formation of a meteorological service during World War I.

The end of World War I brought two major developments to the history of weather services in this country: The first was in military weather services; the second in aviation weather services.

When the war ended, the meteorological

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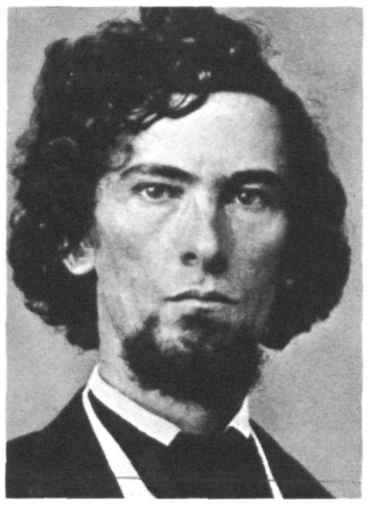

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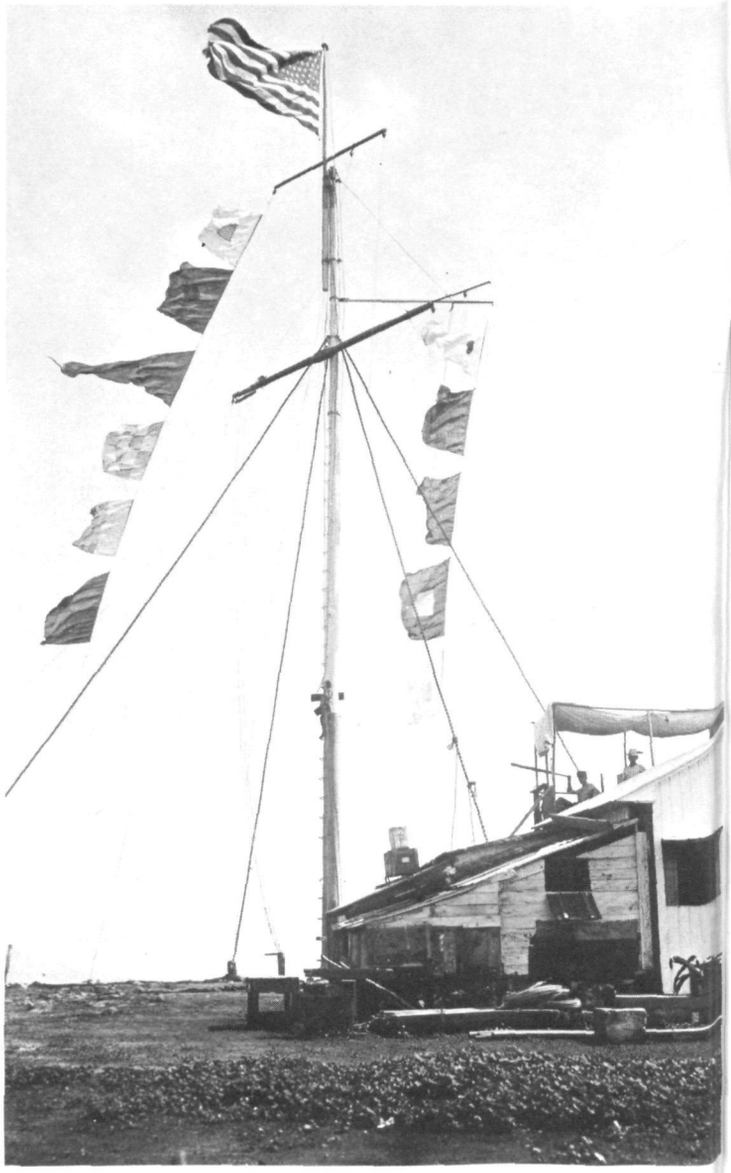

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1. Joseph Henry of the Smithsonian Institution used reports from telegraph operators to prepare weather maps. In 1861, his network reached a peak of 600 stations. 2. Congressman H. E. Paine of Wisconsin introduced the bill establishing the national weather service. 3. After the Spanish-American War, the Philippine Islands became a U.S. territory and signal flags soon were flying from a weather station established at Corregidor. 4. For two decades before World War II, upper-air observations were gathered by aircraft. In this 1926 photograph, an observer attaches a meteorograph to a plane. 5. During World War II, weathermen entered the service and played a vital role in military operations. 6. On the home front, several hundred women took weather observations for the duration.

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activities of the Signal Corps were sharply reduced. The growth of postwar military aviation, however, created a demand for aerological information and services; and weather officers were soon assigned to all major Air Corps maneuvers. Military meteorologists also contributed to the success of such important events as the first around-the-world flight, made by Army aviators in 1924.

Prior to World War I, there were few requests for flying-weather forecasts. The civilian pilot was his own weatherman. If the weather was bad, he simply didn't fly. After the war, however, the airplane was here to stay; and important passenger and mail routes gradually put an end to "flying by the seat of the pants" operations.

In 1926, the Air Commerce Act made the Weather Bureau officially responsible for weather services to civilian aviation. The phenomenal growth of commercial flying during the next 20 years was a major factor in a similarly explosive expansion of the Weather Bureau and its services.

Weather services in many other areas advanced during the period between the two World Wars.

In 1919, the Navy's Aerological Service was established on a permanent basis. Early in 1921, the University of Wisconsin made a radiotelephony broadcast of weather forecasts—the first systematic use of the new medium. Daily radiophone weather broadcasts followed. In 1927, a prototype of the Weather Bureau's airways meteorological service was established on the west coast.

The year 1934 was a historically important one for the Weather Bureau analysis and forecasting activities. At that time, an airmass analysis section was established. Here, at last; was recognition of earlier investigations (already widely accepted) concerning the weather-causing interactions and predictability of "parcels" of air with differing water content and temperature. The Bureau officially adopted airmass analysis techniques in 1938.

In 1935, an improved 24-hour hurricane warning service was established. In 1939, the Weather Bureau initiated automatic telephone weather service in New York City. In 1940, the U.S. Coast Guard began manning ocean weather stations in the Atlantic; the Army Air Forces and Navy established weather centers in Washington, D.C.; and the Weather Bureau issued its first official five-day forecast. Also in 1940, the Weather Bureau transferred from the Department of Agriculture to the Department of Commerce to "permit better coordination of Government activities relating to aviation and commerce generally, without in any way lessening the Bureau's contribution to agriculture."

About 17 months after this last action, America became embroiled in the Second World War. The Air Force and Navy brought their weather arms up to strength in a remarkably short time. In 1939, the Army Air Corps' weather branch (which evolved from the Army Signal Corps) consisted of approximately 200 men. Five years later, in the summer of 1944 when the service reached its peak strength, there were 19,000 officers and men engaged in weather work for the Air Forces. The Navy's Aerological Service with 90 officers and 600 enlisted men at the time of Pearl Harbor, had increased to 1,318 officers and approximately 5,000 enlisted men by August 1945.

During World War II, the Weather Bureau (like most other nonmilitary organizations) was short-handed. The Weather Bureau replaced many men serving in the military services with women. At the beginning of the war emergency, the Bureau had two female technical employees; by the war's end, it had over 900. While many worked as clerks, hundreds of them performed observing duties.

Wartime technology brought two major observational tools to the nation's weather services. The first was radar; the second was the high-flying rocket which eventually was to carry earth-orbiting weather satellites into space.

A third tool, the high-speed computer, was also a long-awaited arrival on the meteorological scene.

Radar, capable of scanning thousands of square miles, provides a unique 3-D view of the location, dimensions, intensity, and movement of storms, as well as changes in their character.

Weather satellites give weathermen an even broader view of cloud formations over the entire earth. Lately satellite-mounted sensors have been developed which provide temperature data from a number of layers of the atmosphere.

Computers offer a means by which complex formulas describing atmospheric processes can be juggled to produce weather predictions.

Aided by these and other technological advances in meteorology, weather services in the United States have expanded into areas undreamed of 100 years ago when terms like "nuclear fallout," "air pollution," and "spacewalk" were meaningless.

Today weather services are woven into the fabric of such agencies as the Atomic Energy Commission; the Department of Health, Education and Welfare's National Air Pollution Control Administration; and the National Aeronautics and Space Administration.

The Department of Interior's Geological Survey makes valuable contributions in the field of water resources, and interior's Bureau of Reclamation is active in weather modification programs.

The Federal Aviation Administration, vitally interested in air traffic control, works closely with the Weather Bureau in observing and disseminating weather information for pilots.

Vessels maintained at fixed locations in the oceans by another Department of Transportation agency, the U. S. Coast Guard, provide regular and vital weather observations from the high seas. In addition, the Coast Guard takes weather observations at many locations on shore, and displays storm-warning flags for the benefit of coastal shipping.

The Department of Agriculture's Soil Conservation Service, Forest Service, and Experiment Stations, all share an interest in providing the best services available to what is perhaps the most weather-sensitive industry in the world.

The National Science Foundation through its National Center for Atmospheric Research supports a great deal of research and development work carried out by a number of scientific agencies with weather-related programs.

ESSA, created in 1965, serves as a focal point for federal weather services to the general public. Within ESSA are the Weather Bureau, the ESSA Research Laboratories, the National Environmental Satellite Center, the Environmental Data Service, and the Coast and Geodetic Survey.

The Department of Defense, through the Air Force, Army, and Navy, provides weather support for military projects and also contributes in great measure to the public weather services of the nation. The best-known of these contributions is the storm reconnaissance performed by the hurricane hunters of the Air Force and Navy, to provide information on the location and intensity of dangerous tropical storms. Other regular services performed by the military for civilian weather programs include observations at the surface and in the upper air; weather reports from aircraft in flight; radar information; data on climate in overseas areas; a typhoon warning service for the western Pacific; and communications support in collecting and distributing weather information.

The American Meteorological Society, also celebrating an anniversary in 1970 (its 50th), is dedicated to "the development and dissemination of knowledge of meteorology in all its phases and applications, and the advancement of its professional ideals."

The next century will see some drastic changes. One forecast has satellites with the most sophisticated weather sensors probing every mile of our global atmosphere, feeding the data gathered into gigantic computers issuing highly accurate long-range weather forecasts "untouched by human hands."

A sunny prediction, indeed. But if you think it's too optimistic, think of how talk of spaceflight, radar, and computers would have been greeted by one of those "observer-sergeants" in the Signal Corps who began the national weather services one hundred years ago. □

Weather Forecast Center USA – 1888 1969

The Weather Service in 1888 was in the hands of the United States Signal Service. To its offices in Washington came a British traveler, Ralph Abercromby, a meteorologist and former Army officer with keen powers of observation and a flair for writing.

This is how the Weather Service appeared to him more than 80 years ago, as he described it in his book, "Seas and Skies in Many Latitudes":

Our primary object in visiting Washington was to inspect the United States Signal Office, which organises and controls the weather-forecasting system of the Union. General Hazen, the chief signal officer, received us courteously, and, besides giving us all the information in his power, introduced us to the leading heads of departments. Much interest attaches to this office,—by far the largest weather bureau in the world, and the one that devotes its chief energies to the problem of weather changes from day to day, rather than to those questions of climate which occupy the leading place in almost all other similar organisations.

We were introduced first to Professor T. C. Mendenhall, who not only presides over the department that verifies and issues all instruments sent out by the office, but also over the laboratory, where new instruments and new methods of observation can be investigated; afterwards to Mr. Cleveland Abbé, one of the professors of theoretical meteorology, who had just completed a bibliography of meteorological publications which contains no less than 50,000 entries; and lastly to one of the most remarkable men in the United States—Professor William Ferrel.

The lobster trick is nearly over at the National Meteorological Center. Lighted by the coral glow of this Tuesday's dawn, meteorologists and technicians and computer types return to the world. Their daytime counterparts come in from the parking lots which moat Federal Office Building Four; for the next eight hours they will trade familiar realities for a world of energy exchanges, invisible gases, universal time, atmospheres built from billions of numbers, and a point of view that is prophetic and broad—continental, hemispheric, global.

It is October 28, 1969, and now, at 7 a.m. Eastern Standard Time, work at Suitland, Maryland, is in a transitional phase, like the slack between tides. The last round of forecasting was wrapped up in a final data sort just after five this morning. Soon, meteorologists and their machines will begin the search for atmospheric futures in the recent atmospheric past. For the moment, the new shift settles into its crowded facility.

Dawn is still a pale line near the prairie horizons of Chicago, and less than that along the Rockies. Milkmen prowl the Pacific gloom; it is a quiet three a.m. in Anchorage, and Honolulu's nightowls are just crawling home. Across the Nation, Weather Bureau meteorologists will soon begin the work of matching the guidance from Suitland with the day-to-day needs of people in their area, a circle perhaps 100 miles in diameter, where a new building or factory or manmade lake or strip of cleared timber or parking lot can make a micro-difference in the weather. This regional or local weatherman is the reason the National Meteorological Center exists; and he is the man behind the forecast we use in making our weather-based decisions.

Home for the Census Bureau and ESSA's National Environmental Satellite Center as well as the National Meteorological Center (called NMC), FOB 4 is one of a class of buildings built just after the second world war to handle a growing government. Designed as the last word in adequacy, its four wings are overoccupied by a factor of three or so. Anachronisms abound; the sleek beige and orange cabinets of today's big computers look curiously displaced in this aging, hospital-shaped structure.

Clocks are everywhere. The weathermen at Suitland spend their working days straddling two worlds of time: the familiar, relative one of local, solar time, and one generated by the needs of meteorology.

To see the atmosphere on a sufficiently large scale, thousands of people must simultaneously observe its state and motions by taking a dynamic "snapshot" at certain intervals of time, over a global area. The resulting view is not continuous, but composite, like the dot pattern in a

More than sixty years ago, he, as a young man in a store out among the backwoods of Missouri, found a copy of Newton's *Principia* among a pile of old books. This he mastered, and then sent—which was then no easy matter—for Bowditch's translation of Laplace's *Mécanique Céleste*. This he also mastered so thoroughly that he eventually found employment in the Nautical Almanack Office at Washington; and more than twenty-five years ago he published a new theory of the influence of the earth's rotation on the atmosphere. This theory, after much discussion, has now been adopted in almost every country except England, and has earned for him among his countrymen the title of the "Newton of Meteorology."

We found the professor—a large, elderly, gray-haired man, with a broad-topped head, big eyes, a thoughtful face, and the unmistakable look of an American—busily engaged over the proofs of a new book in a dingy unfurnished room, where there was scarcely room for two chairs and a table. His deafness made conversation difficult; but it was delightful to listen to the simplicity and earnestness of a man who was pleased, because the only English meteorologist who had taken the new theory up, had so thoroughly appreciated the principles involved, as to detect what the professor himself felt to be a weak point in one of the applications of his system.

I also met Mr. Finley, who has made tornadoes the subject of special study for many years. For some reason or other the United States are exceptionally devastated by these destructive whirlwinds; and within its limited sphere of 200 or 300 yards across, the tornado is more disastrous than the hurricane, and is the most terrific manifestation of nature in the whole range of atmospheric phenomena. Some photographs, not only of the tornado clouds themselves, but also of the destruction wrought by them, were most interesting. The conical spout which forms the body of the whirlwind seemed sometimes to hang down from the clouds, and sway about like an elephant's trunk, and it seemed difficult to realise that so small a whirlwind could lift wooden buildings right up into the air, and even unroof and wreck a substantially built structure of brick.

In another building the instrument

printed photograph, and is called synoptic for its breadth and simultaneity.

The synoptic day begins and ends when local time is midnight at the zero meridian of longitude. No matter what the local time, the synoptic clock ticks to the time of Greenwich, England, and measures what is called Greenwich Mean Time (GMT), Universal Time, or just plain Z.

Noon in Greenwich, 1200Z, is one of two primary synoptic times. As the new shift comes on in Suitland, meteorologists around the world—at surface stations and on ships, in weather reconnaissance aircraft, at rawinsonde balloon facilities—take their measurements, code them, and feed them into the electronic pipelines linking them to NMC.

Until recently, this torrent was met and tamed by a harried quick-footed operator who ripped incoming messages off teletypewriters and pigeonholed them with amazing dexterity and speed. Now an IBM 360/30 computer meets the 1200Z data and records it on discs capable of storing about 10,000 observations each.

Tapes recorded by the 360/30 go to the more powerful IBM 7094 computer, which identifies, checks, and sorts the various measurements and produces lists of error-free data. This takes less than 15 minutes. An IBM 1401 printer then types out a data-location chart, a discrepancy list of erroneous data, and an error-free list for checking, analysis, plotting, and filing. The collection and processing phase of the cycle is almost completely automated—almost, because humans start getting data when the computers do.

The charting room is where forecasts begin, for everything depends on the full analysis of atmospheric conditions as they existed at 1200Z. The first step in this process takes place in a small area in the corner, where weather data enters from the computer In his small domain of photocopiers and a printer, Meteorological Technician Richbell Hastings waits for the machine to spit out its segments of processed information, which he dispenses to the chartplotters with whom he shares the room.

From about 7:30 a.m. they decode coded data, and plot temperature, moisture, pressure, winds, clouds, and other pieces of the weather puzzle. Gradually, the familiar weather map with its isolines and temperatures, its fronts and cloudy free-forms, takes shape beneath skilled hands in the charting room. The technicians restrict themselves to weather at the surface and a pressure level of 500 millibars (about 18,000 feet), two levels reasonably representative of the tropospheric column.

In a smaller enclosure next to the charting room, surface data is being analyzed for both the northern and southern hemispheres. An imaginary equator divides the room. On one side, amid a growing array of incoming information, 1200Z conditions for the northern hemisphere are being analyzed by Meteorologists Roger Cross and Francis Lacny. On the other, with comparatively little data from the predominantly wet southern hemisphere, Meteorologist Donald Bowyer discusses tropical cyclone Katy with William Rammer, Deputy Chief of the Surface Analysis Branch.

Either hemisphere is a talent job. And this is where the human edge over the computer first becomes apparent: much of the information coming into NMC is not intelligible to the electronic mind. Every three hours, the radar view of weather over North America arrives in the form of graphic summaries plotted at the National Severe Storms Forecast Center, Kansas City, Missouri. These facsimile transmissions anticipate the synoptic clock. The last batch came in at 6:45 this morning; the next will come in at 9:45, anticipating the secondary synoptic interval completed at 10 a.m. local time.

Satellite photographs began feeding into the automatic picture transmission (APT) circuits at 6 a.m., as ESSA 8 flashed southward across the eastern North Atlantic. While the satellite climbs the dark arc of its polar orbit, the planet turns another 18½ degrees to the east and the satellite covers another, overlapping strip down the sunlit Atlantic. By

continued

room of the office has been located. Here there was a large assortment of barographs and thermographs, with instruments for recording automatically the direction and velocity of the wind, and also delicate electrometers for measuring the tension of electricity in the air. But the most interesting sight of all was the indications room, where the forecasts of weather are prepared. No one, who only reads in a newspaper a short, clear statement of the probable weather, can have any idea of the enormous amount of labour and organisation which the preparation of that brief sentence has involved.

Three times a day, seventy-five men in all parts of the Union simultaneously read their barometers and thermometers, besides noting the direction and force of the wind, with the appearance of the sky and motion of the clouds.

As often, six other men are waiting in a small room in the Signal Office to receive their reports.

Number one reads out the figures for each station as they arrive through the telegraphic wire.

Number two writes the numbers down with a cyclostyle copying apparatus, so that a few copies of the original records can be reproduced and preserved.

Number three has a much more difficult task. He has before him a large outline map of the United States, and as the observations are read out for each station, he writes them down in the proper place on the map. For instance, suppose he heard called out—New York, 30.0 inches, 79°, S.W. 30, he would mark the barometric height of 30.0 inches in one coloured ink, the temperature of 79° in another colour. An arrow flying from south-west with a little 30 beside it, to denote the number of miles an hour the wind was blowing, all as near as possible where New York would be on the map. This he does for every sta-

9 a.m., Suitland has turned far enough toward the sun to be almost directly under the satellite. As the day moves on, relayed APT photographs come in from receivers in San Francisco and Honolulu.

ESSA 9, the stored-data satellite in the paired system, is 90 degrees out of phase with the APT unit; the two orbits straddle the noon point of the sun. When ESSA 8 makes its southward crossing of the equator at 9 a.m. local time, ESSA 9 crosses the equator going north, 90 degrees to the east, where local time is 3 p.m.

Strips of photographs taken on each orbit are transmitted to National Environmental Satellite Center ground stations, relayed to the Satellite Center headquarters in FOB 4, and computer-massaged into digitized mosaics and other products for use by NMC meteorologists. When the strips are tacked up on the northern or southern hemisphere sides of the surface analysis room, the pictures are less than two hours old.

NASA's experimental Nimbus III carries an instrument that is as revolutionary as the development of weather satellites themselves: the satellite infrared radiometer system, or SIRS. For any meteorologist trying to read the world's weather, the temperature soundings obtained from the Nimbus III SIRS unit are important. For people like Don Bowyer, SIRS fills in thermal information for an area where soundings are few and far between. Sometimes the information is as much as six hours old; but here, as everywhere else in the environmental sciences, acquisition is moving toward real time, in which events are measured as they unfold.

One satellite system is used in that sense, but not on the 1200Z forecast cycle. Applications Technology Satellite (ATS) I, marking time 22,300 miles above a point on the equator, photographs the earth's Pacific disc every 22 minutes. From 1:30 to 6:30 p.m. local time, the Satellite Center at Suitland controls the video, which is used to develop wind velocity data as well as detect cloud systems. This has become a centerpiece in the southern hemisphere analysis.

Next door, a squad of meteorologists builds the first "subjective"—that is, handmade by humans—forecast. Robert Van Haaren and Dennis Politano develop their maximum-minimum temperature forecasts, while John Hurley works on the surface weather predictions. David Olson and Richard Browne discuss their QPF—quantitative precipitation forecast. Atmospheric moisture is one of the toughest weather elements to forecast. Later in the 1200Z cycle, an attempt to improve this situation will cause some unraveling down in the big computer room.

The machines are already hard at work.

After an hour and a half of data collection, a preliminary machine analysis is made for the northern hemisphere from the surface to 500 millibars. This shows wind, pressure, and temperature fields for the area covered, and is drawn by one of the exciting electromechanical gadgets which abound at NMC. Computer-driven curve followers have the longest tenure here, and are a joy to watch as they dervish out isopleths a mile a minute. A more recent development is Digifax, which photographs a television type display generated by the computer, and the still newer and faster facsimile converter, which translates tapes into plotted and analyzed charts and transmits them almost instantaneously.

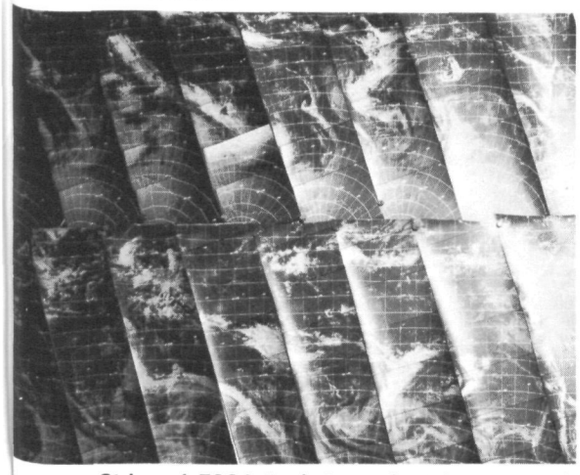
By 9 a.m., Suitland time, enough machine and hand analysis has been done to permit the development of a preliminary forecast for the layer from the surface to 500 millibars over North America. This is the first appearance in the forecast cycle of numerical prediction, where clouds and quanta and droplets and calories are dressed as numbers and driven along imaginary grids by equations of motion.

Computers are natural handlers and smoothers of data, and can be made strong weather forecasters, provided they are given a point of view and some means of expressing their simple yes-no, on-off, binary language. The machines at NMC are programmed to describe not the

continued

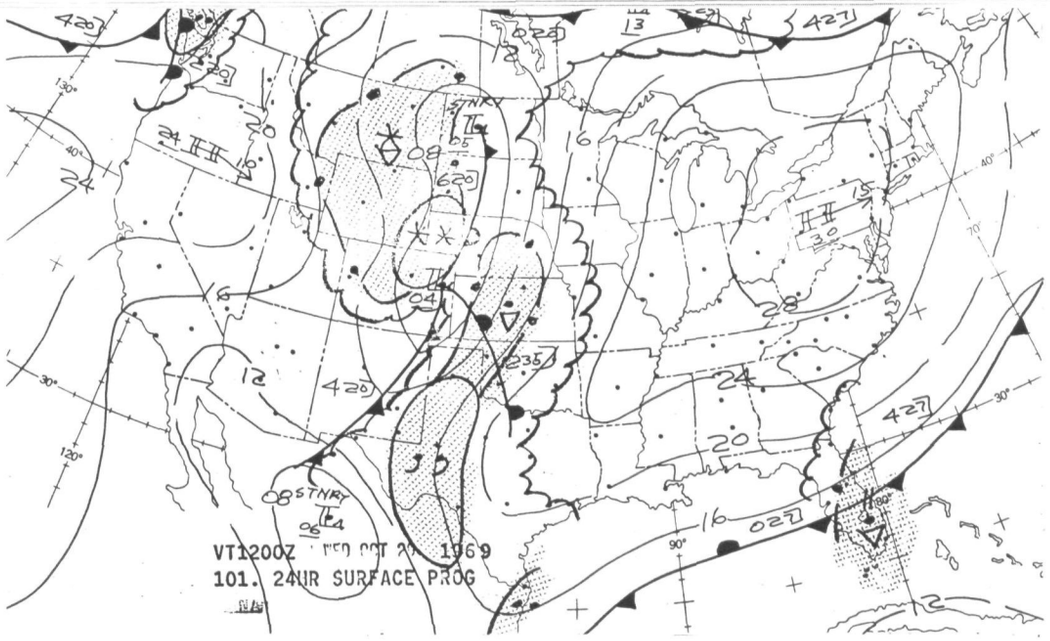
Richbell Hastings waits for the machine to spit out its segments of processed data.

Meteorologist Donald Bowyer discusses a data-sparse southern hemisphere with William Rammer.



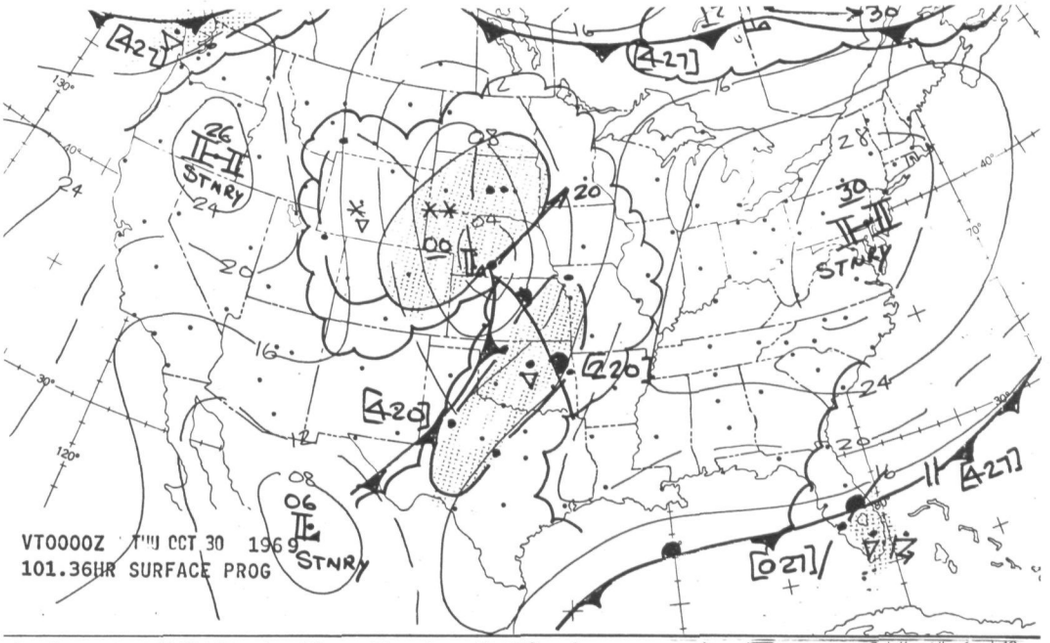
Strips of ESSA 9 photographs taken on each orbit are massaged into digitized mosaics.

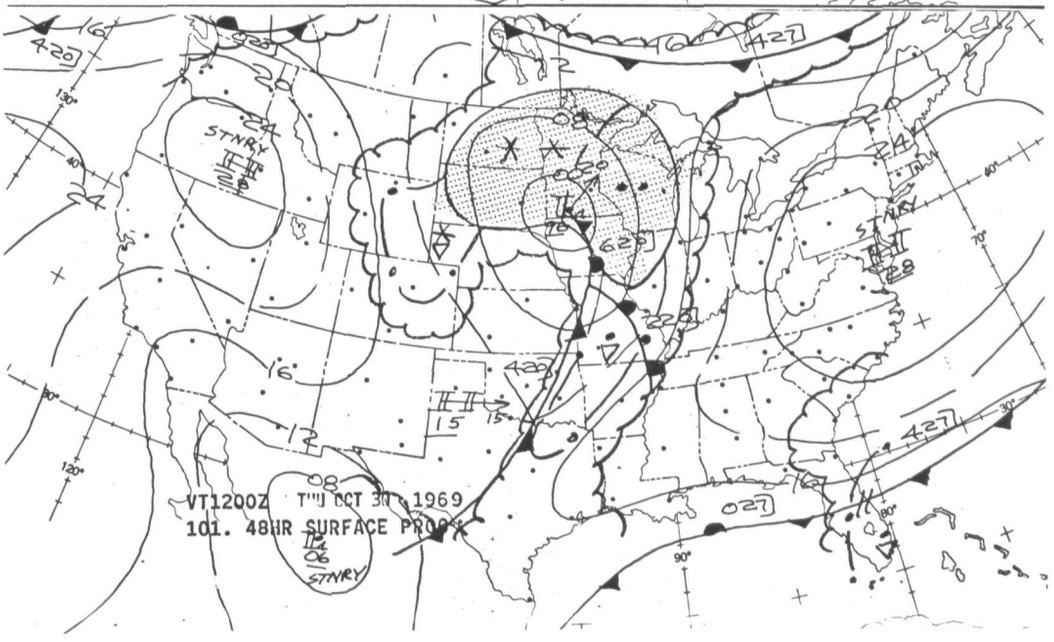
(Below) Conditions for the northern hemisphere are analyzed by Roger Cross and Francis Lacny.

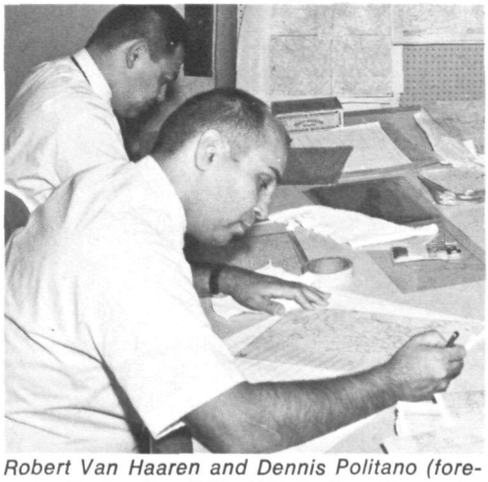


A CENTRAL NMC PRODUCT: 24-, 36-, AND 48-HOUR FORECASTS OF SURFACE WEATHER OVER THE U.S.

PROG DISCUSSION: SHORT WAVE OVER NEVADA AT 12Z SHOULD DVLP A SFC LOW VICINITY OF SOUTHWEST NEB IN LINE WITH BATROP VORT ADVECTION. LOW OVER WYO MOVES E AND WEAKENS. INITIAL THICKNESS FIELD DOES NOT SUPPORT MUCH SFC DEVELOPMENT BUT AS COLD POCKET OVER NW MOVES INTO PLAINS IT SHOULD ORGANIZE THE CENTER OVER NEB AND MOVE IT OFF TO THE NORTHEAST. MAJOR PCPN AREA XPCD TO DVLP IN THE COLD AIR NORTH OF THE LOW CENTER ALTHOUGH MOISTURE INFLOW OVER TEXAS SHOULD PERSIST WITH SHOWERS MOVING SLOWLY EASTWARD IN ADVANCE OF FRONT. NO PE RUN AVAILABLE FROM 12Z DATA AND 3 LVL GUIDANCE RUNNING ABOUT TWO HOURS SLOW. HURLEY







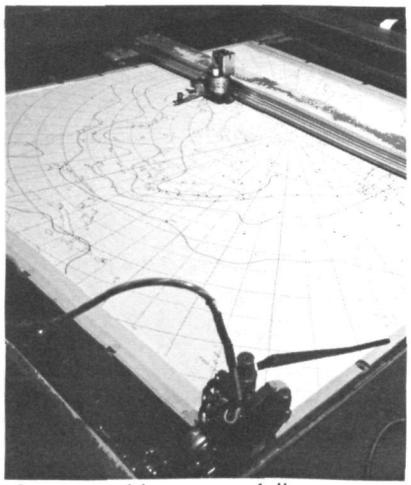
Robert Van Haaren and Dennis Politano (foreground) develop their temperature forecasts.

David Olson and Richard Browne discuss their QPF—quantitative precipitation forecast.

John Hurley's prognostic remarks on the surface charts will show no PE prognosis today.

Shift from analysis to prognosis is marked by map discussion, led here by Harold Jordan.

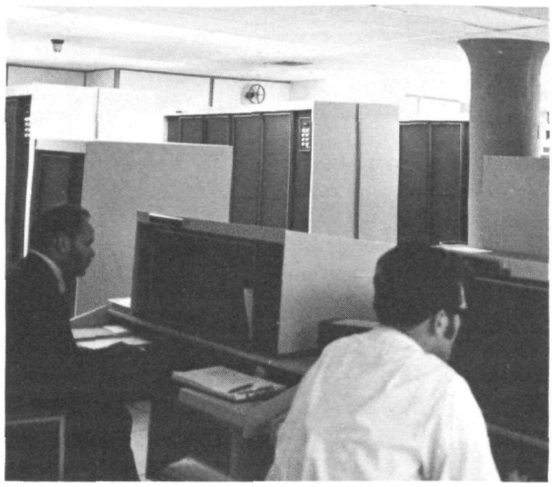
Meanwhile, Mary Kettner and Paula Fuller (background) watch NMC wires.



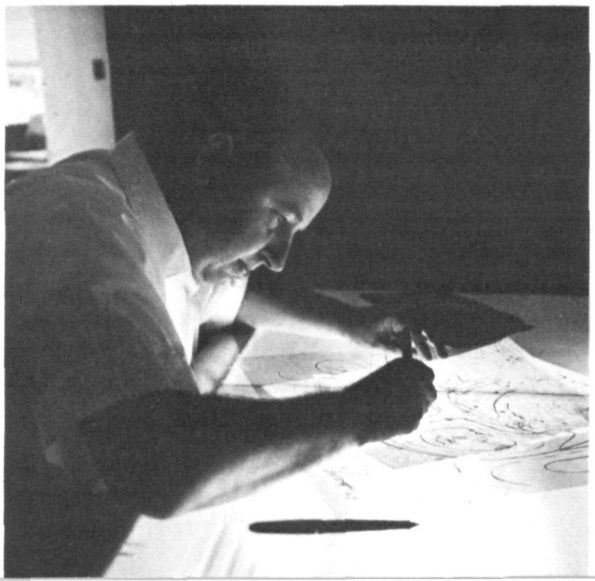
Computer-driven curve-followers can sketch out weather maps in seconds.

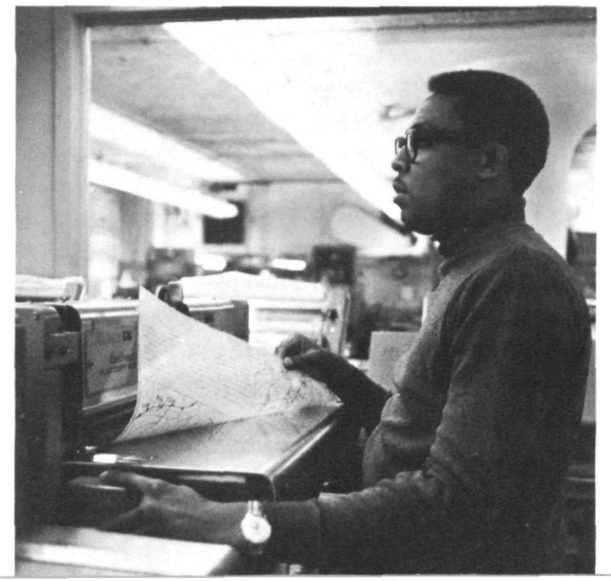
In the 7094 room, William Hagarty, Okey Johnson, and Glenn Souders (from left) try to make PE . . .

. . . model compute, while Johnnie Kelly tries to accept data from the big machines . . .



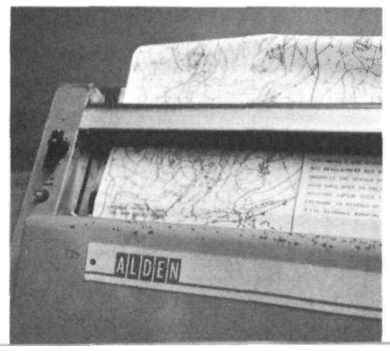
. . . downstairs, where Don Mills (left) and Lee Benge must scrub the PE model run.



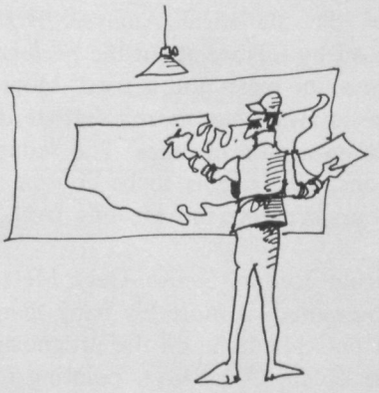


(Far left) John Fedak traces final predictions, which are checked by the Senior Duty Meteorologist and sent out over facsimile circuits to weathermen around the world.

(Left) John Henderson sends the forecasts on their way, ending the predictive cycle which began at 7 a.m. EST, October 28, 1969.



tion, and then waits for a bit to perform some other work, which we shall describe presently. This is far the most important chart; but to get all the possible use out of it, no less than six subsidiary charts have to be constructed, which requires the labour of three more men.



Number four has two blank maps of the United States on his desk before him; but instead of writing down on them what the barometer actually is at each place, he marks on one map how much the mercury has risen or fallen in the last eight hours, and on the other the amount of change in the last twenty-four hours. From these he draws, as it were, a picture of how changes of pressure are travelling across the country, or of the formation of new storms. He also draws on these two charts lines of what are called equal barometric departure, and abnormal variation; but these represent a refinement of detail that we need not explain here.

Number five has also two maps before him, and draws on them lines of equal changes of temperature, exactly as number four has done for pressure. By means of his charts it becomes easy to trace the progress of what are called hot or cold waves across the Union.

Number six likewise prepares two maps; on one he marks at every station the kind of cloud, and the direction of its motion—which may be very different from that of the wind on the surface of the ground—and sometimes the colour of the sunset. On the other he notes the temperature of the dew point, and some deductions from that, which enable him to chart out the position of damp or dry areas of country.

Two hours have elapsed from the moment at which all the observations were taken till they have all reached Washington, and been tabulated and charted as just described; and now the indica-

atmosphere itself but a model of it. The model is made of equations and mathematical functions which express physical laws, real and artificial measurements, and certain behavioral constraints. To a description of conditions at points on numerical "surfaces," the computer adds a fourth dimension: time.

The model itself is simple, orderly, and, to the analog mind, nightmarishly abstract. In the rushing unreality of these fragile, imaginary grids and layers, eddies may develop that eat away theoretical momentum, slowing and finally destroying the deterministic path of prediction, driving the yes-no chatter into a meaningless rant. Gravity waves and other oscillations plague the models, shake them out of control—destroy them, as the mathematicians say. Worlds come and go, bloom and disappear, hurried from birth to maturity to death in microseconds. That is how things are in this high-speed universe of numbers.

This first forecast uses what is called the equivalent barotropic model of the atmosphere, which was first applied operationally in 1955 and which bears only a slight resemblance to the real thing. By 9:30 this simple numerical forecast has been extended out 48 hours and is on the facsimile circuits. Soon after, the first in a continuing series of subjective surface prognoses—"progs," they call them—for 12 and 24 hours is transmitted. These packages arm weathermen in the field with an updated big picture, which can be used to improve local forecasts—for example, the report issued in time for early news broadcasts across the country.

The synoptic clock completes a secondary, three-hour interval. At 10 a.m. Suitland time, meteorologists around the world take their 1500Z set of surface measurements. These become part of the updated subjective surface analyses on the facsimile circuits, part of the continuous flow of guidance which is moving out from NMC.

Now, with about 70 percent of the day's data in and analyzed, NMC stops processing and begins the operational machine analysis. This describes ten levels of the atmosphere from 1000 to 100 millibars (200 to 53,000 feet) for the entire northern hemisphere. Meanwhile, the human analysts have nearly completed their hemispheric analysis for the 1000-500 millibar layer, a manual and highly subjective analysis of the data-sparse southern hemisphere, and charts for wind-shear, tropopause height, freezing levels, precipitable water, and observed precipitation and snow cover. If the job ended here it would still be worth doing.

It is during the operational analysis that the human-machine involvement is greatest. Comparisons of objective and subjective analyses provide a way of smoothing computer products. In general, the people are better at surface analysis, and analysis of the less continuous variables like humidity and precipitation. The computer's speed makes it a superior analyzer of upper-air pressure heights, winds, and temperatures.

This is also a chance to close the gap between actual and ideal data-collection density. Subjective insights, together with radar, satellite, and other computer-illegible matter, interpolate for the unmeasured weather over the oceans and underdeveloped continents—bogus data, this is called, necessary to keep the computer model's grid points from coming apart, added via a punch card reader.

By the time the synoptic surface and upper-air measurements are four hours old, the human-modified machine analysis is being transferred to ESSA's biggest machine, the CDC 6600, and converted to the language of the atmospheric model. The analyses have begun going out on the facsimile and teletypewriter circuits.

The emphasis has shifted from analysis to prognosis, and now a soft voice on the intercom confirms it. "Map discussion, everyone," it calls. "Map discussion in the seminar room." At this busy 10:30 moment, those who can break away head for the meeting, for it is their last opportunity to have a broad discussion of today's forecast, and of the relative

continued

tions officer makes his appearance. It is not everybody who is competent to be an indications officer of the United States Signal Office. Such a man must not only have shown some aptitude for the work, but have gone through a severe course of training for two years, in learning the theory and practice of all branches of meteorology, and in travelling about the country so as to know the local peculiarities of the wind and weather at every station.

The work of preparing forecasts three times a day, at such hours as one and nine in the morning, and two o'clock in the afternoon, is so severe that four men have to take it successively, a month at a time; and each man spends the three months he is off in visiting the different stations, and in doing other less exhausting work in the office.

But let us return to the indications room as the officer enters and finds the six charts more or less ready for his inspection. He first goes to the chart on which number three has written down the readings of the barometer and thermometer, and draws with his own hand lines, called isobars, through all places where the barometer was at the same height, say 30.0 inches, 30.1 inches, and so on; and also another set of lines with a red pencil through all places where temperature is the same, say 60°, 70°, and so on; and then he walks round the room and looks at the five other charts which are all ready for his inspection.

He is then ready to issue his indications—but why, and how? All forecasting depends principally on the lines we have called "isobars." These map out to a trained eye not only the whereabouts of good or bad weather, but also indicate the future course of wind or rain or thunderstorm. The map which the indications officer drew himself is the primary source of his forecast; the other five charts are only refined and elaborate adjuncts to assist in the formation of his judgment. No calculation is possible; everything depends on the skill and experience of the forecaster.

Some men make up their minds quicker than others; and some seem to form their judgment more by instinct, others by study. The difference between the best and worst is, however, about 13 percent; that is to say, that if the most success of yesterday's. There is usually a guest speaker, so that the discussion is a learning session as well.

About a dozen men come in for the beginning of the meeting, taking the first few rows of mixed metal folding chairs, poured glass fiber ones, and old student seats. The seminar room could be in a poorly endowed college, and could be underground. It is friendly business, though, something between an aircrew briefing and a lecture.

James McDonell, chief of the Statistical Analysis Branch and today's guest speaker, starts things off by talking about the performance of the present operational model when a fine mesh grid is used. More meteorologists come in, which means the analysis has moved farther down the mechanical line. Someone brings in an armful of maps. The "educational" talk ends. There are a few questions. One begins to be conscious of the appetite of time: less than three hours separate this meeting from the final operational forecast.

The second speaker is Harold Jordan, Senior Duty Meteorologist on this shift. The forecast, once committed, is more his baby than anyone else's, although each meteorologist puts his name on the prognostic narrative. "Let's look at the last couple of days," he says, pointing to a map showing the surface pressure fields of two days past. "Let's discuss the system that's been moving in." He takes the audience through the maps, which, like slowly animated film, show a low off the Pacific coast drift into the Rockies, where it has begun to re-form. "Something is coming out of the southern plains." He flips another map; the low shifts slightly eastward. "Some sort of complex low is forming in Wyoming." This is the major piece of weather for the United States on October 28. "This low is our one possible source of trouble."

Jordan quickly scans the rest of the continent—some precipitation down south, some in the northwest. "The model knows something about what's going on at the surface," he says, adding that it knows less about the 500-millibar level. Finally, there are questions from the floor. Will a stationary high off California hold the low in close to the northern Colorado Rockies? What about the QPF? How about softening that deep trough dug around the low by the barotropic model? People begin leaving near 11 o'clock, for it is suddenly just 15 minutes before the operational analysis is fed into the computer and extended into tomorrow, and Thursday, and the weekend.

The model used at NMC is called the PE, for primitive equation, model—primitive meaning original, not aboriginal. Evolving in day to day operations since 1960, the PE model is deceptively simple: pressure forces push the air, which cools if it rises, warms if it sinks, and precipitates moisture if it reaches saturation. The model's physical appearance, if it can be said to have one, is that of a layered, gridded box, a kind of square honeycomb. The grid points are 381 kilometers apart at 60 degrees north latitude. "Sigma" is the vertical component of the model, and defines six domains, the lowest being the planetary boundary region, the highest being stratospheric. Evolutionarily, the PE model has acquired new layers and the grid mesh has contracted slightly; six layers are used in the present model, and 3,021 grid points.

On this October 28, the PE model has had another slight mutation. Atmospheric moisture, usually modeled as precipitable water—the amount of water in the atmospheric column if all the water fell as rain—is being treated as several layers in today's PE run.

By 11:15, the PE model is primed with synoptic data for 1200Z, synoptic and airways reports received up to 10:30 a.m., subjectively derived information from satellite photographs and radar summaries, and bogus data to stabilize empty grids. Then a little over four hours after the primary synoptic time, the computer advances the model into time, taking its series of 10-minute time steps for each of the grid points, on each

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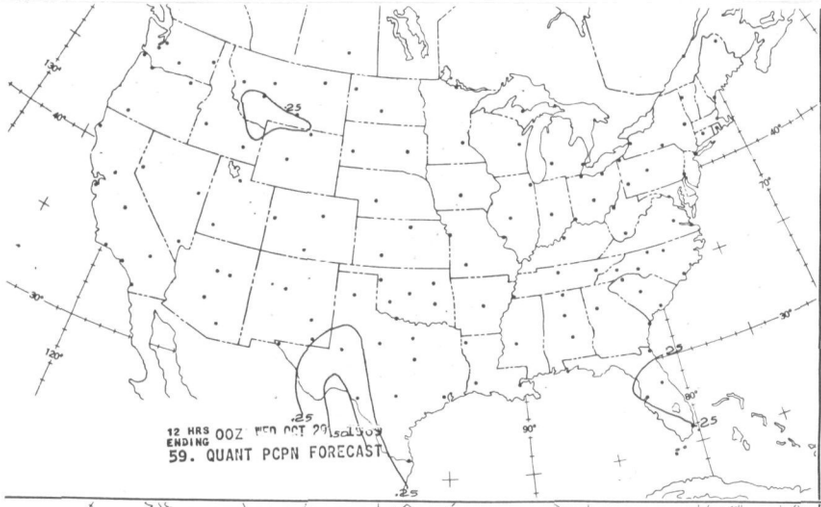
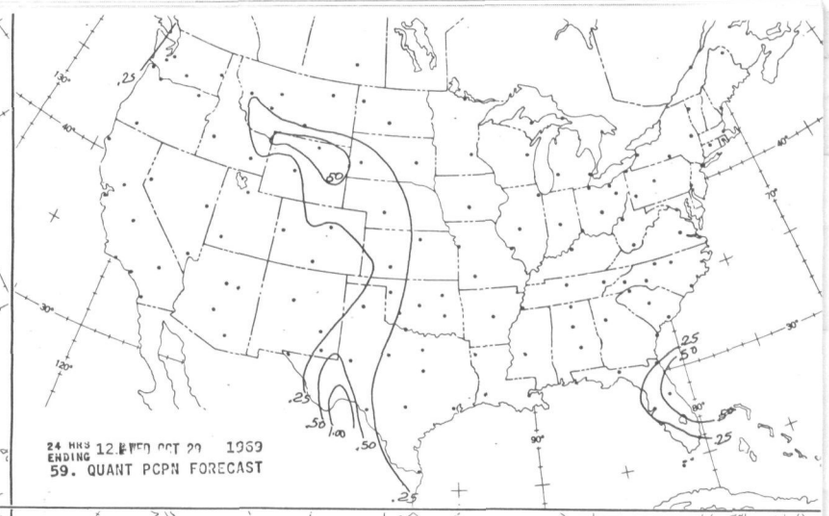
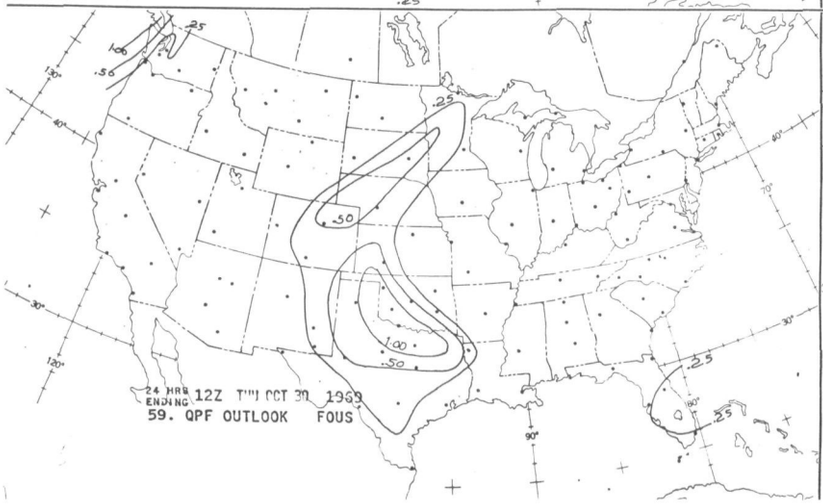
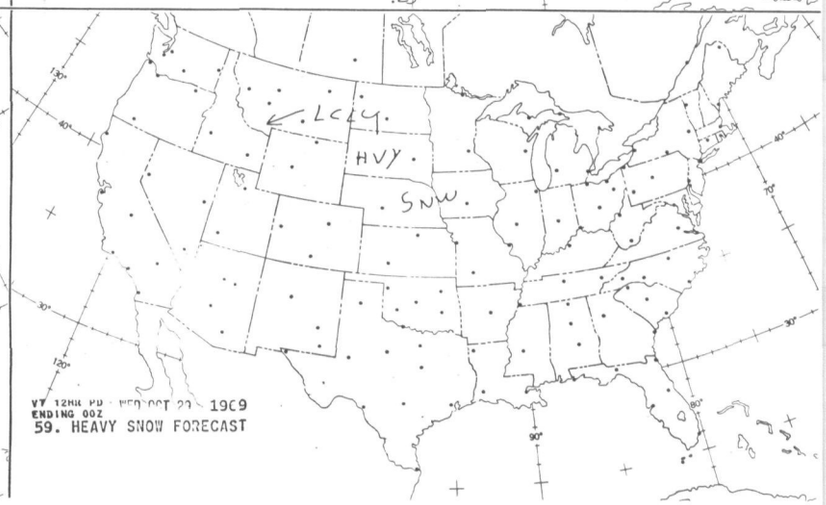
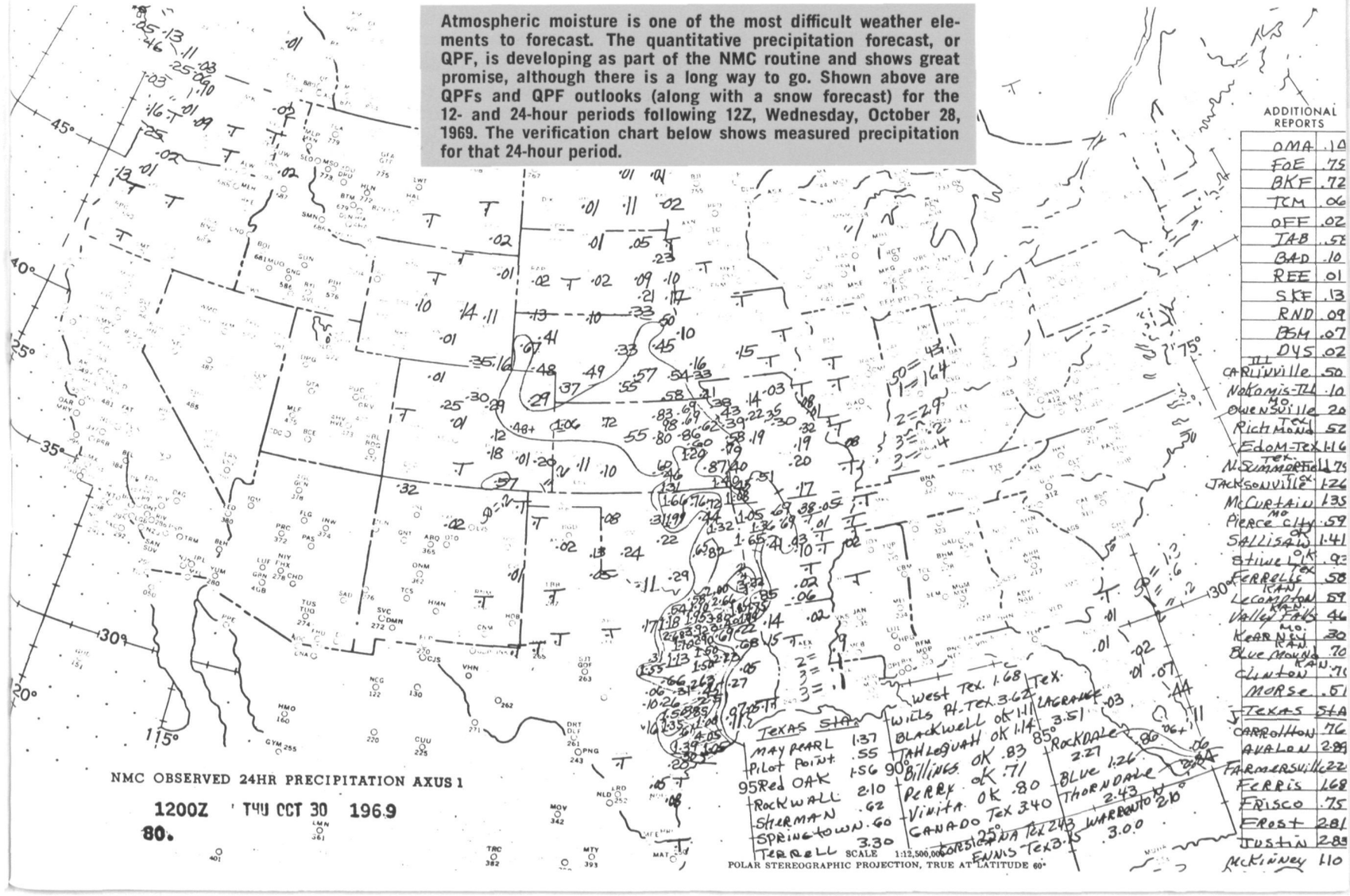








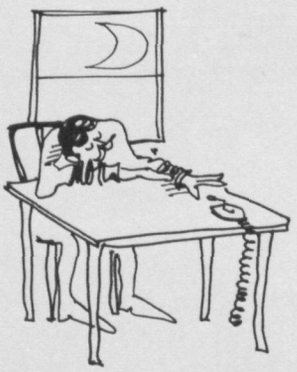
Atmospheric moisture is one of the most difficult weather elements to forecast. The quantitative precipitation forecast, or QPF, is developing as part of the NMC routine and shows great promise, although there is a long way to go. Shown above are QPFs and QPF outlooks (along with a snow forecast) for the 12- and 24-hour periods following 12Z, Wednesday, October 28, 1969. The verification chart below shows measured precipitation for that 24-hour period.



skillful got 93 percent of success, the least skillful would obtain 80 percent of success. Lieutenant Woodruff of the United States Army was the indications officer at the time of our visit, and on looking over the verification of his forecasts for one month at one particular place, we found that he had achieved the exceptionally high figure of 93 percent of success.

As soon as the indications officer is ready he dictates his forecast to clerk number three, who sets it up with logotypes, that is with whole words in a block instead of single letters. For instance, *"Tennessee"* would be in a single block, and many other common words, such as *and, the,* etc. We might be surprised at a man setting up types to dictation, but a forecaster does not speak his carefully-considered sentences at the same rate as an orator like Mr. Gladstone, who perorates at the rate of 120 words a minute.

And now, some two hours and twenty minutes after the observations were taken, the indications are ready to be telegraphed to every city in the Union, and the officer is probably glad to retire to rest, as he will have to turn out again in the middle of the night. . . .



They told us in the Signal Office that the work of even the privates was so hard that it took all of a good man to stand the strain, and we have no doubt that such must be the case. Holidays are short, for the departmental chiefs only get about twenty days' leave in the year, and one could see the look of hard work on all. We left the office with the conviction that we were saying good-bye to a body of men who were not only striving to do their prescribed work, but, with characteristic American earnestness, were trying to excel, and to carry their several branches beyond the present limits of knowledge.

of the model's sigma layers, for each of five variables—more than 100,000 operations per time step. At intervals of 12 hours, the computer normally generates progs for selected atmospheric levels, or for all of them, finally producing forcecasts for 12, 24, 36, and 48 hours into the future. The entire computation should take about 90 minutes and involves more than five million operations, or nearly 1,000 operations per second.

Today is an exception. The new moisture equations in the PE model will not compute. Murphy's and all the other laws governing mechanical perversity have come into play. In the 7094 room, Okey Johnson, Glenn Souders, and Johnnie Kelly are trying to accept data from Don Mills and Lee Benge at the CDC 6600 downstairs, but the 7094 has a slipped memory disc and the transfer is slow getting started. William Hagarty, supervisor of the Digital Computer Systems Operation Section, hurries back and forth, trying to get something computing before time runs out.

The hands of the synoptic clock crunch in; before 1 p.m., the PE run is scrubbed, and the forecasters retreat down the evolutionary chain to the pre-PE model, a simpler, three-layer arrangement which can be run on the 7094, now recovered from its slight debility. John Hurley's prognostic remarks on the end product of the 1200Z run will mention that there was no PE prog today.

The 7094 also puts the raw forecast data into forms acceptable to communications and the curve followers and Digifax. Upper-air prognoses are sent directly to the computer centers of airlines and the military, and applied just as the machines at NMC produced them.

Surface progs, complicated as they are by topographic effects, air-sea interactions, and man's inadvertent modifications, are adjusted by synoptic meteorologists. Using upper-air predictions of the positions of troughs and ridges as a guide, and beginning with the "numerical surface layer" from 500 to 1000 millibars, the forecasters work out the corresponding pressure pattern at the earth's surface. Once the surface pressure and frontal positions have been added by hand, the forecaster inks in the distribution of clouds and weather on the surface chart.

This is the most difficult part of the prediction process. Fortunately, the computer has many by-products the meteorologists can employ here, like a vertical motion chart and machine-made precipitation and cloudiness forecasts.

There are many products—subjective surface weather depictions, hourly products reflecting aviation reports, sea-state forecasts, low-level significant weather charts, vertical velocity charts, wind, wind shear, and tropopause height profiles, and precipitation summaries. Mixed with these is the stream of processed data, fresh from the global stations, more guidance for the field forecaster. And there will be a five-day barotropic forecast, to help sharpen the expertise that eventually should push predictions out a week or more.

But the heart of the guidance package is the 12-, 24-, 36-, 48-hour surface forecast for North America. This is what the past six and a half hours, all the angst in the computer rooms, all the charting and sorting and educated guessing has been about today. By 1 p.m., this central product is back in the chart room, modified by human corrections, and checked and signed off by the Senior Duty Meteorologist. The cycle ends when John Henderson sends out the four-panel chart on the facsimile circuits.

It is 1:30 p.m. in Suitland, 6:30 p.m. in Greenwich, England.

At 7 p.m. Eastern Standard Time, thousands of meteorologists around the world will take another three-dimensional snapshot of the atmosphere. Today's NMC people will have returned to the world by then. New faces will brood over charts and light tables and computer controls. Man will take another shot at prophesy.

While in Denver, today's trouble spot in the Rockies begins to be tomorrow's windy snow. □

TIROS I plus ten

The NESC Director assesses progress in weather satellites and the outlook for the future.

In a special interview for ESSA, David S. Johnson, Director of the National Environmental Satellite Center, considers the present state of the weather satellite and foresees expanding applications in the years ahead.

Q Mr. Johnson, in 1970 we are observing two notable anniversaries—the weather service centennial and, on April 1, the tenth anniversary of TIROS I, the first weather satellite. What, in your opinion, have been the major achievements—the highlights—of the weather satellite program during this decade?

A Probably three milestones since April 1, 1960, really stand out.

The first, of course, was the establishment of the ESSA operational satellite system early in 1966. Prior to 1966, we made operational use of the data available from NASA's research and development satellites—the TIROS series—but we were unable to provide a routine service of observations every day over the entire earth. This routine service began with the establishment of the operational system. We see now in retrospect—approximately three years later—that there has been a fantastic increase in the utilization of these data, not only by the United States, but by all of the countries of the world. Take, for example, the Automatic Picture Transmission subsystem. At last count, there were some 500 ground stations in about 50 countries for receiving pictures directly from ESSA satellites, compared to less than 50 at the time the operational system was implemented.

The second milestone was the launch by NASA of its Applications Technology Satellite—a geostationary spacecraft that provides us a continuous view of a large section of the earth. We have been conducting experimental programs with ATS-1 over the

continued

Satellite pictures, pieced together, show Northern Hemisphere weather.

Pacific and ATS-3 over the Atlantic and the United States. The results of these experiments are most encouraging. We find that a great deal can be done to define the wind field in large, data-sparse areas by tracking cloud motions as seen in movies prepared from the satellite pictures. Tests also have been conducted using the ATS for data collection and relay. Communications is a very serious problem in meteorology, as well as in tsunami warnings and many other fields of interest to ESSA. So the ATS program represents the second milestone and, indeed, is the basis upon which the decision has been made to request from Congress funds to implement the Geostationary Operational Environmental Satellite (GOES) system.

The third milestone occurred last spring with the launch of NASA's Nimbus III satellite, which included two experiments to sound the vertical temperature structure in the atmosphere. One of these—the Satellite Infrared Spectrometer (SIRS)—was developed here in the Center. I think it's almost a mild understatement to say that SIRS is an outstanding success. It has been so successful that data from this sensor are now being used operationally in the National Meteorological Center's numerical analysis and prediction scheme. Also, it has been decided to press forward as rapidly as possible to incorporate a sounding instrument in the ESSA operational satellites beginning in late 1971 or early 1972.

Q What operational uses are being made of weather satellite data now?

A It would take a book to outline the applications that have been made; in fact, books have already been written on the subject. I will touch briefly on some examples.

The Weather Bureau's National Meteorological Center, of course, is interested in getting quantitative data for numerical weather prediction. However, the present ESSA satellites do not provide quantitative data directly; rather they produce pictures of cloud systems around the earth. We've had a concentrated effort for many years to develop means of inferring the state of the atmosphere quantitatively from these cloud pictures, and I am happy to say that this has led to the incorporation of satellite results in NMC analyses. For example, quantitative estimates of the moisture field over the Pacific Ocean are produced which are used in the NMC quantitative precipitation forecast scheme. In our SINAP—Satellite Input to Numerical Analysis and Prediction—program, information on pressure contours and the vorticity field are derived from the cloud patterns. ESSA satellite cloud images have been used in the tropics to define the upper level wind field in the tropics; this is used in tropical analyses because of the lack of conventional observations in that part of the world. The ATS geostationary satellite is much better for this purpose, however, increasing the accuracy and the number of winds obtained. We are now using ATS pictures in an experimental operational program, in which NMC is provided with wind data derived from ATS-1 pictures over the Pacific on a daily basis. I've already mentioned the use being made by NMC of the Satellite Infrared Spectrometer sounding data, and I understand that my colleagues in the NMC feel that this is a revolutionary step in meeting their requirements for global data.

Let's turn now to operational uses in the field. Many Weather Bureau forecast offices have responsibility for oceanic areas adjacent to the U. S. Such offices have demonstrated a variety of applications for satellite data. One that comes to mind is hurricane tracking. The National Hurricane Center in Miami makes strong use of the satellite data in locating and tracking tropical disturbances. This has been a tremendous help in pinning down these storms at a very early stage and in guiding aircraft reconnaissance to find out in greater detail the nature of the storms.

The pictures also are used in tracking west coast storms. In a recent case, the NMC guidance showed that a cold front was approaching California from the west, with rapid clearing expected behind the cold front. The morning APT picture received at San Francisco showed that there were large cumulonimbus clouds behind the cold front. The San Francisco office immediately changed the forecast, calling for damaging storms and high winds to hit the San Francisco area. This revised forecast verified completely.

There are many other examples. Last spring, the satellite images of snow cover in both the upper Midwest and the western United States were of considerable benefit to hydrologists in obtaining a better estimate of the total snowpack. Of course the pictures cannot be used by themselves, without conventional observations, but they serve as an interpolation device between the sparse conventional observations available.

There is another area—what you might call direct operational application—where the satellite pictures are used by persons having an operating problem and where a weather forecast may not be possible or necessary. Let me give a few examples. First, most modern-day mapping of the earth is done by aerial photography and, of course to be useful, the aircraft have to fly where it's clear. We have learned that U. S. photomapping teams, working in various parts of the world under AID programs, have increased their efficiency by factors of two and three by using a portable APT ground station to receive ESSA satellite pictures each morning to determine where they should dispatch their photomapping planes that day. In other words, they are able to complete a given photomapping project in something like half or less the time it would have taken without APT.

Another good example is in ice reconnaissance. The satellite pictures have been used to give information as to where ships could get through the ice packs going to and from the Arctic and Antarctic. The Navy used to operate a weather ship between the Antarctic and New Zealand. They have been able to

dispense with this weather ship because of the availability of jet aircraft and of APT information to determine the weather enroute for the Antarctic resupply missions. I think these are typical examples of direct operational application of the pictures.

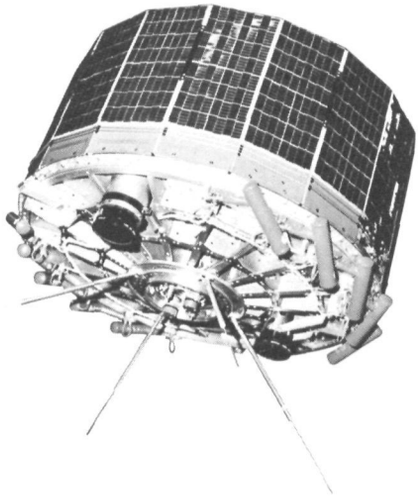
Q Do you think that more could be done in the application of satellite data?

A Oh, the answer is obviously yes. Potential users must be brought to the stage where they accept that they can benefit by using the product, and devote more resources to exploiting the opportunities available in the satellite data. We have tried here in the Satellite Center to serve as catalysts—to stimulate the interest of groups having practical problems which we think could be alleviated by the use of satellite data, and to stimulate such people to become active in using the data. We are pleased with the progress that has been made in the last few years in developing the interest of the users. I think there could be more emphasis in this area.

Q At the present time, what is the value of satellite data for areas where fairly dense conventional observing networks exist—the central United States, for example?

A I think it's safe to say that the pictures obtainable from the present ESSA satellites are of marginal use in such areas. Whether or not they are aware of it, however, they already benefit by improved NMC analyses to which the satellite pictures contribute, but this, of course, is an indirect thing. The problem in the mid-United States is that the direct forecast responsibility involves primarily subsynoptic and mesoscale ranges where the frequency of the present satellite observations is obviously insufficient. This is one of the reasons why we're so excited about the potential of the geostationary satellite. To this end, we are working now at NESC, in cooperation with the Weather Bureau, to develop a plan for a pilot experiment with ATS pictures at Kansas City next spring. We hope to be able to record and display the pictures from ATS-3 at Kansas City in real time. Thus the special problems in the Midwest can be studied where, clearly, you have to have rapid and continuous satellite observations if they are to be of significant value to local forecasting.

On the other hand, the ability to use geostationary satellites to obtain winds, and polar-orbiting satellites to obtain vertical temperature profiles—as we are doing experimently now with SIRS—will have a tremendous impact on forecasting everywhere. If we can get the kinds of observations that have been called for in the Global Atmospheric Research Program and in the World Weather Watch, there can be a significant improvement in large-scale numerical prediction. And this forms the basis from which one starts to do a variety of specialized forecasting and application. It's our view that the only economical way in which the observations required on a global basis can be obtained is by satellite, using these new techniques now emerging from the research and development program. As these techniques become operational, I think we will see a clear impact in the data-dense areas, as well as in the data-sparse areas.



TIROS

Q The problem of application has apparently been one of interpreting the picture data. Why has so much emphasis been placed on cloud photography? If we had concentrated our efforts on quantitative measurement right from the beginning, might we not be further along toward using weather satellite data in numerical prediction?

A Taking numerical prediction as an isolated case—it is only one of the parts of weather forecasting and weather operations—I think it would be fair to say that if we had gone straight for the quantitative measurement of parameters such as temperature, and not done any work on obtaining pictures, we might have reached the present state of atmospheric sounding perhaps a year or two sooner. But by taking technology that was developed earlier, we have been able to apply it to many of the Weather Bureau's public service needs. The ability to detect and track hurricanes and tropical storms should not be minimized. I have mentioned the problems that exist in forecasting for areas adjacent to or over the oceans.

I don't see cloud images and quantitive measurement as competing. In 1959, when we started the development of indirect sounding techniques, we weren't sure that it could be done. It did not seem wise to deprive the nation of the benefits which could be obtained in the meantime through cloud imaging techniques.

Q There is some feeling that the money appropriated thus far to the Weather Bureau and ESSA for the satellite program would otherwise have gone for weather observing equipment, forecasting, or research. Do you think this is true?

A I've heard this said by many people. I frankly don't think it's true. In the early days, the support given by Congress clearly was related to the question of whether or not this country was going to be a leader in the space age. In the last few years, I think there has been a considered judgment within ESSA and the Executive Branch on the balance between the ESSA satellite programs, Weather Bureau, C&GS, research, and so forth. I think if one were to study carefully the testimony in hearings before the Congress on our budget requests, it would become clear that there really is no significant interaction between the various ESSA appropriations. I might point out that in fiscal year 1970 less than $7 million was requested for satellite operations, and I think if you look at the results of the Congressional action to date on the other ESSA appropriations, you won't see that all of a sudden they approved higher requests in these other appropriations. Congress appears to examine each appropriation on its own merit; I don't think there is "switchable money."

Perhaps a number of people fail to recognize the support that comes from the satellite activities, in widely diverse areas such as computer technology and communications. Now that we are providing soundings on an experimental basis and plan to initiate this operationally. I suspect that most of these comments we've heard in the early years will disappear.

Q Do you know whether the Soviet weather satellites resemble ours?

A Yes, I have talked to a number of people from the Soviet Union and have seen a full-scale working model of their satel-

continued

lite. I would say, to try and relate it to a U. S. satellite, that it's similar in many respects and in size to the first Nimbus satellite. It contains two TV cameras of higher resolution than we use in our operational system, one viewing to the left and one to the right. In addition, it has a scanning infrared radiometer quite similar to the HRIR used on Nimbus I, but of somewhat less resolution. And lastly, they have what is called an actiometer, which measures the outgoing terrestrial radiation and the reflected and scattered solar radiation. Again, this is similar to a number of instruments of this type used on ESSA and NASA satellites.

Q Are any other nations working on weather or environmental satellites?

A From the fabrication point of view, there is only one other country at the moment—France. In a cooperative program with the United States, they are developing the EOLE satellite, designed to track constant-volume balloons. But a number of countries now are active in the planning or design phase for meteorological satellites. France is considering the development of a geostationary satellite. The United Kingdom, Japan, and West Germany all are individually considering polar-orbiting weather satellites. The European Space Research Organization is in an active planning phase for a polar-orbiting satellite. Japan also is considering a small geostationary satellite for data-collection purposes.

Q The TIROS M spacecraft was scheduled for launch in early 1970. What is the schedule for the operational version, the Improved TOS?

A TIROS M is actually the NASA prototype of the Improved TOS; the manufacturer, RCA, is constructing the Improved TOS spacecraft under the same contract. If successful, TIROS M will be used operationally just as though it were an ESSA Improved TOS spacecraft. We do not plan to launch the first of the ESSA-funded satellites—which we call before launch, ITOS-A—until such time as the TIROS M spacecraft begins to fail. We would use the same launch criteria as in the past, namely to assure daily coverage. So I cannot give a schedule. If TIROS M lasts a year, it will be a year before we launch ITOS-A; if it lasts three months, then it will be three months.

Q Suppose TIROS M is not successful?

A If there are any serious engineering problems, we would be in difficult straits, because this would require making any design changes which appear to be dictated and appropriately modifying ITOS-A. If this takes any appreciable time, we might be in serious difficulty in maintaining the service without interruption.

Q What are the operational advantages of the Improved TOS?

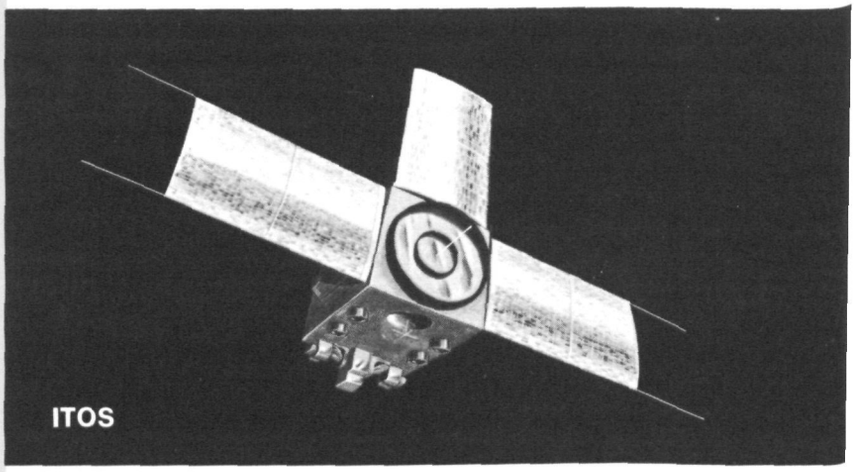
A Well, the first is budgetary. At the present time, we must have two different satellites in orbit to meet the minimum requirements—an APT satellite, like ESSA 8, and an AVCS or stored-data satellite, like ESSA 9. With the Improved TOS, these two functions are combined in the same spacecraft. This reduces the average annual cost of maintaining the system. That is a rather major item.

Secondly, it allows us to extend our observations to nighttime. There is an infrared scanning radiometer on the spacecraft to give us nighttime observations, as well as to measure surface temperatures in clear areas. We will be able to provide observations around three or four in the morning, which is timely for preparing early morning forecasts.

The third advantage is that the spacecraft itself is much more flexible than the previous one and larger, with more power, which will allow us to add new instruments, such as a solar proton/electron detector array for space disturbance forecasting, and the vertical temperature sounder, much more quickly than is possible with the present operational spacecraft.

Q In addition to monitoring solar protons and electrons, will ITOS eventually gather information on other aspects of the environment—such as earth resources and the oceans?

A Up to the present time, our program has concentrated primarily on meteorology. We have been examining ways in which the ESSA satellites could be modified to support other mission areas of ESSA. The first to be incorporated in the operational system is the Solar Proton Monitor subsystem to provide information for space disturbance forecasting by the ESSA Research Laboratories in Boulder. This is included on TIROS M and the ITOS series.


ITOS

We are also developing techniques to use the infrared radiometer data in clear areas for mapping sea-surface temperatures. We are fairly optimistic about our ability to do this, based on results of research using the infrared data from the Nimbus satellites, so this represents a modest beginning in the support of other disciplines.

We visualize the basic ITOS spacecraft being used for some years—I would say well into the latter half of the 1970's. By late '71 or early '72, we plan to add a very-high-resolution scanning radiometer which will have a resolution in both the visible and the infrared water vapor window on the order of half a mile at the satellite subpoint. This is a factor of four better than the resolution of today's visible sensors. We feel that this high-resolution radiometer will have, in addition to certain meteorological uses, considerable application in what you have referred to as earth resources. Our particular interest, of course, is in such things as ice detection, hydrology, and perhaps oceanography. When we talk about earth resources, we in ESSA are generally concerned with fields aligned with ESSA's disciplines. Here at the Satellite Center we are conducting studies on possible sensors and the use of satellite data in the areas of oceanography and hydrology. It's really too early to say what might be introduced operationally. We are in a stage of exploration in conjunction with NASA and other federal agencies, and will collaborate in joint programs, particularly NASA's earth resources satellite development program. But we are a long way from mak-

ing any decision with respect to the incorporation of additional sensors in the earth resources area on ITOS, beyond those that I've already mentioned.

Q What is your relationship with NASA when you are considering a new sensor? They have supported the development of many of these subsystems and then, of course, they fly the experimental instruments; they must have considerable influence on what sensors are ultimately developed.

A That is right, but I must say that the relationship has been outstanding. Actually, NASA has primary governmental responsibility for the development and testing of civilian space technology, while ESSA has the primary responsibility for the establishment and operation of the operational environmental satellite system. The development is a collaborative effort, and the plans are reviewed by a satellite program review board, co-chaired by the Administrator of ESSA and the Associate Administrator of NASA for Space Sciences and Applications. This mechanism has been very effective. NASA has been responsive in carrying out those developments which we feel are needed to improve the ESSA operational satellite system. For example, NASA funded our effort in designing and building the Satellite Infrared Spectrometer. Now they are funding the development of a smaller instrument that does more or less the same thing; after its development we will pay for its use in the ESSA satellite system.

Q The ESSA operational satellite system has been providing daily global cloud picture coverage. What is the schedule for achieving quantitative measurement of the atmosphere and continuous viewing of the earth's weather?

A Continuous viewing, of course, would be achieved by the Geostationary Operational Environmental Satellite system which has been proposed by ESSA. In fiscal year 1970, NASA plans to initiate the development of the prototype spacecraft, and ESSA to initiate the establishment of the command, control and reception facilities required at our Wallops, Virginia, Command and Data Acquisition station. Of course, this will require continuing funding to bring the system to full operation. NASA hopes to launch the first prototype of this system sometime in late 1971 or early 1972.

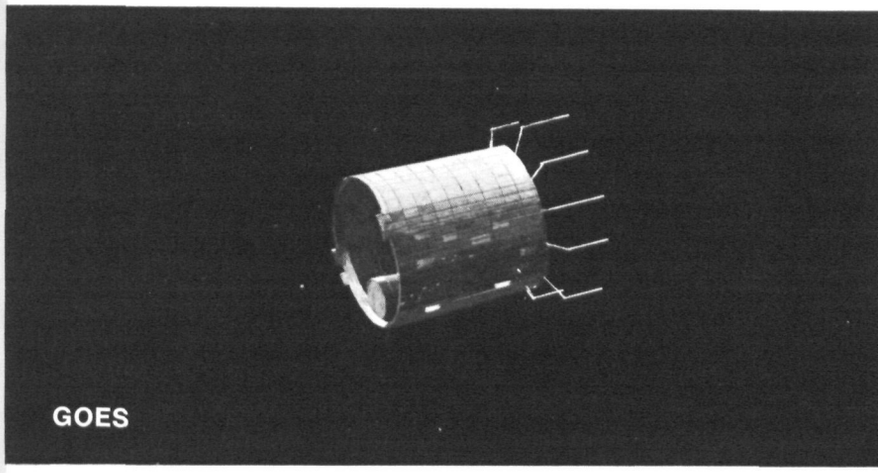
We expect quantitative measurements of the atmosphere to be available operationally in 1972, first with the institution of the geostationary satellite from which we can get winds from cloud displacements, and secondly by adding a temperature sounding device to the operational polar-orbiting satellite—the ITOS series. The temperature soundings will be available on a global basis with, we hope, some limited moisture information—probably the total moisture content of the atmospheric column; and, within the field of view of the first geostationary satellite—about one-fourth of the earth—estimates of the wind field from cloud displacements at low and high altitudes. There are a number of other developments in progress, but I think a very major step will have been made in 1972, with continued improvement through the rest of the decade.

Q You have referred to the Geostationary Operational Environmental Satellite—GOES. Will it be similar to ATS?

A The operational geostationary satellite will be different in many respects from ATS. Probably the major difference, as far as the user is concerned, is that it will have a 16-inch aperture telescope for infrared observations both day and night. The cloud top temperature data obtained will be used to infer the heights of clouds appearing in the pictures and will improve our ability to map winds. The ATS satellites have no infrared observations. Therefore, we have to guess the altitudes of the clouds from their texture and appearance, rather large errors often result, particularly for the upper-level winds.

The satellite will be equipped to collect data from isolated observing points—mostly automatic observing stations and ships, and relay these data to a central analysis point. It will also be capable of disseminating certain products from the NMC and NESC to isolated forecast offices not served by facsimile. The selection of products to be broadcast will be based on the needs of those offices in remote areas not served by adequate, conventional communications services.

A Solar Environment Monitor (SEM) system will be included in support of the space disturbance and telecommunications forecasting responsibilities of the ESSA Research Laboratories.



GOES

Q GOES will collect data from many kinds of remote stations for the fire weather service, the agricultural weather service and others, and relay the data for central processing. Have you plans for expanding facilities for handling the data? And then how will it get to the user? It looks like a very, very large operation.

A It is not quite as formidable as it sounds. Actually, the major data-handling load will involve the processing of imaging data—rectification, adjustment, calibration and, more particularly, extracting winds from cloud displacements. It's a very tremendous job. We are making a start on this aspect, but frankly I am not very happy at the present rate of progress. Here is an area where we are definitely under-funded.

Turning to data collection—interrogating and getting responses from automatic stations—we are talking about a small volume of data by satellite standards. We have been operating on a routine basis with upward of a billion bits of data a day, so a few hundred thousand more just doesn't make much difference. It's true that some special programming and computer capacity will be required, but I do not personally feel that it's the same magnitude of problem encountered in processing the continuous imaging data.

Now, as to the question of getting the processed data back out to the field; the answer is simple: just provide the needed communications. Here, we come to a philosophical question with respect to the application of modern technology. Decisions will

continued

have to be made—I suspect hard decisions—on the relative priority of the resources. It's going to cost money, for example, to put out the rain gages with the transponders on them. When we talk about the geostationary satellite system and its data-collection aspect, the major cost is *not* in the satellite subsystem. It costs perhaps half a million dollars at most to add that capability to the satellite. The real cost lies in the ground platforms that are able to measure and respond, and in the utilization of the data after it is delivered to the user, such as the Weather Bureau or C&GS. I think that the problem of funding for ground platforms, communications and so forth, will have to be handled at a policy level on an overall program-balance basis. The Satellite Center is more than ready to handle whatever load is imposed by program decisions that ESSA may make with regard to the number and location of remote stations.

Q The ground receiving stations for direct readout of geostationary satellite pictures are rather expensive. Will there be any provisions for making the pictures available in real time to the National Hurricane Center and the Severe Storms Forecast Center? Since the pictures will be available every 20 minutes, they would be a great aid in storm forecasting.

A Again, in collaboration with the Weather Bureau, we have been considering this, and there are plans for remote stations to receive the picture data from the GOES satellite. Such stations certainly would be located at Kansas City and Miami. There are other unique forecast applications where it appears that considerable payoff can be obtained from frequent imaging data. The present plan is to start out the first year with four forecast offices equipped to receive these data and then expand as experience dictates and funds permit. Also, we are planning to conduct tests using ATS-3 pictures at both Kansas City and Miami to obtain better information on which to judge what offices might obtain the maximum benefit from this type of receiving equipment. On the other hand, we do hope that the general needs of most forecast offices can be served by central products.

Q Won't the GOES provide much of the information on medium-scale weather systems that is now obtained by radar?

A GOES will provide the area of visible cloud as viewed from above and a reasonable approximation of the height of the tops of clouds. But it will have trouble in displaying layering; for example, if there is a lower cloud layer beneath higher overcast, the lower cloud layer will not be seen. We can infer where precipitation most likely is occurring, particularly with cumulonimbus buildups, but certainly we cannot tell for sure that there is precipitation or estimate the amount as can be done by radar. I visualize radar and GOES being complementary, and look forward to devising experiments whereby a display device would be used to combine the signals from these two instruments in a time-lapse montage. You might, perhaps, see the cloud field with an outline of the temperature of the cloud tops or their height and the radar echoes in a different color—possibly on a color TV type of presentation. In this way, you could see immediately the correlation between these two types of data. It seems to me that this could become a very powerful observing tool.

Q How many spacecraft will there be in the GOES system? Will we still have polar-orbiting spacecraft?

From 22,300 miles in space, earth-synchronous spacecraft such as NASA's Applications Technology Satellite take and transmit photographs of the continuous motions of weather systems over half the earth.

A For global coverage—except for polar areas—there should be four geostationary satellites. The present approved plan for the GOES system calls for one such satellite to be maintained at all times in a position covering North and South America and adjacent ocean areas. We hope this initial system will be expanded to a minimum of two satellites, which would then also provide coverage of most of the Pacific and Atlantic Oceans.

If one looks at a minimum system, and again looks at it from the point of view of global coverage as required in the World Weather Watch and the Global Atmospheric Research Program, it would include a single polar-orbiting satellite reliably there every day in addition to four geostationary satellites. Polar-orbiting satellites are needed to obtain atmospheric soundings and coverage of the high-latitude areas which cannot be reached by the geostationary satellites.

Q On the occasion of the weather services centennial, we want to look ahead—possibly as far as 100 years. How do you think the expanding capabilities of satellites will alter the national weather service?

A I surely can't look ahead 100 years. Let me try to look ahead 10 or 20 years. Really, this is not very hard, based on the results obtained in the last year or two in quantitative measurement of the atmosphere, And, of course, associated with this is the work that many groups are doing on numerical modeling and prediction. This, of course, is central to the World Weather Watch and the Global Atmospheric Research Program.

With the availability of very-high-speed, large-capacity computers and improved models, and with a major portion of the required global observing system being based on the use of satellite platforms, I would visualize a marked increase in the quality, the accuracy, and the time period of the large-scale Northern Hemisphere or global analysis and prediction.

I would think that the availability of satellite soundings suitable for large-scale prediction will result in a reorientation, for example, of the Weather Bureau's present upper-air program. I do not believe that we will see the conventional upper-air soundings disappear, as some people have suggested. The only thing I could see replacing conventional sounding techniques would be a successful indirect sounding technique, looking up from the ground, which could give the detail in the vertical structure of the atmosphere—say from the surface to about 20,000 feet—required for many operational purposes and for local short-term forecasting. Such detail cannot, in our judgment, be provided by soundings from satellites. In the absence of a revolutionary new technique of observing the atmosphere from the ground up, I would see the conventional upper-air observations changing in character—in the location, the maximum altitude to be reached by the balloon—with the frequency of observations being dictated by short period, local or regional forecast requirements rather than by the global observational requirements. I think this would be the nature of the change.

Beyond that, I think that we will see a steady increase in the use of satellite data—data that we cannot even foresee now—in meteorological operations, and in presenting a full picture of the weather to the user—not just to the Weather Bureau, but through the Weather Bureau to the user—so that the public and specialized users will have a better basis for making their operational decisions.

Q Do you foresee that aircraft storm reconnaissance will still be necessary?

A Unless there is a change in our understanding of hurricanes which would obviate the need for detailed information on pressure, wind, and temperature within the storm, I do think that satellites will do away with aircraft reconnaissance. We already have seen a rather major change in the use of aircraft reconnaissance since the introduction of weather satellites. In earlier years, the aircraft were "looking for a needle in a haystack." They would fly regular courses and hope that they would stumble onto something. Now the reconnaissance aircraft usually are vectored to a storm which has first been detected by satellite. So the efficiency of aerial reconnaissance has increased tremendously. But I cannot visualize the type of detailed information now required within the storms being provided by the satellite itself.

Q Do you think there is any prospect for an international weather satellite system?

A If you mean a cooperative program between countries on an international basis, very definitely yes. This has been discussed in many forms in recent years. And I think it's quite clear that there will be at least the same type of international collaboration and coordination that has existed for many years in the field of conventional meteorological observing techniques. We are particularly interested in other countries joining in the establishment of a global geostationary satellite system. As a minimum, four such satellites are required, equally spaced around the earth at the Equator. The present official plan is for the U.S. to provide one of these and, of course, our technical plans call for a minimum of two. We are trying to encourage other countries of the world to provide the remaining satellites that are needed. The question becomes somewhat less clear when we get into the polar-orbiting area. As I have mentioned, a number of countries—in addition to the U.S. and U.S.S.R.—wish to become involved in meteorological satellite activities and will be developing and launching experimental satellites. I think it's a little premature at this stage to say what the ultimate configuration and collaboration might be. But all of the countries with which I have had any dealing are interested in a cooperative, coordinated effort. □

DAVID S. JOHNSON became Director of the National Environmental Satellite Center when ESSA was formed in 1965. He had previously directed the National Weather Satellite Center since 1964.

Mr. Johnson was one of the prime movers in establishing the Weather Bureau's Meteorological Satellite Laboratory, forerunner of the Satellite Center. He served as chief of the Laboratory from 1960 until the Satellite Center was created in 1962 and he became its Deputy Director.

Since 1958, Mr. Johnson has been engaged in research, development, and technical management of meteorological satellites and rockets. He is a member of the Department of Commerce/NASA Meteorological Satellite Program Review Board and serves on the editorial board of the Journal of Remote Sensing of the Environment.

He has represented the United States at a number of international meetings, and was a member of the U.S. team that negotiated a cooperative weather satellite program with the U.S.S.R. Currently, he is a member of Working Group IV of the International Council of Scientific Unions' Committee on Space Research; the working group is planning the role of satellites in the Global Atmospheric Research Program. During the past year, he has served as a consultant to the Joint Planning Staff of the ICSU/WMO Joint Organizing Committee for the Global Atmospheric Research Program.

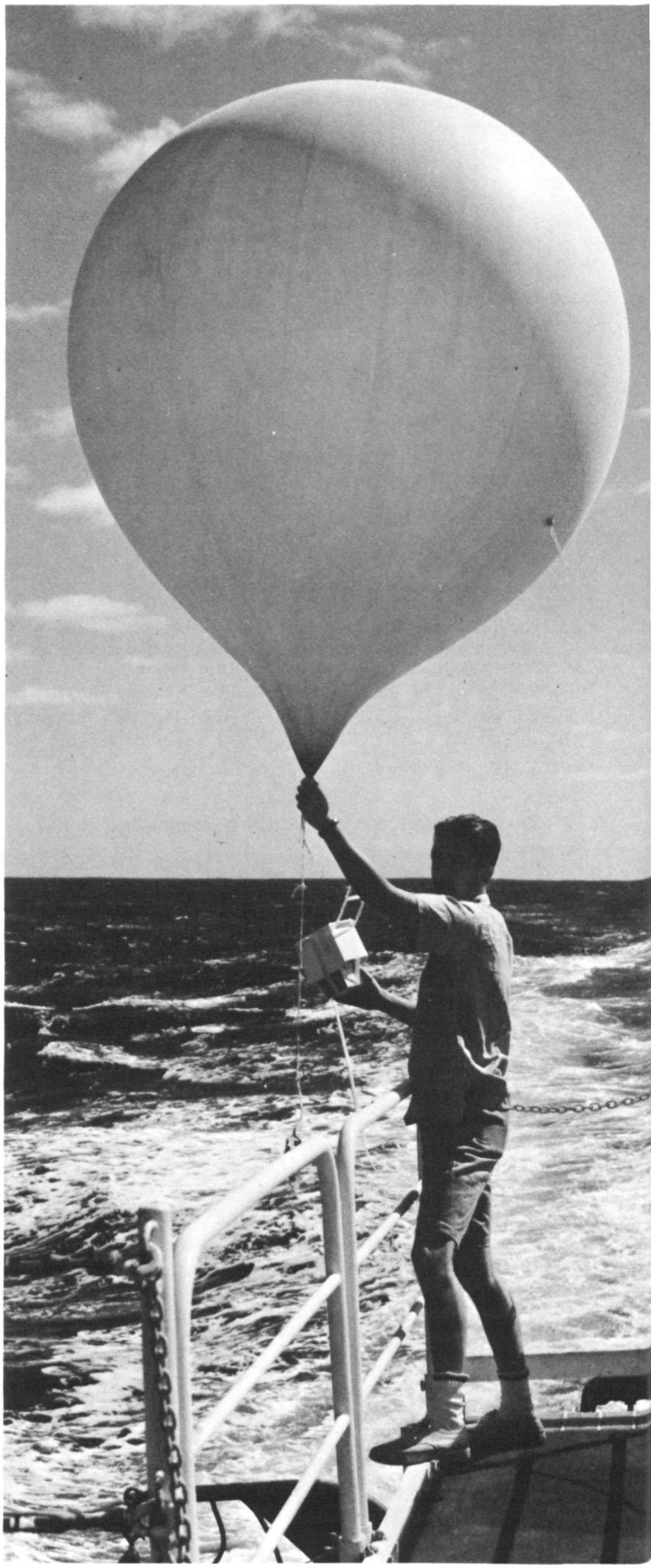
Mr. Johnson is a member of the American Association for the Advancement of Science, an Associate Fellow of the American Institute for Aeronautics and Astronautics, and a Fellow of the American Meteorological Society. He also serves as Councilor and as a member of the Executive Committee of the AMS.

In 1962, he was a semifinalist in science for the Arthur S. Flemming Award, given to outstanding young men in the Federal Government. He holds bachelor's and master's degrees in meteorology from the University of California.

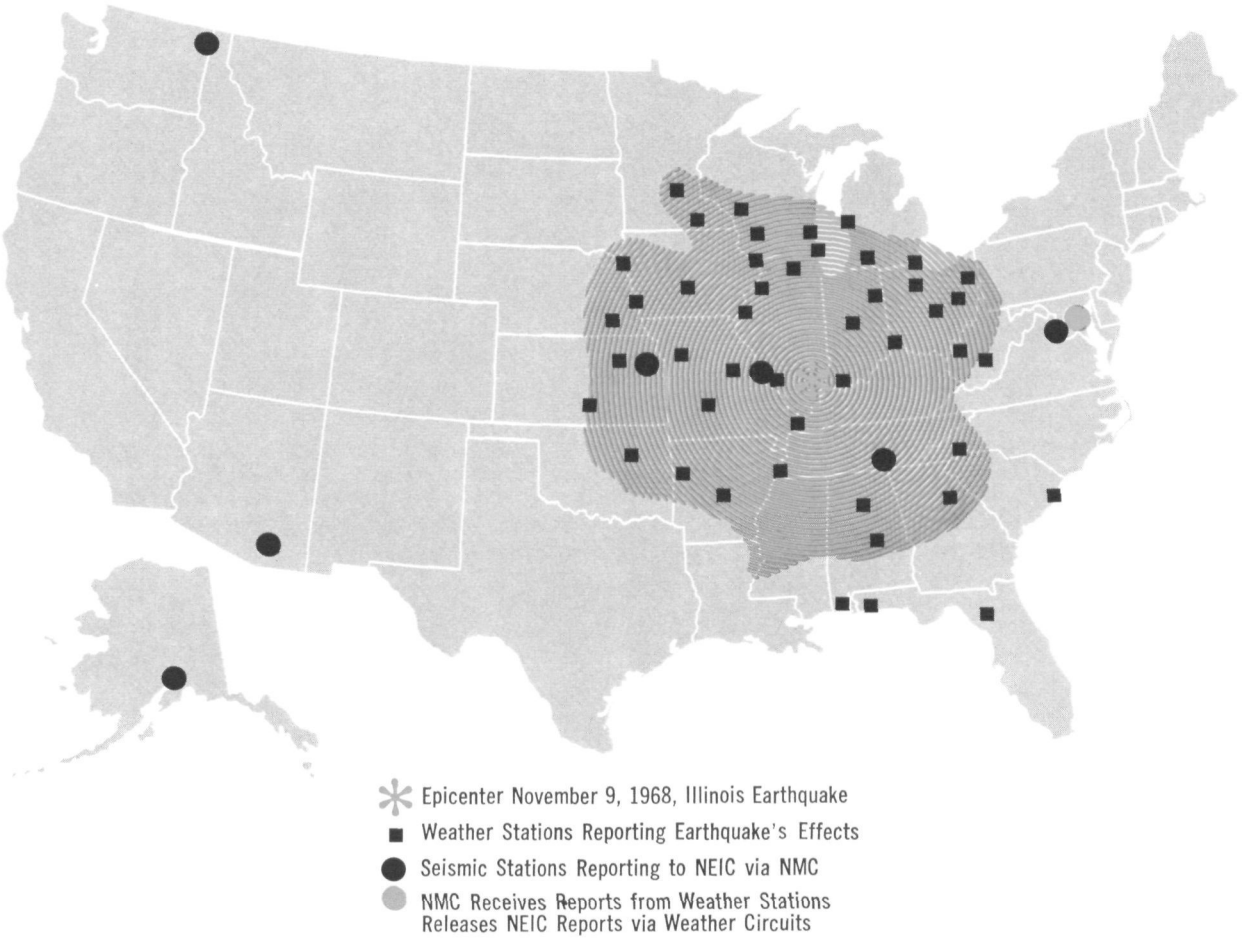
Mr. Johnson is an avid weekend sailor, whose other leisure-time pursuits include such wide-ranging fields as electronics and photography.

CENTENNIAL SECTION

In many vital missions, the Coast Survey helps the Weather Bureau . . . and VICE VERSA



BY RAYMOND WILCOVE
Coast and Geodetic Survey



WHEN THE temperature fell to a new low of 66 below zero at College, Alaska, the Coast and Geodetic Survey recorded the observation.

When the Weather Bureau requires an ocean platform for checking the weather at sea, the Coast and Geodetic Survey provides space on its oceangoing vessels.

When the Weather Bureau needs additional printing facilities, the Coast and Geodetic Survey supplies them. In 1968 the Coast Survey printed more than two million weather charts for the Weather Bureau.

These are just a few of the ways in which the Coast and Geodetic Survey assists its sister agency in the Environmental Science Services Administration. And the Weather Bureau reciprocates.

The Weather Bureau cooperates with the Coast Survey's Honolulu-based National Tsunami Warning System by operating tide gages at weather stations in remote areas of the Pacific and the Aleutian Islands. Weather Bureau personnel are also available at all times when requests are received for data from the Coast Survey's Honolulu Observatory.

The Weather Bureau Communications Center in Suitland, Md., provides the Coast Survey with a vital link for receiving telephonic reports of large earthquakes from Weather Bureau field offices. The Center also alerts the on-duty geophysicist of the Coast Survey's National Earthquake Information Center in Rockville, Md., and distributes NEIC reports of earthquakes over its meteorological circuits.

In South Bend, Ind., the Weather Bureau provides office space for the Coast Survey mark maintenance man and in Kansas City, Mo., it furnishes the Coast Survey's Mid-Continent Field Office with all its personnel services, including placement, processing of personnel actions, and virtually all classification.

Even before the formation of ESSA in 1965, the two Commerce Department agencies cooperated when they could. Since then, this cooperation has increased.

Indicative of the way in which the two agencies have worked together is the role they have played in the field of seismology. Prior to 1925, the Weather Bureau engaged in various seismological investigations. In January of that year, however, the President approved an act which provided that "the Coast and Geodetic Survey is hereby authorized to make investigations and reports in seismology, including such investigations as have been heretofore performed by the Weather Bureau."

Although the Weather Bureau was divested of its responsibilities in this area, it continued to report the local earthquake effects noted by its weather observers. For almost a half century now it has provided this valuable support to the Coast Survey. Whenever an earthquake is felt within the United States, each weather station wires its observations so that an immediate evaluation can be made of the earthquake's effects. In the near future, the Weather Bureau may also furnish reports from weather observers in other agencies and from cooperative observers, many of them private citizens.

It is probably in communications that the two agencies work most closely. The Weather Bureau provides communication services for the Coast Survey's Technical Communications Center. This has made it unnecessary to operate expensive duplicate communication channels. All seismic telegraphic traffic over military or civilian circuits is sent to the Weather Bureau's facilities at Suitland, Md., and then relayed to the Rockville headquarters of the Coast Survey over a local circuit. Most

continued

The Coast Survey and the Weather Bureau cooperate in many ways to promote safe navigation. Joint exhibits are displayed at major boat shows across the nation.

communications received by the Coast Survey in Rockville follow this route.

In addition, the Weather Bureau is developing a system whereby the independent non-government seismic stations in the United States will be able to report routine observations of seismic wave arrival times over meteorological circuits. This will improve the timeliness of data available to the program.

The Weather Bureau has provided essential support in the Coast Survey's efforts to utilize international weather circuits for transmitting seismic data. Data from many stations are now reported from nine seismic network centers on an experimental basis under bilateral and trilateral agreements established over the past four years.

Weather Bureau representatives are also seeking international approval of this program through the World Meteorological Organization. If approved, the program could revolutionize international seismology.

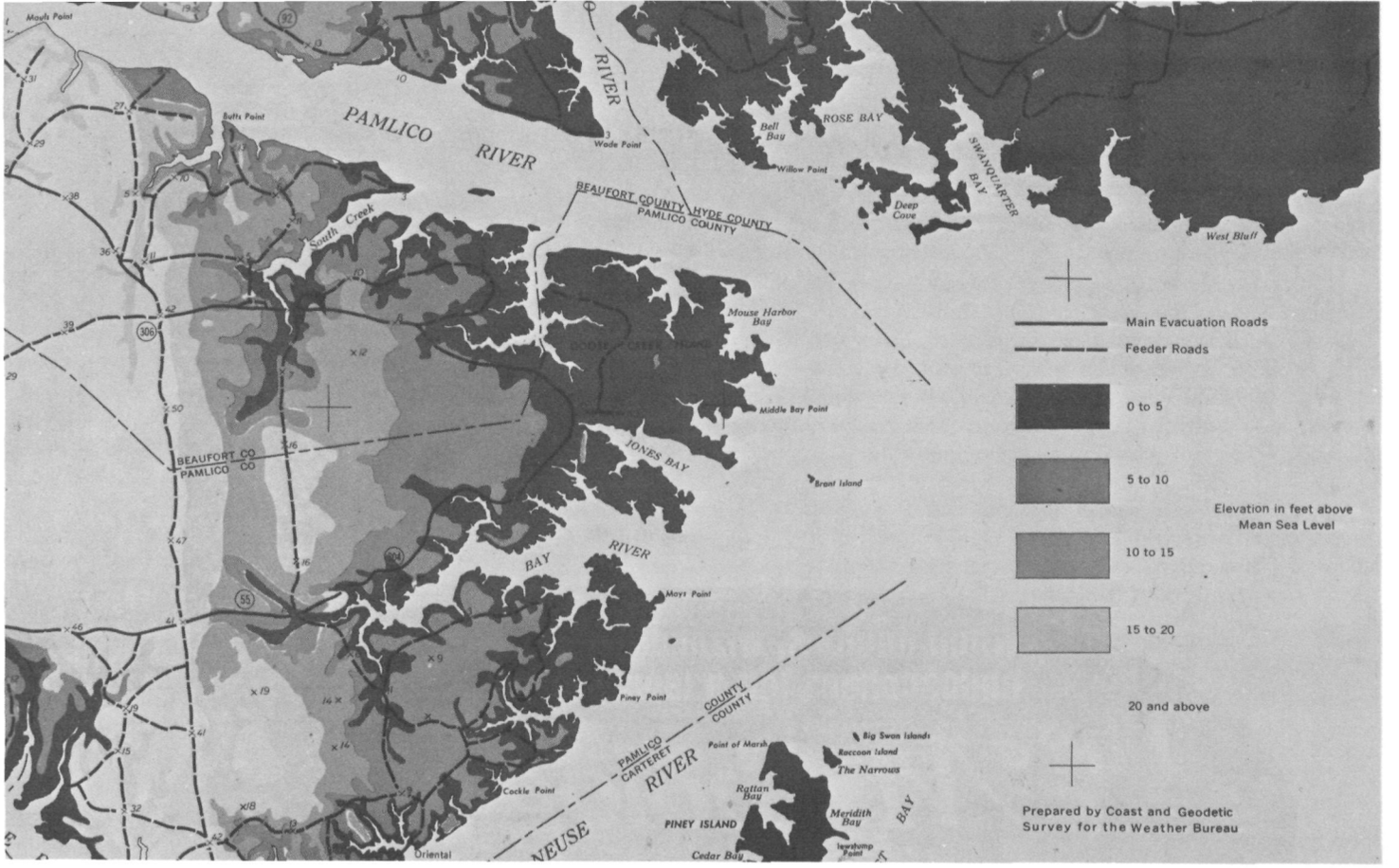
Once the seismic data are introduced into the system, the Weather Bureau provides the support services essential for their translation into operations. This requires frequent updating of the computer program to monitor and sort reports and to relay these data over the local circuit to Rockville. Future developments will include the automatic relay of seismic data over the Weather Bureau's meteorological telecommunications system to the powerful ESSA computers for remote analysis. The results would then be transmitted over these circuits to scientists all over the world.

In addition to making its communications system available for the transmission of seismic information, the Weather Bureau serves as an important link in the National Tsunami Warning System in the Pacific between the Coast Survey's Honolulu Observatory and La Plata, Argentina, a recent addition to the network. On some of the smaller Pacific islands, the Weather Bureau acts as the dissemination agency for tsunami warnings, relaying them to the local population.

In the area of hurricane warnings, where the lives of thousands may depend on timely warnings, the Weather Bureau and the Coast Survey work closely together. The Coast Survey installed and now maintains 26 tide stations which telemeter data to selected Weather Bureau forecast offices. This project was begun in 1955 after Hurricane Carol.

The hurricanes and ocean storms which played havoc along the Atlantic and gulf coasts during the 1950's and early 1960's emphasized the need not only for warning the populace of the oncoming danger, but also for providing information on suitable routes over which people could flee to safety. The Weather Bureau envisioned a map that could be displayed on television to alert local citizens in the path of a storm and to indicate evacuation routes and areas where flooding could be expected. At the request of the Weather Bureau, the Coast Survey agreed in 1962 to survey and compile a prototype storm evacuation map for the Cape Hatteras to Pamlico Sound area of North Carolina.

The Coast Survey's unusual know-how in the field of nautical and aeronautical charting is at the disposal of the Weather Bureau. Coast Survey air photo missions determine and furnish mean sea level elevations for Weather Bureau station barometers. Geodetic field parties also lend a hand from time to time in aiding Weather Bureau stations to determine elevations of their barometers above mean sea level. The air photo missions have assisted Weather Bureau researchers by photographing clouds with both panchromatic and color film, and Coast Survey cartographers have mapped and contoured the clouds. Hundreds of



At the request of the Weather Bureau, the Coast Survey prepared a map of hurricane evacuation routes for the Cape Hatteras to Pamlico Sound, N.C., area.

aerial photographs are furnished free to Weather Bureau installations.

From the Weather Bureau, the air photo parties receive regular weather briefings which are essential to the success of their missions. These are especially important in Alaska, where the parties operate from June through August. Long before the formation of ESSA, a comradeship existed because of the mutual interest in weather, enhanced by the vital importance of obtaining accurate weather information over remote areas of Alaska. In these pre-ESSA days, the air photo parties would often reciprocate by furnishing aerial photographs and airport obstruction charts covering Weather Bureau installations.

The services of the Coast Survey and the Weather Bureau are vital to the safety of those who follow the sea. The Coast Survey's nautical charts are essential to safe navigation, but so is accurate weather information. So the two agencies coordinate their efforts to provide this vital information for commercial shipping and recreational boating.

The Weather Bureau furnishes reporting, forecasting, and warning services, weather maps, warning display signals, coastal warning facility charts, and weather broadcasts by commercial and marine radio stations. The Coast Survey, in turn, provides tide tables which provide predicted times and heights of high and low water at selected sites for every day in the year, tidal current tables and charts, Coast Pilots, information for Notices to Mariners, topographic and hydrographic surveys, air photographs, oceanographic data, geodetic control, and satellite triangulation.

Storm warning stations, marine weather broadcast stations, and storm warning signals are indicated on Coast Survey nautical charts from data furnished by the Weather Bureau. Coast Survey tide prediction and current information are included in marine and commercial weather forecasts.

An offshoot of this cooperation is the jointly planned ESSA exhibit at boat and air shows, designed to acquaint the public with the products and services of the two agencies. The exhibits are jointly staffed by Weather Bureau and Coast Survey personnel and annually attract hundreds of thousands of visitors.

At seven observatories in Arizona, Alaska, Virginia, Hawaii, Guam, and Texas, the Coast Survey maintains for the Weather Bureau a daily record of the amount of precipitation and the minimum and maximum temperatures. Where applicable, the observatories also keep the Weather Bureau informed concerning unusual river ice conditions and measure the amount of snow that falls every 24 hours and the total amount on the ground. At College, in central Alaska, as much as 12 feet may accumulate in a year. In an emergency, the observatories assist the Weather Bureau stations in other ways. Thus, when nearby Fairbanks was threatened with floods this year, the College observatory helped answer the torrent of phone calls from concerned citizens.

In Kansas City, the Weather Bureau handles for the Coast Survey, procurement and contractual arrangements, in addition to personnel services. In Seattle, Washington, the Coast Survey's Pacific Marine Center provides storage and some material handling for the Weather Bureau.

In Antarctica, where both agencies have conducted operations for more than a decade, mutual assistance has been more or less a way of life due to the remoteness of the area. During 1970, the Coast Survey geophysicist at Byrd Station will aid the Weather Bureau by assuming the added responsibility of taking synoptic weather observations throughout the year. □

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Witch doctors, wizards and Greek philosophers left a legacy of lore

The Mythology of Meteorology

BY PATRICK HUGHES
Environmental Data Service

4

5

WORRYING about the weather is one of man's oldest preoccupations. He has always tried to understand it, to influence it, and—most of all—to predict it.

Modern meteorology, the science of weather, was born only a few hundred years ago. Until the invention of the thermometer and the barometer, accurate measurement of the basic elements of weather was impossible.

For thousands and thousands of years, superstition, pseudoscience, and imagination were the principal wellsprings of weather "knowledge," generating a cumulative mythology of meteorology, the prehistory of our modern science.

The witch doctor of some neolithic clan may well have been the first weather wizard to rely on ritual and incantation to bring rain or still the storm. Indeed, in our own Southwest today, rain dancers continue to beseech ancient gods, even as airplanes overhead seed clouds with silver iodide.

Clay tablets in the British Museum tell us that the ancient Babylonians associated weather with the positions and motions of heavenly bodies. The priestly profession of astro-meteorology they developed, however, was more interested in "omens" than meteorological forecasts, as illustrated by the ancient adage of Asaridu, a Babylonian priest: "When it thunders in the day of the moon's disappearance, the crops will prosper and the market will be steady."

The early Greeks, in their turn, related weather (and all natural phenomena) to their gods. The rainbow was the many-hued robe of Iris; earthquakes were caused by the restless movement of Typhon in his underground prison; and lightning was a manifestation of the anger of Zeus, father of the gods, whose sign was the thunderbolt. In many lands, there was even a special stone or statue worshipped for its magical power over weather.

About 750 B.C., the Greek poet Hesiod, ignoring the gods, published some weather rules based on observation, and they were sound. The Greeks began making regular weather observations about the fifth century before Christ. During the same century, Hippocrates, the father of medicine, wrote of the effects of climate on human health and comfort. A little later Aristophanes, in his play, "Clouds," questioned whether Zeus really made it thunder, or whether the noise was caused by clouds "banging together."

It was a Greek philosopher and astronomer, Anaximander of Ionia, who gave us the first recorded scientific definition of wind: "a flowing of air," a definition still difficult to improve.

Some 200 years later, probably between 347 and 335 B.C., Aristotle published *Meteorologica*, a monumental milestone in the history of weather science. In *Meteorologica*, Aristotle collected most of the previous writings on astronomy and meteorology and attempted to explain all natural phenomena. He included the work of Hippocrates, Democritus, Anaxagoras, Anaximenes, and Empedocles, espousing one grand, relatively simple theory embracing all—shooting stars, the aurora borealis, comets, haloes, rainbows, the Milky Way, rain, clouds, mist, dew, frost, snow, hail, winds, rivers, seas, thunder, lightning, earthquakes, typhoons, fire-winds, and thunderbolts. Since his work was based on the then-accepted theory that everything in the universe is composed of only four basic elements (earth, air, fire, and water) Aristotle was eventually proved wrong in most of his conclusions; yet *Meteorologica* was the "weather bible" of men of science for almost 2,000 years.

(Left) 1. Hopi Indians performing a snake dance to bring rain. 2. Ra, the Egyptian sun god. 3. Thor, the Norse god of thunder. 4. Two Chinese weather gods riding a cloud herald the approach of a thunderstorm. 5. Zeus, Greek god of the elements.

CENTENNIAL SECTION

Even in Aristotle's Greece, the man in the street wasn't much interested in scientific explanations of the weather; he just wanted to know if it was going to rain the next day. To satisfy this popular demand, Tyrantus, a disciple of Aristotle, writing under the pen name of Theophrastus, published the *Book of Signs*, a long collection of rules for weather forecasting based on a mixture of "science" and folklore.

About 270 B.C. another Greek, the poet Aratus, wove these rules into popular verse and proverbs, many of which survive to our own day. A familiar example is the following verse form of one of Theophrastus' rules:

"Red sky in the morning
Sailor take warning;
Red sky at night
Sailor's delight."

A slightly different version of this proverb was later used by Christ when the Pharisees and Sadducees asked for a sign from heaven:

"When it is evening you say, 'The weather will be fair, for the sky is red.' And in the morning you say, 'It will be stormy today, for the sky is red and lowering.' You know how to read the face of the sky, but cannot read the signs of the times." (St. Matthew, 16:2-3)

From the earliest days, farmers and sailors have been credited with the ability to predict the weather by watching the sky, and people have associated weather changes with their bodily aches and the behavior of birds and animals. This cumulative store of ancient observation and imagination, often colored by superstition, was the basis for Theophrastus' and Aratus' work. Since many short-term weather proverbs and signs are based on intelligent observation, they often have considerable validity—though usually only for the locale where they originated.

Little was added to the knowledge of weather by the Romans, who were noted for their "borrowing." They accepted Aristotle's ideas and passed them on. Virgil, borrowing freely from Theophrastus' work, published some weather forecasting rules in his *Georgics*, establishing the tradition of including weather "signs" in handbooks or almanacs for farmers.

After the breakup of the Roman Empire and through the Dark Ages, weather "science"—indeed all fields of knowledge—generally remained stagnant or deteriorated. Despite this, feudal astrologers had the thankless, often fatal, job of forecasting the weather for military campaigns. If the forecast and the campaign ended in disaster, the astrologer's life might well be forfeit.

Meteorologica was rediscovered in the 12th century and quickly became the last word on weather science—a distinction it enjoyed until the age of instrumentation dawned in the 16th and 17th centuries. Aristotle's work and the folklore of the Greeks were adopted by the people of the late Middle Ages, who added some folklore of their own, based principally on pious imagination.

From the mid-thirteenth century almost until modern times, it was considered wrong to question the causes of weather and evil to investigate its processes. Original thought in meteorology, as in most branches of science, was to be blocked for hundreds of years. □

"A thunderstorm was being probed as no such storm had ever been probed before"

Rooftop radar dish on a van used together with another van top electric dish in a new technique for probing the inner processes of thunderstorms that will take Doppler radar close to the limits of its meteorological capability.

THE THREE-DIMENSIONAL LOOK

CENTENNIAL SECTION

BY RALPH SEGMAN
ESSA Research Laboratories

Late last summer Dr. Roger Lhermitte pushed the starting switch for the electronics in a white Department of Commerce van parked on Gunbarrel Hill, a few miles northeast of Boulder, Colorado. It was a nervous moment. Ten years in the making, the last two an orgy of instrument building. Lhermitte, whose name translates into "the hermit," had been living in magnificent isolation amongst pieces of Doppler radar, computer programs, magnetic tapes, and ideas.

The rooftop radar dish swung into its automatic scanning mode, as did an electronical dish on a van at Marshall, 11 miles southwest. A thunderstorm some 40 miles to the northwest was being probed as no such storm had ever been probed before. In front of the visual displays on the instrument panels, Lhermitte felt akin to a radiologist watching a heart pulsate on a fluoroscope screen. The intellect and sweat that had been poured into development of the system had coalesced and everything in the complex mechanism was working.

What is exciting about Lhermitte's multiple Doppler radar system is that it can probe the inside of a storm in three dimensions. This had never been practical before. Lhermitte, a physicist at the ESSA Research Laboratories' Wave Propagation Laboratory, believes that the new technique will take Doppler radar close to the limits of its meteorological capability. The tremendous amount of new data expected from the multiple Doppler system should significantly improve the understanding and prediction of a variety of atmospheric phenomena, especially severe storms. It may also lead to a measure of control over such storms.

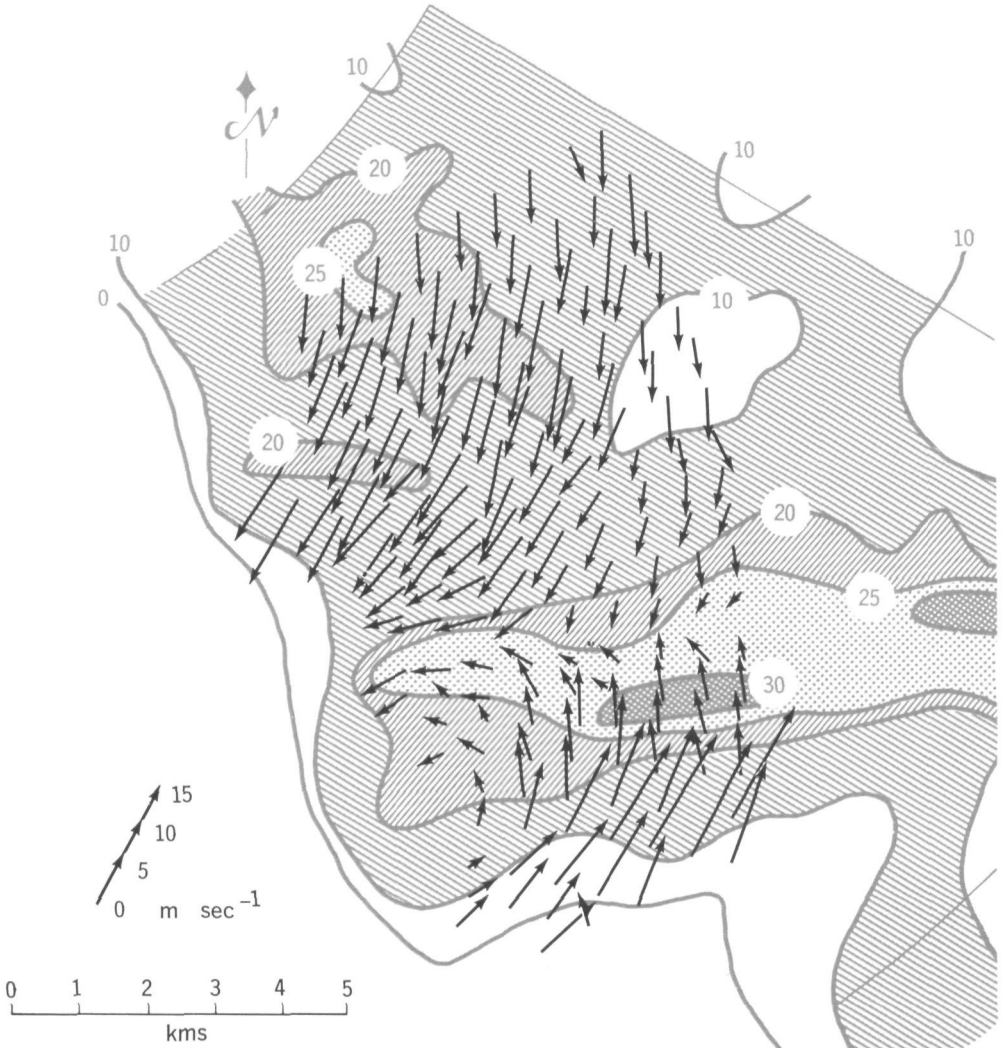
"The understanding of the dynamics of severe storms," says Lhermitte, "is one of the most stimulating areas of meteorological research. It has received a lot of attention from meteorologists. However, progress in the study of storm dynamics has been slow due to a lack of appropriate means of observing the inner processes of storms."

Lhermitte points out that research aircraft generally are not used to penetrate thunderstorms for fear that they would be ripped apart by shearing action of adjacent updrafts or shredded by hailstones. While the use of airborne radiosondes is not impossible, it would be a logistical nightmare to chase thunderstorms along roads and across fields, releasing instrumented balloons and tracking them through moving storm cells. Conventional radar over the past 20 years enormously increased knowledge of the structure of storms, but has added little to internal storm dynamics.

Doppler radars have been used in meteorological research for the past ten years. Like conventional radars, they can locate storms, determine the general movement of the storms, and map out areas of precipitation within the clouds. The fundamental difference between the radars is that Dopplers can measure the radial velocity of wind-blown precipitation particles inside the clouds—radial velocity being the speed with which the particles are moving directly toward or directly away from the antenna. By combining radial velocities obtained with two or three Doppler radars probing the same storm, meteorologists will be able to work out the true velocity direction of the winds within that cloud.

"It must be emphasized," says Lhermitte, "that for the first time in meteorological research we will be able to study the updrafts, downdrafts, convergence, divergence, and vortices in a developing storm by actually observing them."

Doppler radar takes advantage of the fact that electromagnetic waves will change their frequency when they bounce off a target that is moving toward or away from the antenna. The radial velocity is measured in terms of the change in frequency of the reflected wave. For example, a target moving straight up the beam at a velocity of 30 feet per second reflects a radar wave which exhibits a higher frequency indicating that the target's radial velocity is indeed 30 feet per second. On the other hand, a target moving at the same velocity at a 45 degree angle across the beam angle produces a radial velocity of 20 feet per second. Moving at a 90 degree angle across that beam, the target is neither approaching nor receding from the antenna and the radial velocity registers zero. A 30-foot-per-second target moving directly down the beam results in a decreased frequency showing a radial velocity of 30 feet per second away from the antenna.



HORIZONTAL WIND FIELD INSIDE A CONVECTIVE STORM ESTIMATED FROM TWO DOPPLER RADARS SCANNING THE STORM FROM DIFFERENT DIRECTIONS. ALTITUDE—200m. THE ARROWS INDICATE THE WIND DIRECTION AND THEIR LENGTH IS PROPORTIONAL TO THEIR SPEED.

Since most of the targets move diagonally with respect to the radar beam, it is difficult for a single Doppler radar to determine the true velocity and direction of the precipitation particles, since assumptions must be made about the character of the motion.

Lhermitte, as long ago as 1960, felt that Doppler radar had the capability of being a prolific source of then unavailable wind and turbulence data. It was, in fact, this capacity for producing vast amounts of information that held back the development of meteorological Doppler techniques. Processing the data required high-speed digital computers that did not exist at the time.

"Fortunately," says Lhermitte, "digital computers are now becoming a substantial part of our scientific environment and have the demonstrated capability to handle efficiently this complex data-processing requirement."

This encouraged him to design a three-radar system that could observe radial velocities of precipitation particles in the same volume of a thunderstorm from three different directions. With these data and the means to process them rapidly, Lhermitte can observe in three dimensions the birth, the development, the internal wind field, even hailstone growth, and the death of convective thunderstorms, some 1800 of which are in progress at any instant around the world.

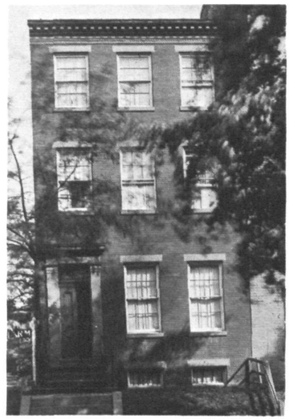
Lhermitte's Doppler radars, two of them already built, work on a pulse and range-gate principle. Like any other radar they transmit a signal, which reflects from the target (in this case small precipitation particles) and returns to the antenna. The range or distance to the target is determined by the time it takes for the radar signal to make the round trip. The radar beam actually penetrates the storm cloud, but it is partially reflected all along the penetration path. Scientists can select the part of the penetration path they want to examine by opening an electronic "gate" at precisely the right time to let in that reflection and no other.

In their present form Lhermitte's Dopplers simultaneously observe a series of 24 points in range along each radar beam. The gates open once for each radar pulse but at a slightly different time so that they receive reflections from progressively deeper cloud penetrations. This allows him to receive radial velocity data for precipitation particles at the 24 points from front to rear of a storm. Every two seconds the antenna automatically shifts to a new direction and observes another 24 points. Working under simultaneous digital control, the radars complete a total-volume scan in a few minutes. By repeating the scan every few minutes during the storm's lifetime, Lhermitte feels that he can observe the air circulation and structural dynamics of the system. This, he says, is the whole point of his work. Scientists studying convective storms have in the past combined inadequate observations with unsupportable assumptions. With the three-radar system, they will develop models and theories almost entirely on the basis of observations.

Lhermitte hopes that by next spring, using the two available Dopplers and digital computer capabilities in Boulder, Colorado, he will make the first conclusions about the life and development of convective storms. While this work is on a relatively small scale, atmospherically speaking, it should help scientists studying large-scale and global circulation patterns. He also feels that it will contribute significantly to the understanding of convective processes in the tropical belt and the vertical exchange of energy between the lower and upper atmosphere. The most important measurement that needs to be made in meteorology, Lhermitte says, is vertical air motion, a factor that controls to a great extent the weather of the world.

The new technique has already been applied to the study of storms in western New York. Lhermitte plans to join a mountain wave study in Colorado by observing clear air turbulence, using metallic chaff as targets. In addition to the further study of convective storms, he hopes to investigate air-sea interaction off Florida, waterspouts (which resemble tornadoes in having very strong vortices) off the Florida keys, warm-front precipitation in England, and hail suppression in Colorado.

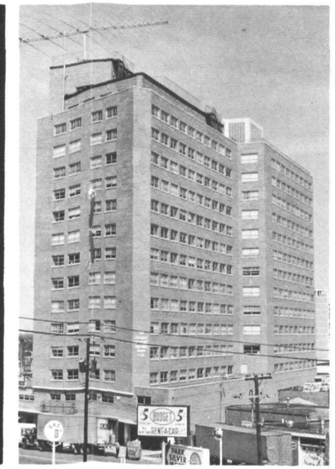
Lhermitte says the three-Doppler system is too complex and technologically advanced to be manufactured commercially at present. But he believes that in the next few years it will generate new and valuable information that will help atmospheric scientists improve man's knowledge of weather and that will lead to an upgrading of the meteorologist's ability to observe and forecast, to identify and provide warnings of severe storms, and to modify weather effectively. □



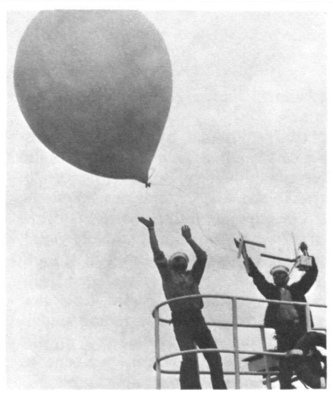
The world of meteorology changes and is changeless, a place of contrasts and paradoxes, pragmatism and prophecy, talent and technology.

CENTENNIAL SECTION

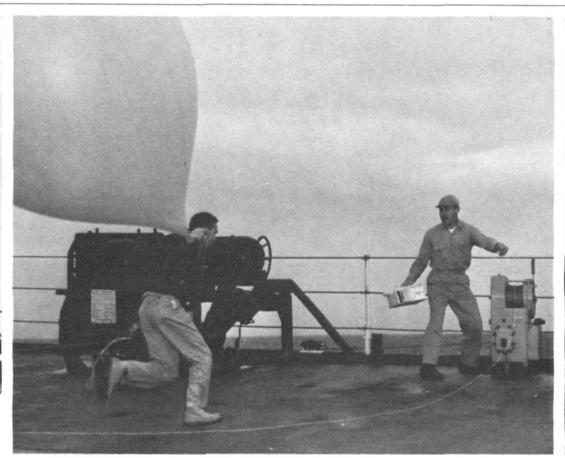
Some Meteorological Observations



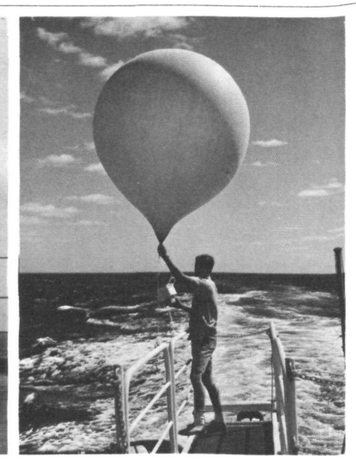
The headquarters buildings of one era are replaced by the gleaming towers of another. . .



They are called, and call themselves, "balloon blowers," but this misses the individuality found in the act of launching. It can be a *pas de deux* . . .

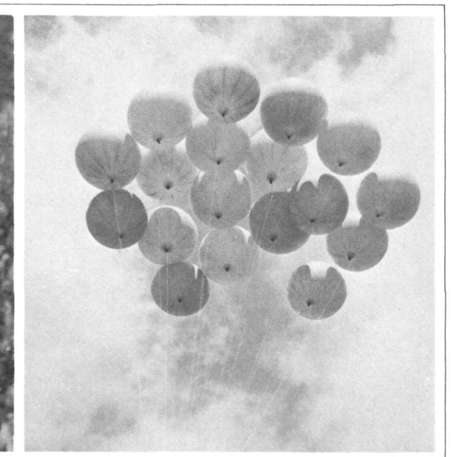


. . . a handoff from quarterback . . .



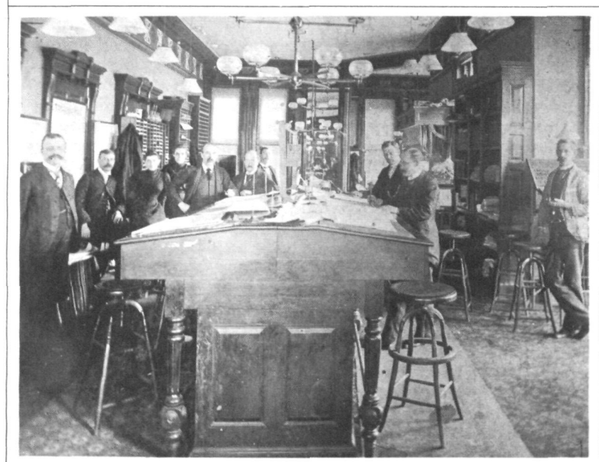
. . . excelsior!

A prisoner released . . .

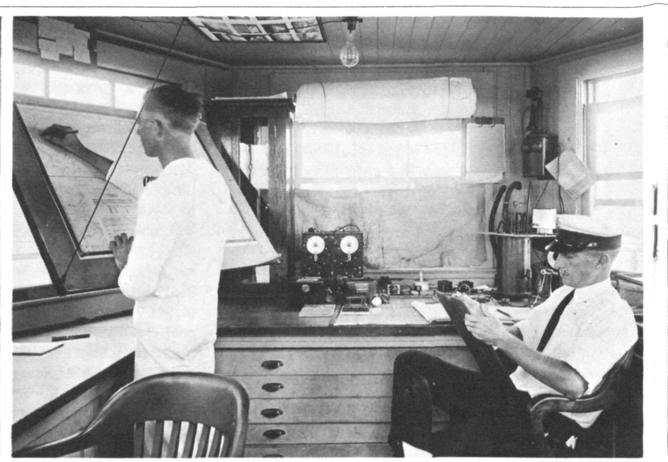


. . . . . a party.

. . . but meteorologists strike the same old pose.



The office of one period . . .



. . . is like the office of another . . .

. . . except there is more to do . . .

. . . and it must be done better and better.

Weathermen still go into the field . . .

. . . but transportation has improved—up to a point . . .

. . . equipment is better . . .

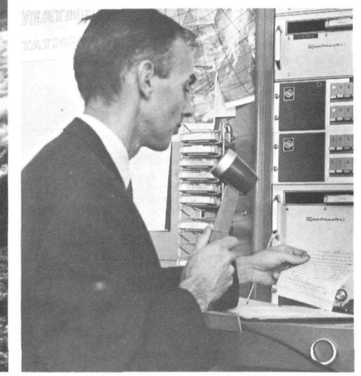
. . . still the going can be hard.

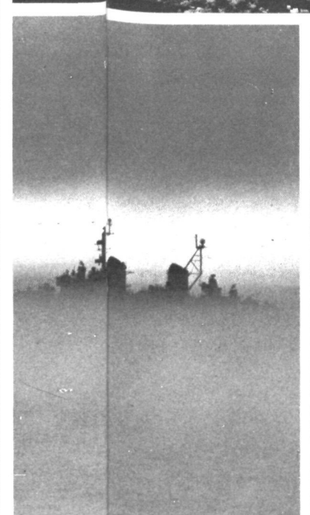
The South Pacific weather tents are shabby against the slick mobile systems used today. . . .

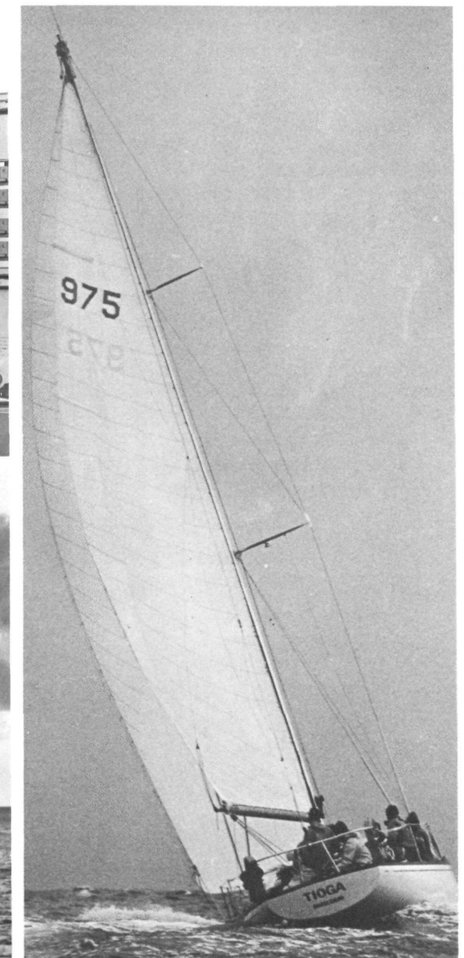
. . . but one wonders if military meteorologists in air-conditioned vans would have given typhoons ladies' names.

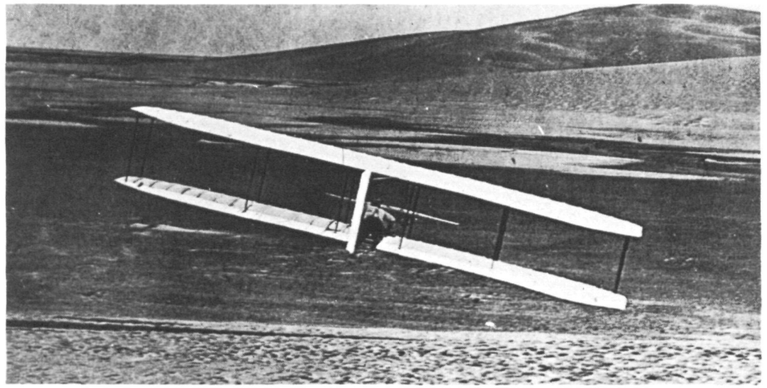
Meteorology has followed the need of special, weather-vulnerable activities. "Ag weather" is a big service, getting bigger, for the success of farmers and ranchers is critically linked to atmospheric events.

So is marine weather, which describes conditions along the stormy boundary of air and ocean, for fishermen and sloops and men o'war, weekend skippers and wartime fleets.

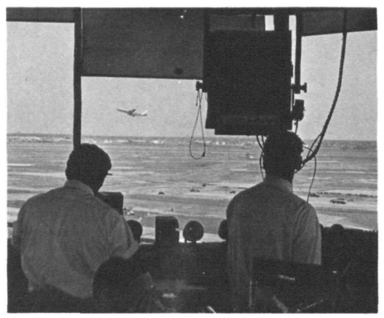


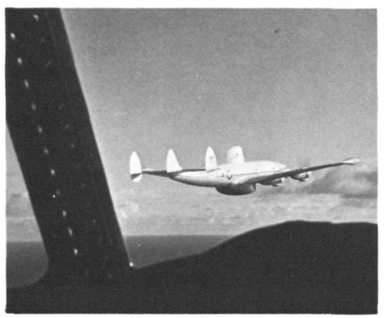


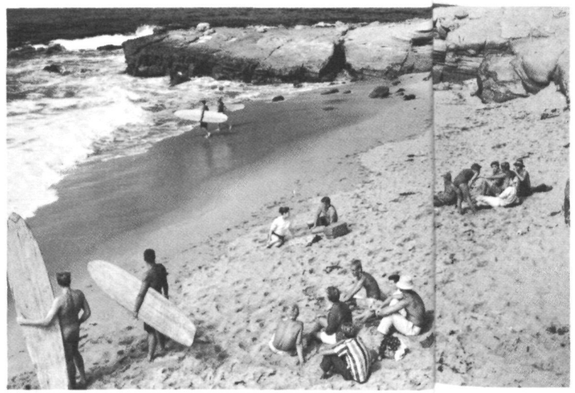


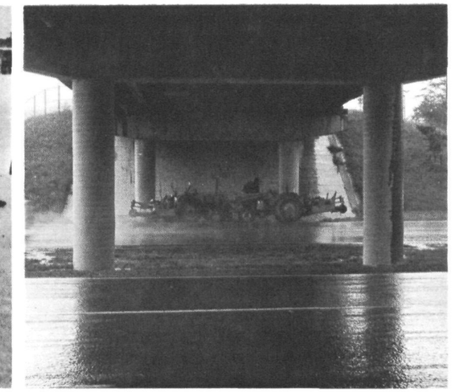


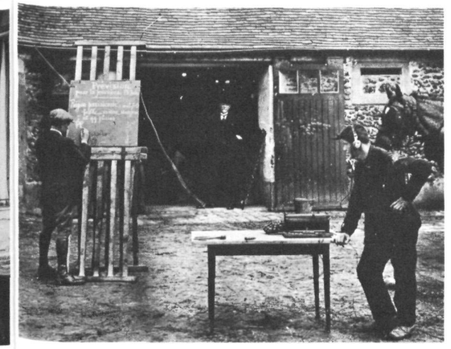
As it helps shield the act of flight from the weather, meteorology has evolved one of its broadest and worthiest families of service. Man's avian dream is not realized without much day-to-day, hour-to-hour meteorology—not even Apollo quite transcends the effects of weather. And if the weatherman's dream of prophecy is to become real, the atmospheric order will be read in part from flying laboratories in chaotic skies.











For most of us, weather is less a matter of success or failure than of vague changes in the quality of life. Small decisions are involved: to carry an umbrella, go skating, mow lawns.

The decisions get bigger as the atmosphere moves toward its violent extremes. The watches and warnings against atmospheric and hydrologic hazards are the urgent side of the public weather coin. The differences between disasters of the remote or recent past are academic except that more people are around, and more developed, costly property is destroyed. Although, to the hazards laid on us by nature, we have added a few of our own.

A curious science, meteorology blends Renaissance inventions like the barometer and thermometer with uniquely, even symbolically, modern ones.

Electronic computers grew up on numerical meteorology, where days of mathematical weather unravel in a few seconds of processing time. But technology is everywhere in the weather sciences.

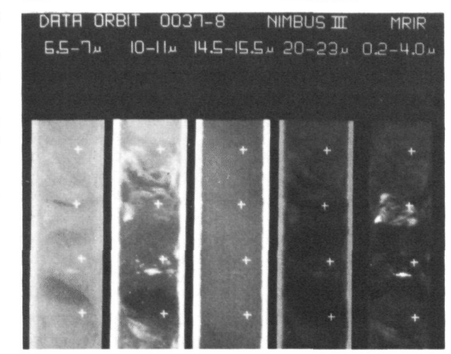
The cluttered instrument array is becoming more like AMOS III-70, a drawer-sized, automatic weather station.

Where meteorologists once listened to the telegraph key and called out data, computers and high-speed printers listen now.

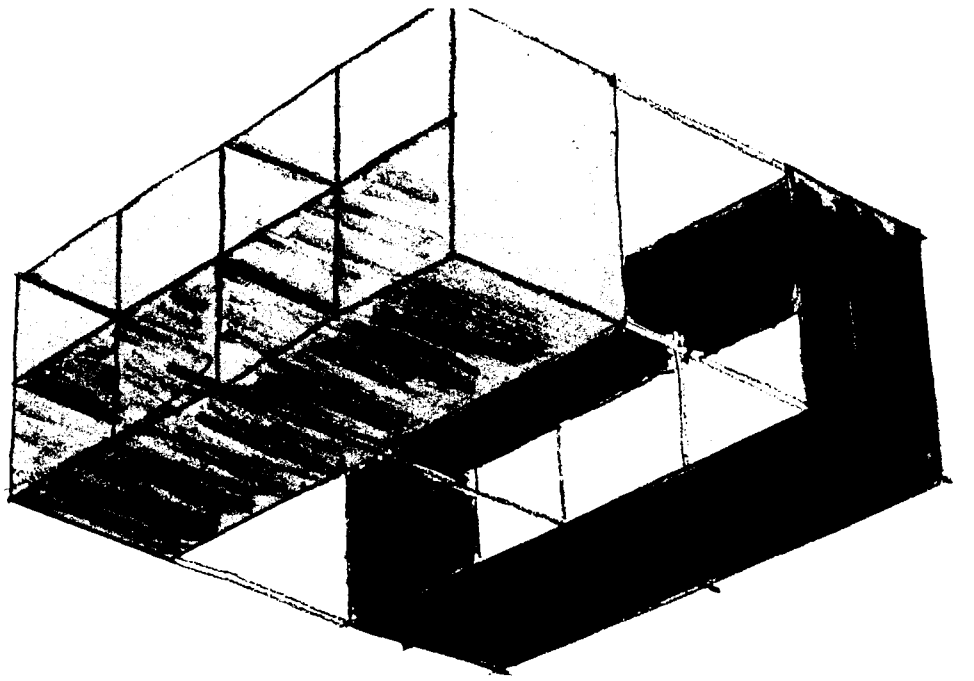
Radar has become a major instrument of meterology, the jerry-built colossi of World War II becoming mobile, and more competent: Doppler radar systems being developed today can measure wind fields inside a thunderstorm cloud, something man has not been able to do before.

Satellites *are* technology to many people, and nowhere have they achieved more than in meteorology. In just ten years, the coarse fragments from TIROS I have been replaced by the more comprehensive messages of Nimbus III and the ESSA series.

It is more the beginning of a new century than the end of an old one.



CENTENNIAL SECTION



Read about a passing moment in the history of meteorology, and then

GO FLY A KITE!

CHILDREN of all ages—up to 90—love to fly kites. Bright in the sky, they lift the hearts of countless others who never knew the enjoyment of making and flying them.

In the Weather Bureau, from the late 1800's until the mid-1930's, however, kite-flying was serious business. Kites were the Bureau's vehicles for obtaining aerial measurements of wind, temperature, and pressure, which formed the basis of forecasts.

This was hardly original with Americans. Oriental kites are believed to have been used for navigation and weather forecasting by the Polynesians before the instrument was introduced to the western world. In 1749, two Scottish students made the first recorded weather experiments with kites—a temperature check.

In 1823, the Rev. George Fisher and Sir William Edward Parry took weather readings by kite from an island off America's northeast coast. A few years later James Espy, a noted American meteorologist, and members of the Franklin Kite Club, performed numerous experiments, mostly electrical in nature.

Then the weather balloon came into being and kites were all but forgotten until the 1880's, when an Englishman, E. Douglas Archibald, measured wind velocity with an anemometer attached to a kite. This sparked a resurgence. In 1890 Willis L. Moore, then head of the U. S. Weather Service, cited his conviction that a kite-train laden with automatic instruments could explore conditions at high altitudes. Less than a year later William A. Eddy, using five kites to loft a self-recording thermometer, made the first automatic record of the temperature aloft at the Blue Hill Observatory in Boston.

A major exponent of the usefulness of kites, Charles F. Marvin (for 21 years Chief of the Weather Bureau) began using them regularly for weather observations in 1895. And in 1910, weathermen at Mount Weather, Virginia, lifted a 10-kite train to a record 23,835 feet. From 1898 to 1906, the Weather Bureau had 17 kite stations. The stations continued in operation, in varying numbers, until the last one closed in 1933.

In the early days, a meteorograph designed by Marvin was the basic instrument used on kites. It was an ingenious combination of devices used to measure pressure, temperature, relative humidity, and wind velocity.

The kites were not things of beauty—plain boxes, large, but fashioned with extreme attention to detail. Reams of instructions were written about how to build, launch, and land them. It took at least two persons to make a flight. Even the sites were chosen with great care. ("Experience has shown that the best location is one in level country rather than on a mountaintop, the latter being undesirable because of its influence on the meteorological elements and the resulting erroneous

relations indicated between the surface and free-air conditions. The country surrounding a kite station should be as free as possible from forested tracts, lakes, marshes, rivers, etc.; also from towns, steam and electric railways, and high-tension power lines. . . . Fairly good roads are necessary in order that kites that have broken away may be readily recovered. . . . The Weather Bureau . . . selects sites with open country to the east but with a small town approximately one kilometer to the west. The plot used as a kite field is usually square and contains 40 acres of land, as nearly level as possible, cleared of trees, stumps, etc., and surrounded by a sufficiently strong fence to keep out livestock. . . .")

A kite station consisted of a main building, 1½ stories high, with space for a carpenter shop and storage. With it was a reel house which served as a nerve center when a flight was underway. The reel was powered with an electric motor, and elaborate precautions were taken for protection against lightning. Piano wire was used to fly them.

A launch was executed with precision. The Weather Bureau instructions called for the man holding the kite to "walk out with it held up at an angle of about 45 degrees with the horizon, keeping a good tension on the wire between himself and the reel all of the time. When the head kite is to be launched in a moderate wind, it should be taken about 60 meters to the leeward of the reel house and released, if possible, while the wind is fairly steady; in a light wind it should be taken out 100 meters or more and pulled up into the air by reeling in; if the wind is strong, it should be released while walking away from the reel and should be allowed to go out rapidly. . . ."

The kites are history now, supplanted by a reel-less object hundreds to thousands of miles in space. But they were a moment of Americana, and in their time they served the nation well.

For those who are mechanically adept and suitably nostalgic in outlook, *ESSA* outlines here the directions for making an old-fashioned Weather Bureau kite, exactly as it would have been made around the turn of the century. Happy flying!

(The following instructions are taken from "The Construction of a Weather Bureau Kite," by Alfred J. Henry, published in the *Bulletin of the Mount Weather Observatory*, April 30, 1910.)

Three sizes of kites are in use. They may be classed as High Wind Kites, Moderate Wind Kites, and Light Wind Kites. The details of construction for the different sizes are precisely the same. As will be understood from the description and detail drawings which follow, this form of construction has certain advantages and disadvantages. One of the chief disadvantages is its frailty. Collision with the ground or other object is almost invariably followed by a bad smash of the kite; likewise when the sails become waterlogged the shrinkage of the cloth is frequently powerful enough to crush the framework of the kite. On the other hand the broken sticks are easily and quickly replaced and the kite itself is conveniently collapsed for shipment.

As is well known, the kite consists of two cells joined together by longitudinal strips of straight-grained spruce. The front cell has a middle plane in it. The details which follow refer to what is known as the "moderate-wind kite," for winds of 12 to 30 miles per hour (5.4 to 13.4 meters per second). Its extreme dimensions are as follows:

Length or distance fore and aft
6′8½″ = 204 cm

Width or distance from side to side
6′5″½ = 197 cm

Depth or distance from top to bottom of cell
2′8½″ = 83 cm

The area of sustaining or lifting surface is 68 square feet (6.3 square meters), and of steering surface 22.8 square feet (2.1 square meters). It weighs about 8½ pounds (3.8 kilos).

For light winds (8 to 10 miles an hour or 3.6 to 4.5 m. p. s.) a kite having 120 square feet of sustaining or lifting surface is occasionally used; and for high winds (30 to 40 miles an hour or 13 to 18 m.p.s.) a third size is used.

The material required in the construction of the moderate wind kite includes:

(A) Forty-one sticks of the following dimensions:

1, ⅝ inch x ½ inch x 7 feet 5 inches. Center bridle stick; square edges.

5, ⅝ inch x ⅜ inch x 6 feet 7 inches. Corners and back center; square edges.

8, ⅝ inch x ¼ inch x 6 feet 7 inches. Horizontal front and back edges of cells; rounded edges.

12, ⅝ inch x ⅜ inch x 2 feet 1 inch. Horizontal sides, tapering to ⅝ inch x ¼ inch at ends.

8, ⅜ inch x ¼ inch x 2 feet 1 inch. Horizontal intermediates, bracing horizontal sides; rounded edges.

4, ⅜ inch x ¼ inch x 3 feet 2-3/16 inches, for horizontal center; rounded edges.

3, ⅜ inch x ¼ inch x 2 feet ¼ inch. Vertical center; rounded edges.

(B) The sticks are made of straight-grained spruce. All horizontal sticks should have their edges rounded, so that the end resistance of the kites to the wind will be less. Thirteen yards of Lonsdale cambric 26½ inches wide; some coarse waxed linen thread for lashing angles to sticks; 175 feet of fine piano wire, diameter 0.028 inch, for bracing.

(C) Forty-eight metal angles as shown by detail sketch, figure 6, are used to fasten the principal joints, 1 to 24, figure 4; thirty metal angles as shown by detail sketch, figure 7, for all intermediate joints, excepting at *N*, *P*, *Y*, and *W*, which are simply lashed with waxed thread. The isometric detail, figure 6, shows how these joints are fastened. These metal angles are made especially for the Weather Bureau. They are not on the market.

Figure 1 is an elevation of the front or bridle face of the kite, i.e., the lower surface when flying. The opposite face, i.e., the upper surface or rear surface of the kite, is the same except as to the size and length of the bridle stick. Figure 2 is a sectional elevation showing the central or bridle truss, and figure 3 is an elevation of one of the two side trusses. The fine diagonal lines in figures 1, 2, 3, and 4 show the system of wire bracing necessary to preserve the form and rigidity of the framework. This bracing is all done with very fine piano wire secured to the metal angles as shown in figure 6 for the vertical cross bracing; in the horizontal and the long vertical bracing the wire is looped over the small bolthead in the metal angles before the bolt is tightened up. All metal angles are lashed to the sticks with well waxed linen thread.

After the frame is put together and securely braced, care being taken that all angles are true and square, the kite is ready for the sails. These are made from white Lonsdale cambric[a] 2 feet 2½ inches wide and 7 feet 2 inches long, being hemmed ½ inch on each edge and each end. A strong cord should be passed through this hem to lessen the danger of tearing. The sails are stretched around the kite frame and lashed to the horizontal and vertical sticks with waxed thread.

A middle sail is placed in the center of the top section extending from *MV* to *QZ* (see fig. 4). This sail should be exactly 2 feet 1½ inches wide and 6 feet 5 inches long after being hemmed as described for the main sails, and should be lashed to the sticks in a similar manner.

The method of attaching the kite to the line wire is shown in the isometric detail, figure 5. A stout cord about 18 inches long is fastened to the bridle stick at point 11, to this is attached a cloth-bound elastic bridle, looped and fastened as shown. To the end of this bridle is attached another stout cord, double looped about 18 inches long, with a strong brass ring at the end. This cord extends as shown, and is fastened to the extreme front end of the bridle stick. From this point a wire brace extends back and is fastened at point 14, as seen in figure 2. The elastic cord used in making bridles is manufactured especially for the Weather Bureau. It consists of thin strips of rubber about one-quarter of an inch wide tightly bound in a cloth cover, in the form of a small rope about five-eighth inch in diameter. On ac-

continued

[a] The rear cell and sometimes both cells are covered with a black fabric known to the trade as "mercerized" silk. It has the property of shedding water to a much greater extent than cambric. For that reason kites covered with it are preferred during fog.

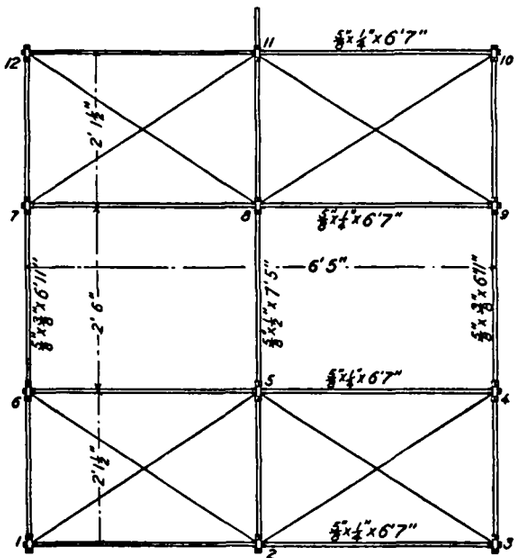


Fig. 1.
front

Kite Sticks, Clamps &c.

1	5/8"x1/2"x 7'5"	square edges.
5.	5/8"x3/8"x6'11"	" "
8.	5/8"x1/4"x6'7"	rounded edges.
12.	5/8"x3/8"x2'1" tapering to 5/8"x1/4" at ends.	
8.	3/8"x1/4"x2'1"	rounded edges.
4.	3/8"x1/4"x3'2 3/8"	" "
3.	5/8"x1/4"x 2'1/4"	" "

48 Metal clamps – Fig. 6.
30 " " " 7.
175 ft. No. piano wire
13 yds. Lonsdale Cambric 26½" wide.

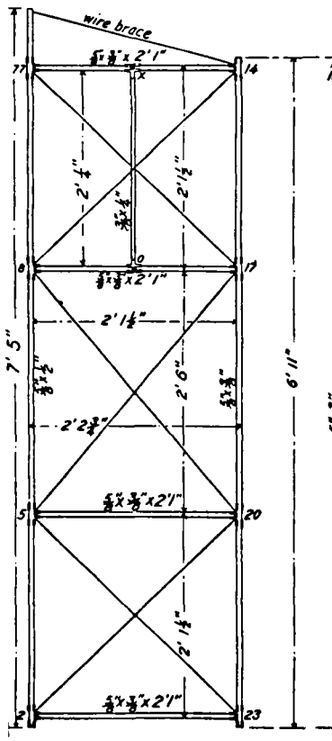


Fig. 2.
center

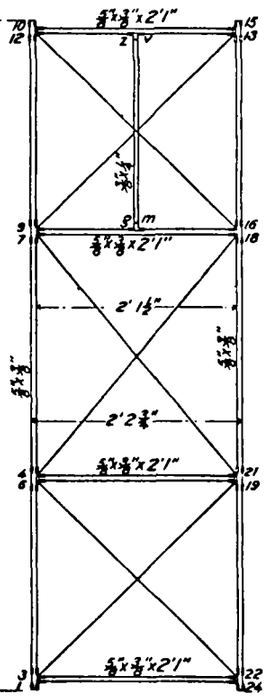


Fig. 3.
ends

CONSTRUCTION OF A WEATHER BUREAU KITE

In these early plans for building a weather kite, Figure 1 shows the front; Figure 2, the center; Figure 3, the ends; Figure 4, an isometric view; Figure 5, an isometric detail, with the metal clamps appearing in Figures 6 and 7. Figure 8 depicts a simple form of kite completed and the details of several parts appear in Figures 9, 10, and 11.

Fig. 4.
Isometric view.

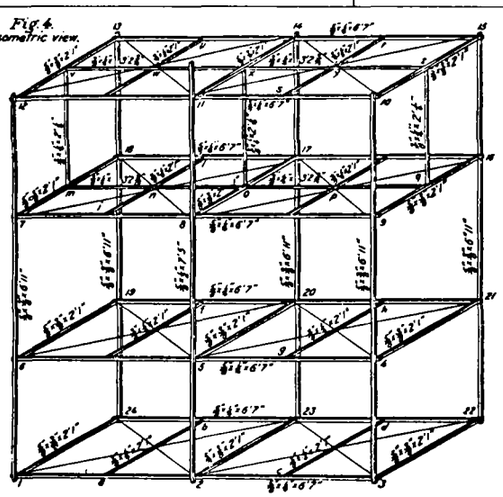


Fig. 9.

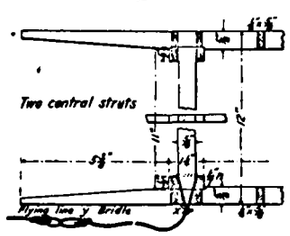


Fig. 11.

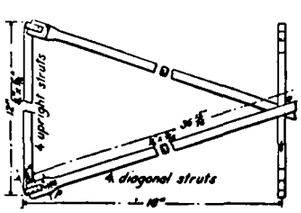


Fig. 10.

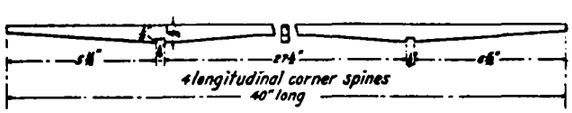
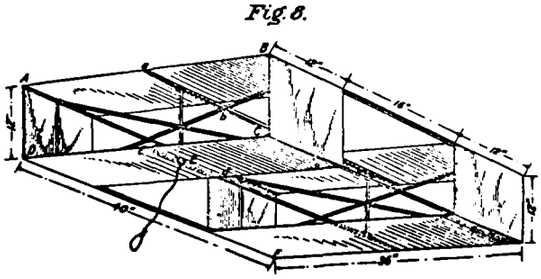


Fig. 8.



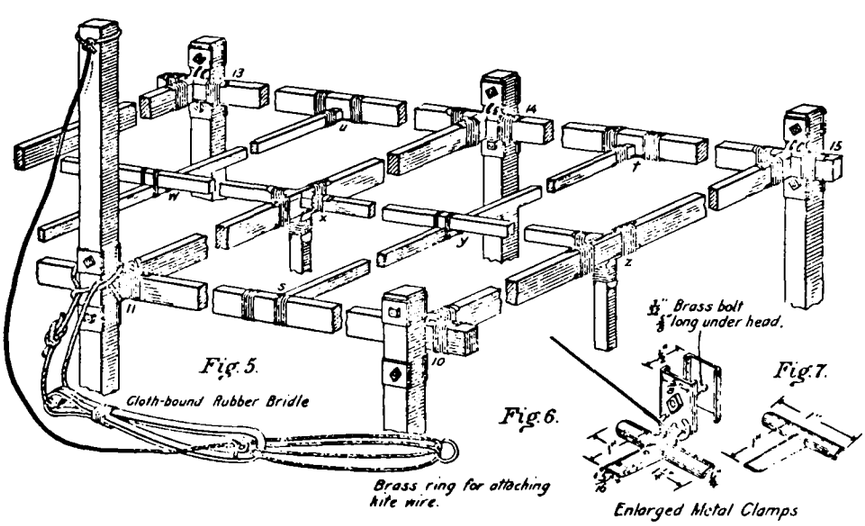
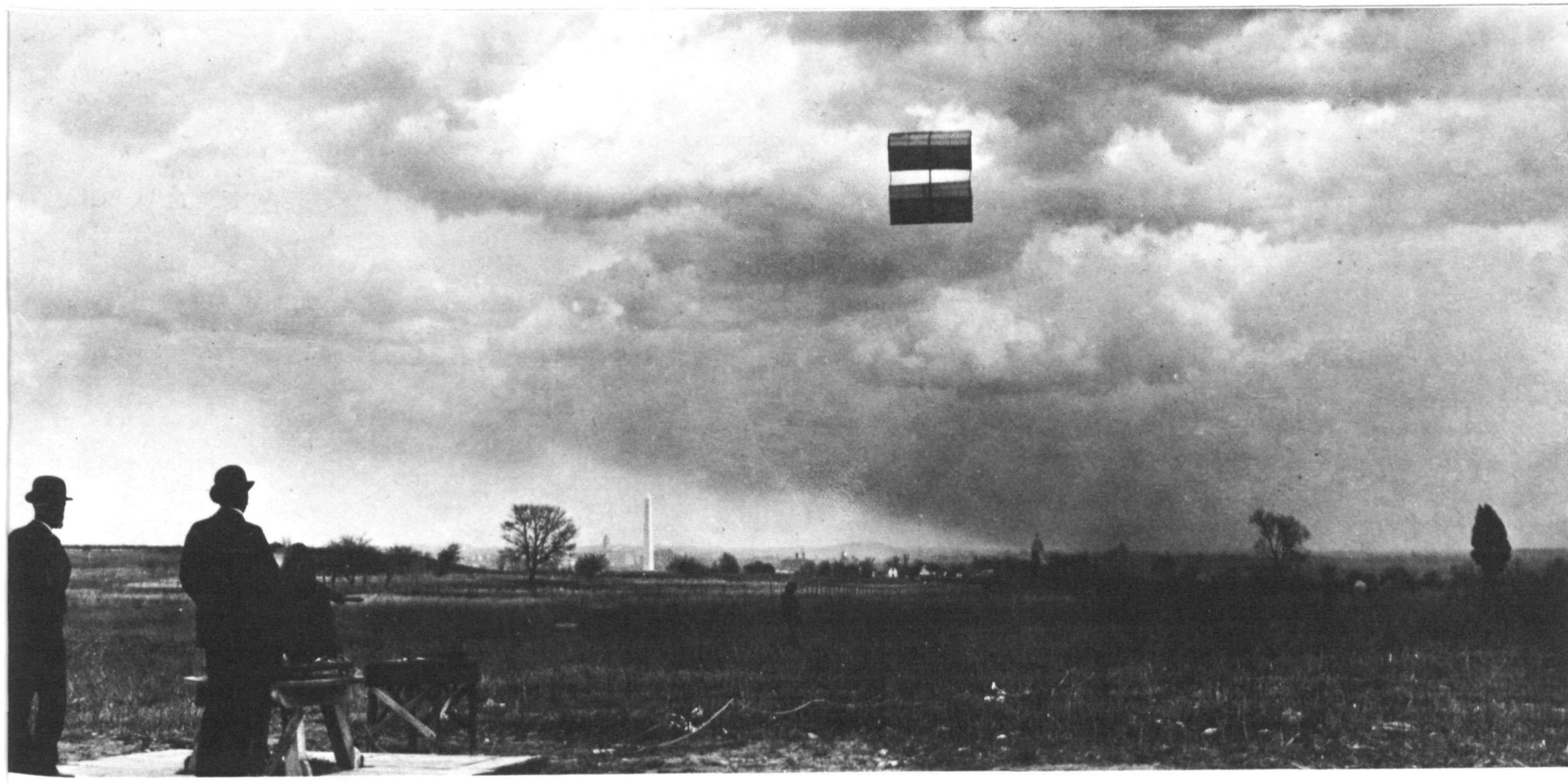
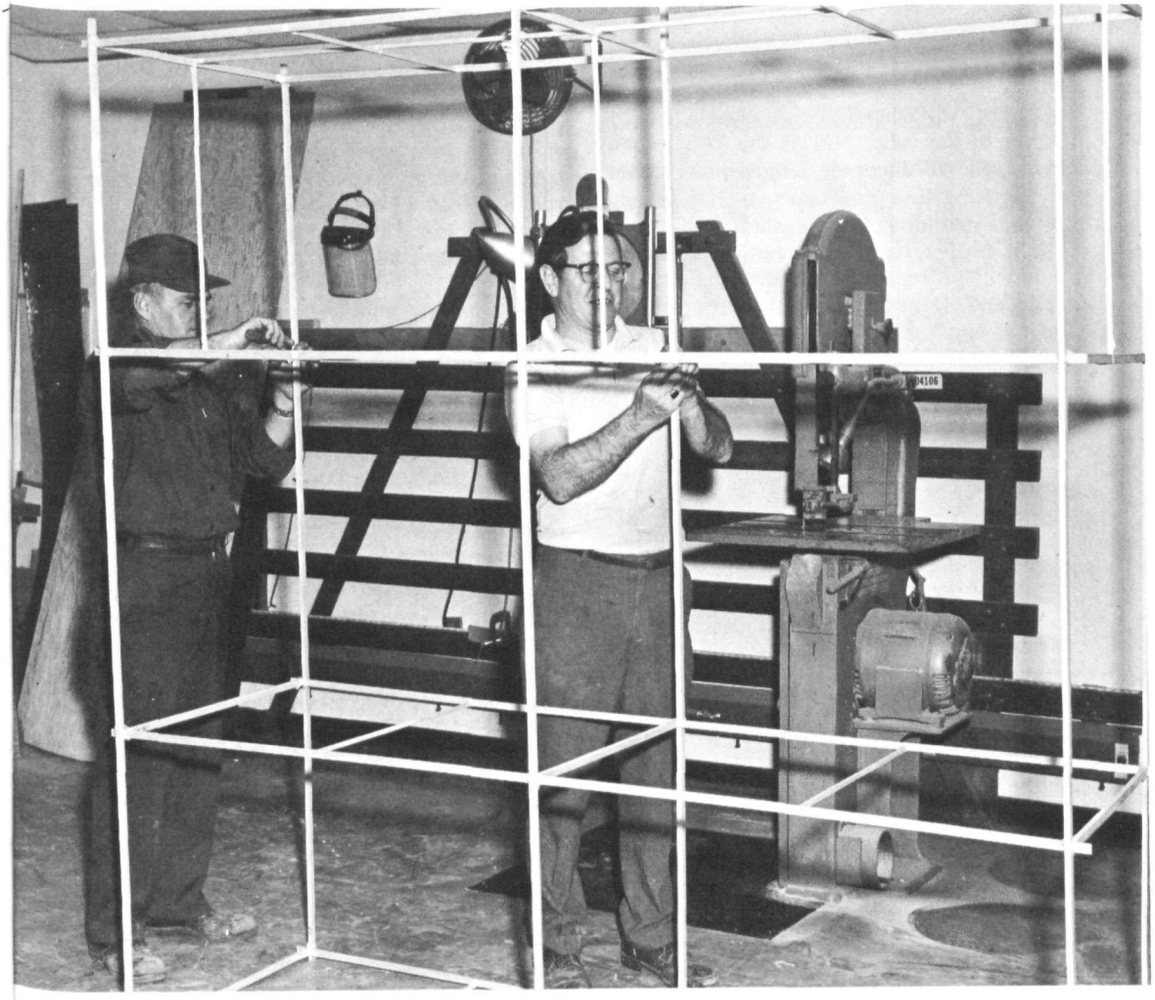


Fig. 5.

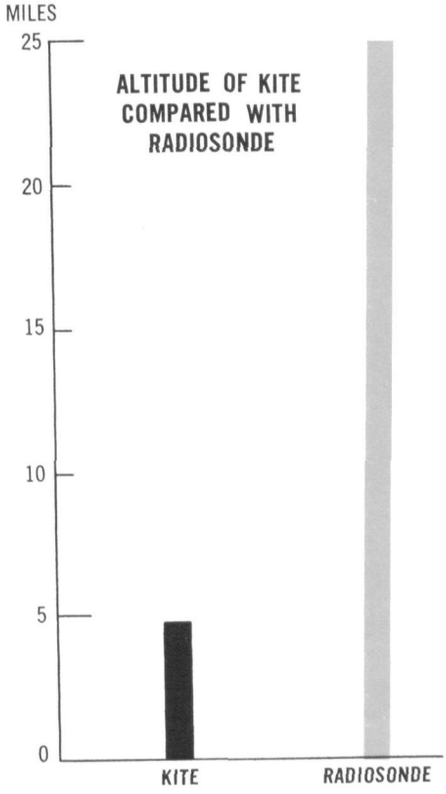
Fig. 6.

Fig. 7.





(Above) The Nation's Capital provided a scenic background for this long-ago kite launching on the Virginia shore of the Potomac River. The reel is in the left foreground. (Left) Eugene Elliott and Herbert Hallman of the ESSA Visual Services Branch Exhibits Section, construct a kite following the instructions in this article.



continued

count of the elasticity of the rubber this arrangement protects the kite and wire from sudden gusts of wind by allowing the kite to take a smaller angle, thus diminishing the pull.

The head kite, which carries the meteorograph, has its brass ring fastened directly to the line. Secondary kites are attached to the line by means of cords about 125 feet long. These cords are attached to the line in the following manner: A piece of No. 12 soft iron wire about 6 feet long is bent so that a small open ring about an inch in diameter will be formed near one end; about an inch of the wire at each end is then bent at right angles, thus: . Wrap the soft iron wire tightly about the line and then tie the cord holding the secondary kite into the ring.

Figure 8 shows such a simple form of kite complete, and figures 9, 10, and 11 show the details of the several parts. The sticks are made of straight-grained spruce, but white pine will answer as well. Either Lonsdale cambric or calico may be used for the covering. Small tacks and coarse waxed linen thread are required. The sticks should be cut to the shape and dimensions shown in figures 9, 10, and 11 in detail.

The kite is constructed upon a central truss, which is shown in figure 9. The longitudinal sticks, *a* and *c* figure 8, are ¼ inch x ⅝ inch x 40 inches. At 5⅜ inches from each end a slight notch, which should not exceed 1/16 inch in depth, as shown at *N* figure 9 is formed to receive the uprights. The uprights which are cut as shown in figure 9 must have their ends perfectly square and true. They must be seated squarely in the notches of the long spines and be firmly lashed in place with coarse waxed linen thread.

Figure 10 shows the form to which the corner longitudinal spines *A, B, C, D* (fig. 8) should be dressed; the long straight edges are to be slightly rounded as shown in section. Notice that the distances of the notches from the opposite ends are not the same.

The covering for the kite is made of two long strips of cloth. Both edges of the strips should be hemmed even if the edge has selvage, and when so hemmed the width should be just 12 inches. The total length of the strip, when stretched as it will be on the kite, should be 96½ inches, the half inch being allowed for the lap of the cloth in sewing the ends together. The opposite end of each cloth strip should be carefully and evenly overlapped for half an inch and strongly sewed together with a double seam, thus forming two endless bands.

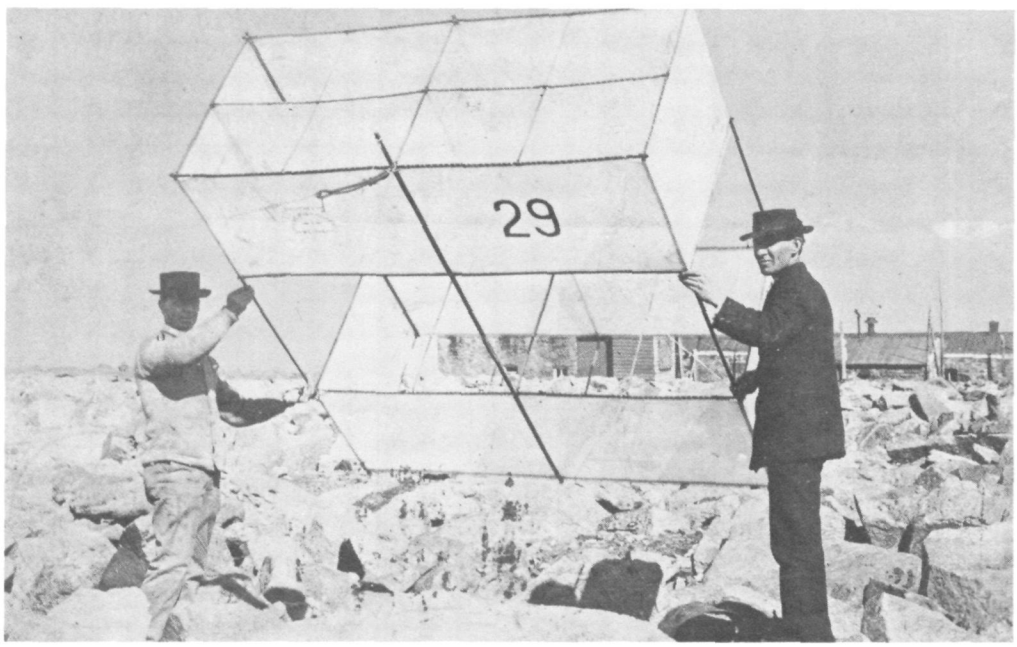
The next step is to mark the cloth bands at the places that are to be fastened to the frame. Stretch each cloth band out smooth and straight over two thin sticks run through inside the band. It is well to make the seam in the band come over or near the edge of one of the sticks. When the band is smooth and evenly stretched, draw a pencil line across the band exactly in the middle, where it turns around the edge of each stick.

The cloth bands are now ready to be tacked to the frames of the kite. Put one of the bands over the central truss and tack from *a* to *b*, figure 8, with a few small 2-ounce tacks along the top stick of the truss. The lower side must be tacked in a similar manner to the opposite truss, from *c* to *d*, figure 8, care being taken that the truss is exactly in the center of the cloth band. The other band is tacked in a similar manner to the other end of the kite frame. Finally, the four corner longitudinal spines are passed within the bands, taking special care that the notches in the spines will stand in their proper relation. Referring to figure 10, it will be recalled that the small notch at one end of each spine is nearer its end than the opposite notch is to its end. This is done in order that the diagonal struts shall pass on each side of the uprights of the central truss as shown at *o*, figure 11. In other words, see that the short ends of the spines are in the *A* and *C* corners and the long ends in the *B* and *D* corners.

It is difficult to determine the exact length of the diagonal struts because the amount that the cloth bands will stretch is uncertain. The length indicated in figure 11 is about right if all the other dimensions are adhered to. In order to be sure that the diagonal struts fit in the proper manner it will be found better to make up a pair of struts about half an inch too long at first, then by trying them in the kite and cutting out the notches deeper and deeper a perfectly satisfactory fit can be secured, and the cloth braced out smooth and taut. Care must be taken to keep all diagonal struts of the same length. This fitting had better be done before reducing the cross section of the spines between the forked ends. The forked ends when finished should have about the dimensions shown in figure 11 at *P*. In order to prevent the forks from splitting off it is quite necessary to lash the ends just back of the notch with a serving of good waxed thread. Instead of cutting these struts out of a solid piece, as assumed above, some may prefer to build up the forked enlargements at the ends by gluing on small cleats, finally lashing on the waxed thread over all as before. In order to prevent the sides of the kite from pressing in, four upright struts are provided, the ends of which are tacked to the corner spines close to the diagonal struts, as shown in figure 11. After the cloth has been stretched smoothly and evenly over the frame, it should be lashed securely to the corner spines and the central truss with stout twine, sewing through the cloth and around the sticks.

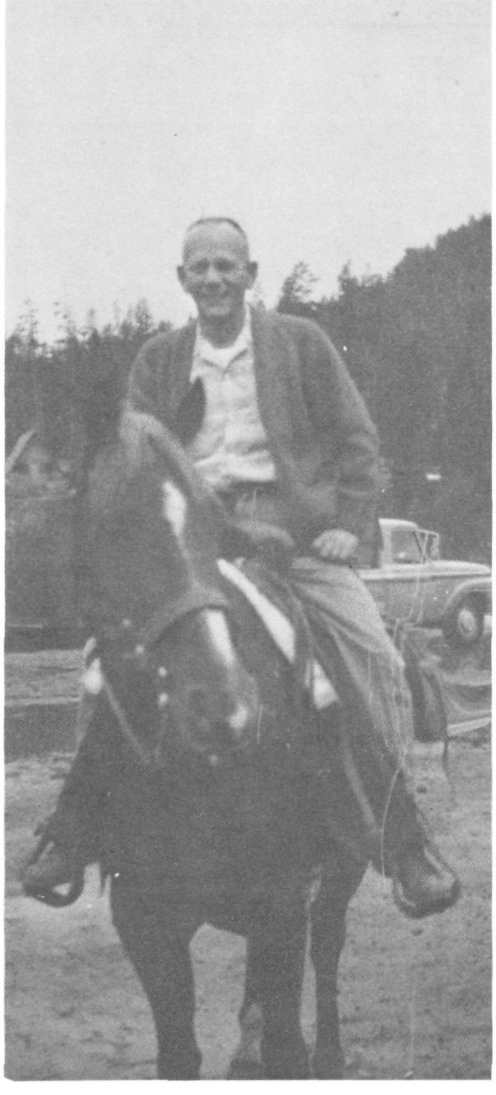
To bridle the kite cut off about 6 feet of stout cord and tie one end to the central truss as shown at *E*, figure 8, the cord passing through small holes pierced in the cloth covering. The knot employed at this point is shown at *X*, figure 9. The flying line should be tied to the free end of this cord by means of bowline knots as shown at *Y*. This knot is strong, never slips, and can be easily untied, no matter how much the line may have been strained.

To be perfectly safe the flying line of this kite should have a tensile strength of from 50 to 60 pounds, and be equally strong throughout. If the wind is favorable for flying, the best way to start the flight is to run out 150 feet or more of the twine while the kite is held by an assistant. When all is ready the assistant should toss the kite upward a little in the direction in which it is to go. It will then take care of itself. It is important that the kite be cast off directly in line with the wind, otherwise it may dart badly. When fairly up the kite may sweep a little from side to side, but if it ever darts or turns over there is something radically wrong, probably an uneven distribution of the cloth surface, or some distortion of the framework. □



Ready for takeoff from Pike's Peak, 1908.

1



2

3

1. Horsing around in cowboy country, Bruce Leslie rides toward Pahaska 5N, Wyoming, where he will install a snow storage gage. 2. The iron horse is a mainstay for network specialists, even when they run out of road and have to take a short, wet cut across a spillway. 3. West of Minot, North Dakota, where spring flooding was severe in 1969, Keith Blessum rows a mile to read a gage mounted on a bridge. On these lonely voyages he is sometimes accompanied by river rats. 4. Winter snows in the high Rockies replace the specialist's horse, truck, rowboat, or whatever with a Sno-Cat which can push into snowbound areas like Loveland Pass, Colorado.

4

DIPLOMATS *with muddy shoes*

BY CHARLES THOMAS
Weather Bureau

LLOYD SEIDEL, the Weather Bureau's Substation Network Specialist working out of the State Climatologist's office in Columbus, Ohio, has the real lowdown on the romance of desert islands and, according to him, they're not all the Technicolor paradises depicted in Hollywood epics.

Seidel visited a desert island out in Lake Erie every six months for five years and this one would make Dorothy Lamour trade in her sarong for coveralls and hipboots.

Seidel is one of a small cadre of Weather Bureau men whose job it is to see that the 13,000 cooperative weather observing stations across the nation are kept in first-rate condition and that the flow of weather, climatic, and hydrologic data from these stations is accurate and uninterrupted. On the road year-round, these men arrange to have new stations set up at desirable locations, check the instrumentation at established stations, and, perhaps most important, serve as the only personal contact between the Weather Bureau and its thousands of volunteer weathermen.

The island Seidel found so un-idyllic was one stop on his continuous rounds of the 278 substations in Ohio.

On a typical visit to service a recording rain gage installed on West Sister Island, he took a 40-foot Coast Guard boat to within 100 yards of shore, transferred to a smaller boat, and, barring a sudden swamping in the shoaling water, stepped ashore for a long trek inland through dense undergrowth. Brushing away swarms of hungry black flies and making a bit more noise than absolutely necessary to warn away snakes of all sizes and colors which infested the island, Seidel picked his way through rusting canisters and artillery shells, mute evidence that the island was once in the middle of an Army firing range. Finally he arrived at the gage mounted on

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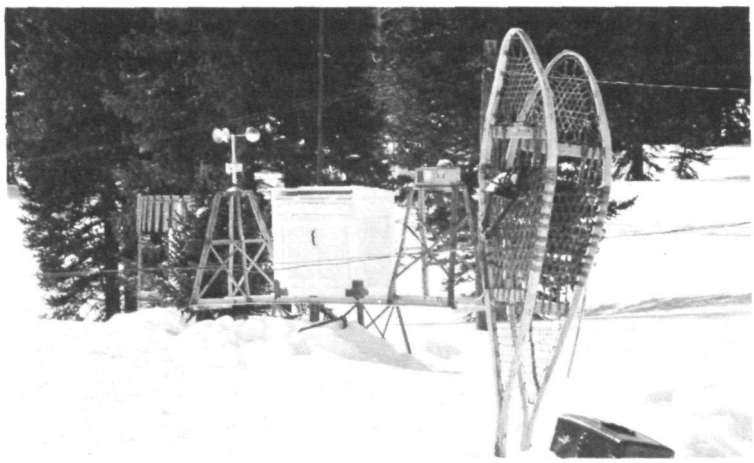
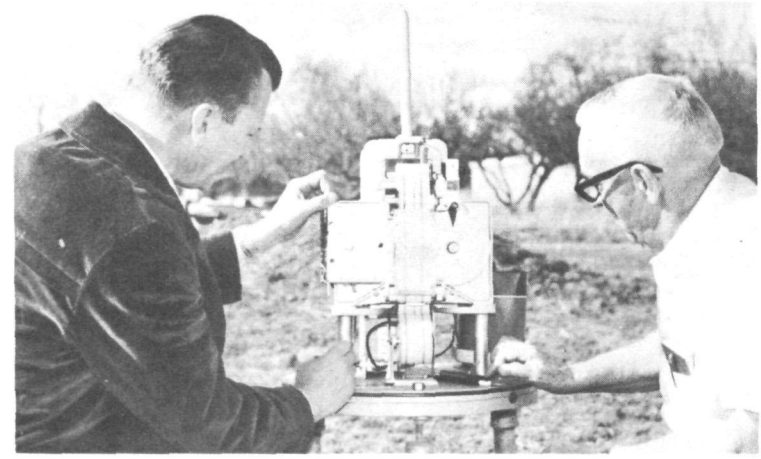
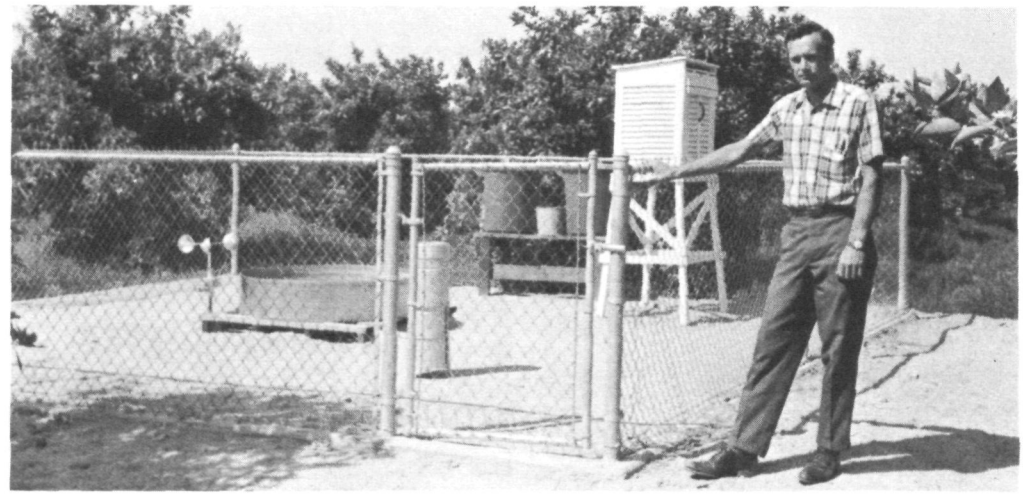




(Above) Snowshoes are an essential part of the substation network specialist's equipment when he covers stations like this one at Brighton, Utah, 10,000 feet high. (Above, right) Training observers in the use of their equipment is part of the network specialist's job, especially in the age of the electronic computer. Here, observer James Williams of Granville, Utah (right) receives instruction on a partially dismantled punch-tape recording precipitation gage, which will provide computer-ready data. (Right) Observer Floyd Sharp and his fenced evaporation station provide important data for the Tacna, Arizona, area. Evaporation station equipment includes (from left) an anemometer and vane to record wind speed and direction, an evaporation pan to measure rates of evaporation, a precipitation gage, and a shelter containing thermometers.



a tower in a low spot that was usually knee-deep in water. Keeping an eye out for snakes and underwater "obstructions to navigation" which appear on no Coast and Geodetic charts, he waded out to the gage, removed the punched tape record of precipitation for the past six months, installed a new tape, carefully inspected the gage for wear and tear (with the addition of some grass and twigs, the circular opening of a rain gage makes a comfortable nest for small birds), and finally headed back for the beach.

Dunked, bitten by assorted insects, scratched by brush, bruised by logs and rocks, disturbed by snakes, Seidel reports he was not sorry to see this substation closed down last year.

Seidel's experiences on West Sister Island is merely an example of the lengths to which the Weather Bureau goes to keep its vast network of cooperative weather stations running smoothly.

Substation Network Specialists in all of the Weather Bureau regions are kept on the go. For example, in the Central Region each one travels about 25,000 miles a year. The present 15 specialists have criss-crossed the 14-state region to the tune of 3¾ million miles to accomplish their work.

Each of the Weather Bureau's Substation Network Specialists must possess a unique array of knowledge, skills, and capabilities that enable him to function as a diplomat, calibrate a sensitive instrument, or dig a post hole with equal alacrity.

Perhaps the most exacting job these specialists have is the establishment of a new station.

While there's no lack of volunteers who are willing to act as cooperative observers, finding the right man at the right spot at the right time is a taxing chore to say the least. The Weather Bureau wants its substations spaced in accordance with a predetermined plan in order to obtain a good sampling of weather conditions across the entire country. Therefore, while twenty people in the suburbs of Atlanta may volunteer their services, only a few may be needed.

In addition to network spacing and the consideration of the routine requirements for the proper exposure of weather instruments such as topography, prevailing winds, proximity to trees, plants, buildings, etc., the specialist is faced with a number of other problems. These include anticipating environmental changes at the observer's home or farm. (Cutting down a stand of trees or creating an artificial lake nearby could subtly change local observational data.) Also, the specialist must solve the problem of locating gages that automatically record precipitation in remote sections of a river drainage basin in order to satisfy hydrologic needs and, at the same time, make the gage relatively accessible to a cooperative observer for periodic reading or for changing the autographic record. In fact, convenience to the volunteer observer who will man the station is of utmost importance in selecting the location.

The most convenient location for a substation (which, in most cases, consists of a shelter in which maximum and minimum thermometers are enclosed, and a rain gage) is in the observer's back yard. Unfortunately, the equipment lacks aesthetic appeal.

"Cherchez la femme," says Oliver Asp, Chief of Substation Management in the Weather Bureau's Central Region, who reveals a few "tricks of the trade" used by Substation Network Specialists who are looking for new station sites.

"Find the potential observer with the neatest yard since then you most likely will receive the most meticulous record. If the husband agrees and the wife does not agree, you might as well start looking for another

(Above) Servicing a steel standpipe requires specialists with the climbing talents of linemen. (Right) Network specialist Bill Ryan instructs two new Anchorage, Kentucky, observers, Mr. and Mrs. George H. Potts.

observer. On the other hand, if the wife wants to be an observer and the husband is only lukewarm to the idea, it's usually all right to go ahead and appoint her.

"We have had a number of instances where, by not having the lady of the house agree, we have had to move the station after a few months. In fact, in several cases where the wife was not at home when the husband agreed to be the observer, the appointment had to be 'annulled' immediately after the wife returned."

As the specialist searches further afield for observers in sparsely populated areas, his problems multiply.

Many years ago Substation Network Specialists (then called "Field Aides") drove black cars through the hills of Arkansas and Oklahoma and for a time were surprised when people along the roads doffed their hats as they passed by. The vehicles were mistaken for funeral hearses. In those days the specialists would have been glad to exchange their "official-looking" cars for something sportier—in some areas they were regarded as "Government Revenuers."

Finding observers in sparsely populated areas is often difficult, if not impossible. Sometimes the Substation Network Specialists can get leads from established observers or other contacts such as city and county officials and postmasters; but likely as not the specialist is on his own. This means a door-to-door survey. One key to the success of a recruitment effort is the specialist's ability to sell the unpaid observer on the importance of the program. To do this effectively he must speak fluently of the variety of uses of the data after it is acquired. He must be personable as well as knowledgeable on local and colloquial topics in order to gain and keep the confidence of prospective and recruited observers.

Visits to established observers give the specialist a chance to discuss problems, look over the equipment, and, in general, give the observer the impression that the Weather Bureau is interested and grateful on a personal level.

These station visits are not one-way affairs. Seidel's Ohio observers, for instance, provide a real education. "After discussing the weather program," Seidel says, "it's a good idea to listen to the observer. Most of them like to talk about their farms, oil wells, factories, children, cattle, banks, ailments, and so on. One of our observers has a coal mine in his back yard, another got gored by a bull, another was making locomotives to ship to Africa, and another demonstrated embalming to me.

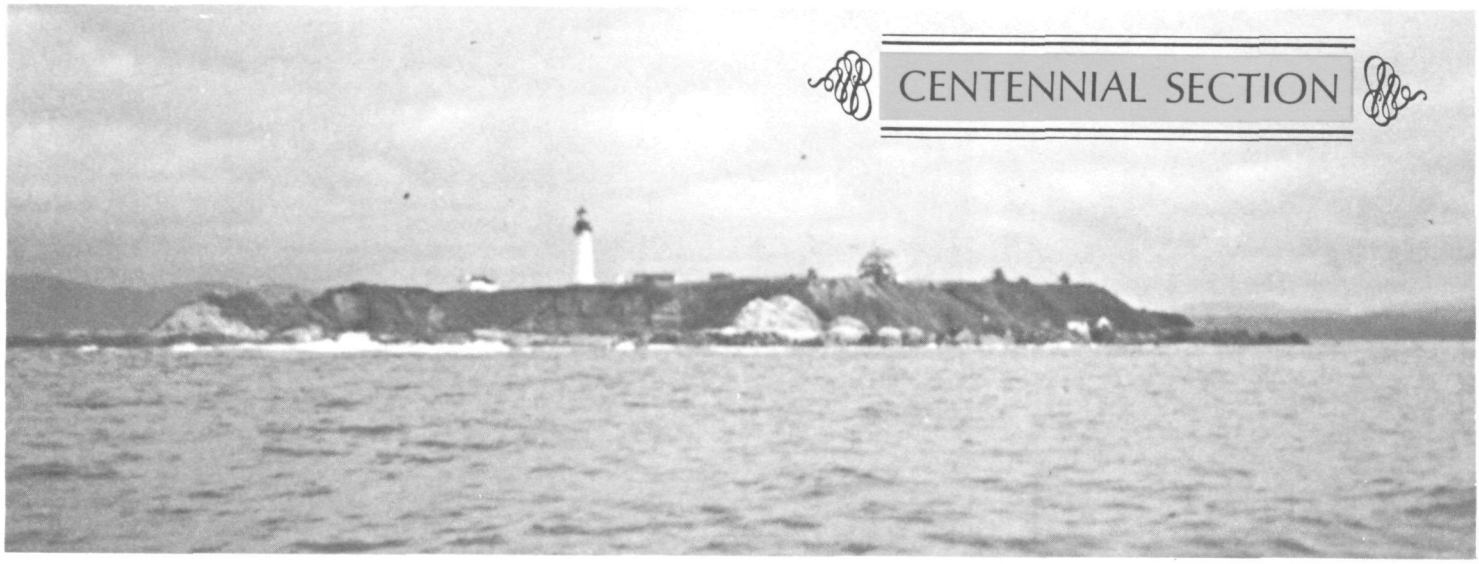
"On one visit to a firehouse the alarm rang in the middle of our weather discussion, so I went along to fight a grass fire. I have talked to observers while they were milking cows, or on the job, one in a railroad switch tower, another in an oil field, and one in a hospital."

A real challenge to the specialist is the unmanned station. Like the one on West Sister Island in Lake Erie, some stations are located in remote and uninhabited areas where observers cannot be recruited and the specialist must do the annual or semi-annual servicing and readouts himself.

Unique in the Western Region for sampling precipitation in sparsely inhabited mountainous and desert areas is the unattended storage gage, serviced once yearly by the specialist. The 16-foot standpipe is representative of the many types used. Water collected in the pipe is tapped off through a spigot at the bottom and weighed to calculate the year's precipitation. Using a lineman's safety belt to reach the orifice of the gage, the specialist hauls up buckets of a recharge consisting of antifreeze and an evaporation retardant oil. Sometimes the specialist is frustrated to find that, after miles of struggling through brush and snow, the storage gage's catch has been lost through holes blasted into the instrument by "sportsmen."

At many of these remote locations, getting there, while maybe not half the fun, is an interesting challenge. Substation Network Specialists walk, ride horseback, fly in airplanes and helicopters, ride in snowcats, snow-mobiles, and boats, and if they're not careful crossing mountain streams, part of their journey may be made by swimming.

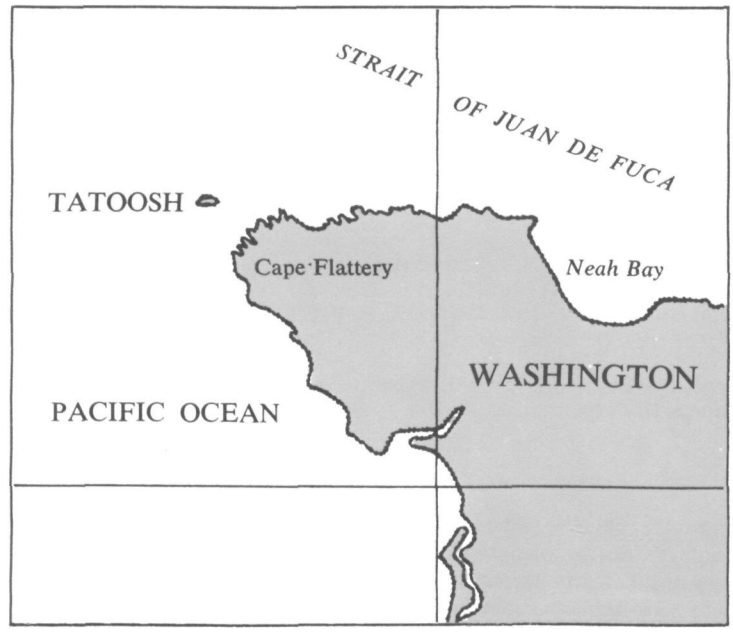
While the services of the cooperative observer whose records form the backbone of the climatological history of the United States and whose watchfulness during times of floods and severe weather are an invaluable contribution to the welfare of the nation, much credit must go to the Substation Network Specialist—the Weather Bureau's Diplomat With Muddy Shoes. □



"Like a sentence to Devil's Island . . ."

Requiem for Tatoosh

BY VINCENT F. CALLAWAY
Weather Bureau



Tatoosh Island, just a thousand yards off Cape Flattery at the northwest tip of the State of Washington, is a forbidding 17-acre expanse of rock, ringed by steep cliffs, and assaulted by some of the worst storms and seas of the eastern Pacific Ocean. The island guards the entry to the Strait of Juan de Fuca. Until the installation was moved to Quillayute on the mainland in August 1966, Tatoosh was the site of a Weather Bureau station assigned the task of providing surface and upper-air observations.

Access to the island, limited by weather and sea conditions, is mainly by Coast Guard boat, though there are a few private operators who will make the trip for a fee, weather permitting. The most dangerous part of the trip is the landing, for Tatoosh offers no easy harbor. On the contrary, men and materials must be hoisted up an 80-foot cliff while the sailors below struggle to keep the boat off the rocks. To many, assignment to Tatoosh was like a sentence to Devil's Island; but tours of duty were generally kept short, so an unusually large number of Weather Bureau employees saw service there.

The island is actually composed of two segments, a north and a south island, and the wooded mainland is easily visible, five-eighths of a mile away, across an expanse of very treacherous water. Soil is thin on the island, but it grows a good cover of shrubs and bushes. In the summer, when the constant storms die down and the sun comes out, it is a beautiful sight, with a profusion of rhododendron and other flowers.

Alexander Sampson, lighthouse keeper, was recording precipitation measurements on Tatoosh in 1869, a year before Congress authorized the Signal Corps ". . . to seek out and report to the public, the development and progress of storms. . . ."

On October 1, 1883, the first of three daily observations was taken by the Signal Corps at Tatoosh Island and transmitted by telegraph to Salt Lake City, Utah. Credit for that first official observation goes to Private C. Conner. Other names appearing on the roster between 1883 and 1898 were C. Stewart, R. L. Sebastian, C. E. Buster, W. Bunfield, E. C. Hobbs, F. R. Behan, and Mrs. E. A. Behan.

The first office building was on the northeast corner of the island where a second-order station was established. It became a third-order station in 1889, with lighthouse keeper Sampson again taking the observations but with the instruments remaining in their original location. In 1891, under the supervision of the Department of Agriculture, the station was reopened as a second-order station, and it continued until July 12, 1898, when the station was closed, the buildings sold, and the entire observation program moved to nearby Neah Bay on the mainland

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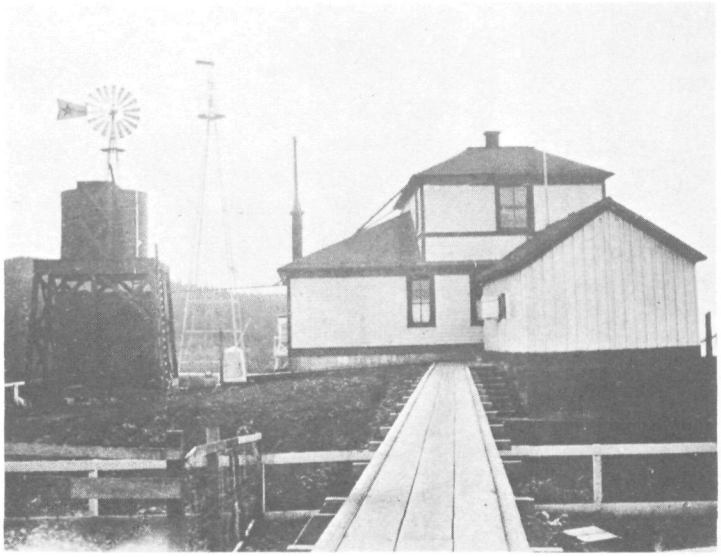

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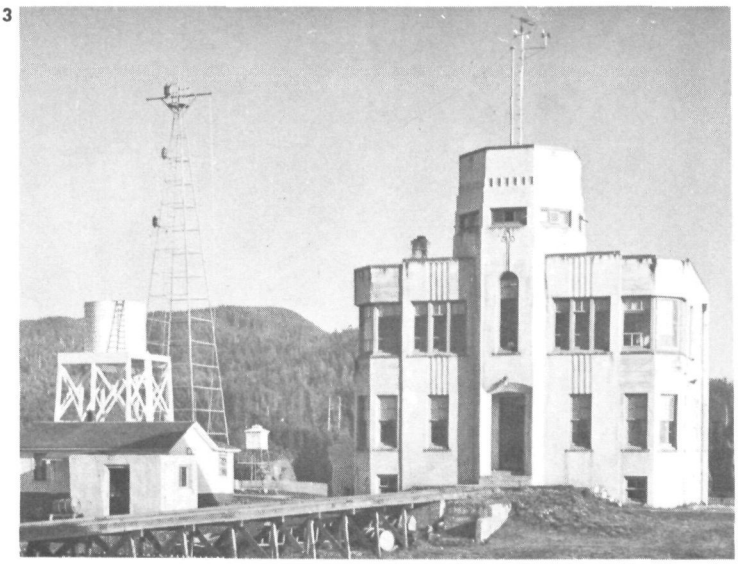

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1. Tatoosh Island, "a forbidding 17-acre expanse of rock, ringed by steep cliffs and assaulted by some of the worst storms and seas of the Eastern Pacific Ocean" lies against the low profile of Cape Flattery. 2. In 1916, the Weather Bureau installation on Tatoosh looked like this; later that year the windmill disappeared in a wind storm. 3. The new building, shown in a 1932 photograph, lost its water tower and tank in a 1965 wind storm. 4. This view from Tatoosh lighthouse shows the Weather Bureau complex and its vintage truck; radar observations taken with the unit on the main building were discontinued in 1964.

as a second-order station. It remained at Neah Bay until December 5, 1902. On that date the observational program was moved back to Tatoosh Island. New buildings were built, new instruments provided, and the Tatoosh Weather Bureau Office began the last 64 years of its life. In 1940, the Department of Commerce took over supervision of the station as part of the national weather service.

When the station was moved from Neah Bay back to Tatoosh, F. R. Behan, who had served earlier, was put in charge of the station with L. G. Sutton as his assistant. Behan's daughter, Hazel, was the first child born to the first white family to live on the island. She is now Mrs. Hazel Pearson and lives today in Port Angeles, Washington.

If there were a list of all the personnel who participated in the Tatoosh observational program from its inception, it would require a good-sized directory. The earlier weathermen stationed there were made of pioneer stock.

Few western sagas could equal the Behans' efforts to transport one milk cow from Neah Bay to the island in a whaling canoe, shoving and hoisting her from water level to the top of the 80-foot rocky cliff at the landing site. Transporting the piano from Neah Bay in two canoes lashed together and lifting it safely to the top of the island called for courage, too.

Mail and all supplies were generally brought out in canoes. Fuel (sacked coal) was as precious as water to a desert rat. Under these conditions, it is not surprising that there is a graveyard on Tatoosh. It *is* surprising that there are only two headstones in it: one was the child of a Weather Bureau family and the other a Navy family's child.

Houses and other buildings were built without solid foundations and had to be lashed down to keep the wind from tearing them apart and blowing them out to sea.

Several new buildings were constructed as the station developed, but it was not until 1932 that a new modern building was erected which had room for the Weather Bureau office as well as two apartments for living quarters. At that time, the building cost $31,635. By 1943, it became necessary to build better quarters for the increased number of bachelor personnel. The building contained four complete apartments, housing two men to an apartment. This frame building was erected at a cost of $47,132.

When the upper-air program started, ceiling balloons, and later rawinsonde balloons, were inflated in several old outbuildings. Not until 1947 was a regular inflation building constructed.

The storms that constantly tore at Tatoosh Island seemed to have two prime targets: one was the roofs of buildings, and the other the water tanks. One of the earliest sources of power was a windmill mounted on top of a 10,000-gallon water storage tank. The windmill provided the power that pulled the water up into the tank, and from there it flowed through service pipes by gravity into the buildings. In 1916, one of the most severe

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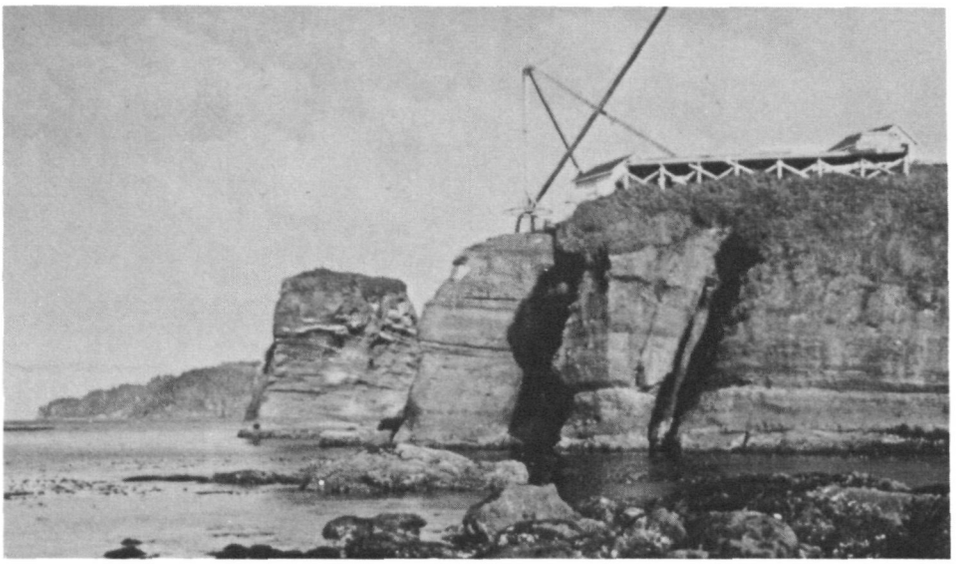


Hoist and loading dock form bridge between life on Tatoosh and incoming supply boats.

Moving supplies, like everything on the island, is done the hard way.

storms in the history of the island destroyed this windmill and actually scattered pieces of it over the ocean.

In 1965, a 10,000-gallon tank atop a 28-foot tower was shattered into kindling wood by winds that gusted over 110 miles per hour. The trestle crashed to the ground within six feet of the walls of the apartment building. The 1¼-inch pipe leading from the ground to the tank held the tank a matter of seconds, and then it smashed to the ground in the middle of the fallen supporting timbers. Had the pipe broken at the same instant as the tower, the tank would have crashed into the bedroom where two men were sleeping.

Bringing supplies to the island and getting them up to the top of the cliffs, regardless of the type of boat that was used for transportation, depended almost entirely on the condition of the sea at the foot of the cliff just under the hoist. The normal swell of the waves is a west-to-east movement. A westerly wind tends to heighten the waves, while an easterly wind tends to smooth out the waves. This tendency was one of the first things observers learned. The condition of the sea held the answer to the problem of whether personnel would get on or off the island or whether pay checks, mail, and groceries would arrive on time and in a usable condition. Sad was the day when the Coast Guard boat departed Neah Bay with personnel, mail, supplies, and groceries and then, because of sea conditions at the foot of the cliff, had to return to Neah Bay and wait for one or more days before the sea promised a successful trip.

Except for the first few years, most of the transportation was by Coast Guard boat, and over the years many a bosun's mate received excellent boat-handling lessons from his routine trips to Tatoosh. Some mastered the art and could make a successful trip in almost any weather and sea condition. Others never learned the secret and, even on calm seas, transferring from boat to the hoist-basket was a very dangerous procedure. But as boat, basket, and hoist were the only available modes of transportation, most personnel accepted it. Others waited long enough to get back to Neah Bay to end their weather careers.

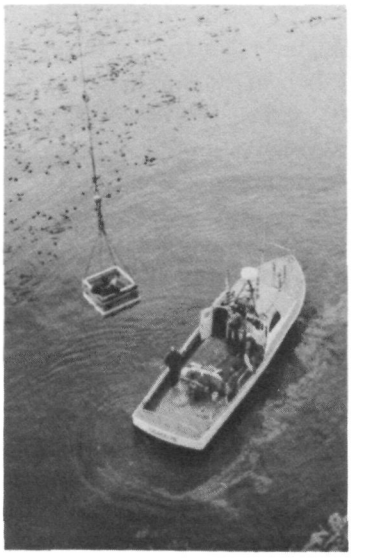
In addition to weather observations, one of the duties assigned to Weather Bureau employees was watching and reporting ship movements by the aid of a high-powered telescope. When the new building was constructed, a special room was added on the roof to house the telescope. This room was later preempted by a WSR-3 radar console. Weather radar observations were taken for two years and then the radar was decommissioned.

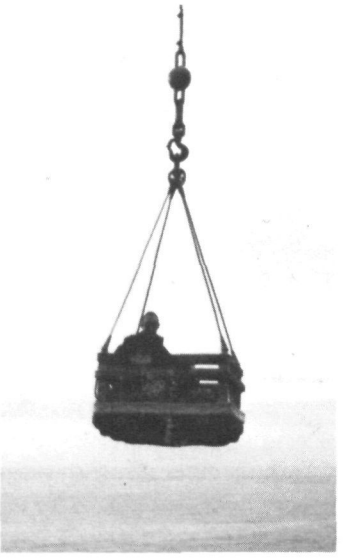
Upper-air soundings became part of the station program in 1940. Helium for the soundings was transferred to the island in pallets of ten cylinders, which were hoisted from the boat to the loading dock at the top of the cliff. To move the helium to the inflation building a quarter of a mile away, a copper tube was laid from the dock to the inflation building. This line was attached to multiple regulators, eliminating the necessity of moving the cylinders from dock to building. Later a truck was added to the station's equipment, and enterprising observers rigged up a boom and hoist on the bed of the truck. This boom, operated by the truck's winch, would then be fastened to irons placed under the pallets of helium cylinders and the helium transported to the inflation building, swinging along like a cow's tail and with every bump and curve in the road threatening to tip over the truck.

Early observers received a $200 bonus for duty on the island, and this brought their yearly salary to nearly $800. From 1883 to 1894, the total cost of operating the station, salaries excluded, was $2,492.37.

Annual precipitation at Tatoosh Island ranged from 52.58 inches in 1911 to 121.85 inches in 1879. Excessive precipitation amounts reached a record of 10.02 inches in 53 hours and 49 minutes during March 1916. Tatoosh averaged 192 days a year with .01 inch or more of precipitation. The maximum monthly amount was 25.84 inches in December 1886, and the least monthly amount was .01 inch recorded in July 1889. The average annual snowfall was 8.4 inches, with 32.5 inches measured as the greatest monthly amount in January 1950. The greatest 24-hour amount of snow, measured in February 1893, was 13.8 inches.

The average monthly temperature on the island was 49.3°F. The average yearly maximum was 53.1° and the minimum 45.5°. The lowest temperature officially recorded on the island was +7° in January 1893, and the highest was 88°, recorded in





(Left) Old truck hauls helium cylinders from loading area. (Above) Passengers and cargo must be hoisted past the island's 80-foot rim.

Suspended over the cold waters of the northern Pacific, a newcomer begins his meteorological exile on bleak and barren Tatoosh Isle.

July 1924. Over a 63-year period the maximum temperature was 32° or below on only two days.

When precipitation or high winds were not present, they were usually replaced by fog, especially during July, August, and September. Suntans were hard to get and sunburns were rare since clear days occurred on the average of only five days a month. For those few days, the Coast Guard foghorn was silent.

Wintertime amusements consisted mostly of card games and table tennis, and in later years a pool table was donated for use by Tatoosh personnel. Outdoor amusements during the rainy season were almost nil. Looking for glass floats that had drifted across the ocean from Japanese fishing grounds was one occupation that was not a respecter of weather. There seemed to be an unwritten law that you couldn't transfer out until you had found a least one glass float. The writer came very close to not qualifying. Only while cleaning out the 30,000-gallon cistern did he discover a small float. It was, however, enough to qualify him for transfer. Crawling under the island to explore the holes and tunnels hollowed out by the restless water was another diversion for the island inhabitants, and several men traversed the island from one side to the other in that manner.

Spring came to Tatoosh, not by official calendar indication, but with the arrival of the first migrating flock of small birds. They lingered a day or two, ate ravenously on weed seeds, and then departed to make room for the next flock. Game birds also came near the island, but only a very few ever stopped long.

Rainfall at Tatoosh was not just something to measure and record. It was the only water the island possessed and was used for all purposes from drinking to mixing cement. Every building was fitted with gutters and downspouts, and every drop was directed into storage tanks. In 1934, a 30,000-gallon cistern was constructed, and in 1942 three new wooden tanks, each having a 20,000-gallon capacity, were included in the water-storage system. Storage of 90,000 gallons of water, however, was frequently not sufficient to serve the weather personnel when rainfall was below normal. Often a Coast Guard tender had to bring water to the island, lay hoses from ship to shore, connect onto water lines dropped over the cliff, and then pump water to the storage tanks on the island.

Because of the ever-present need for more water than could be stored in the available tanks, a drilled well was attempted. After drilling over 600 feet, it appeared that a fresh water supply had been found; but when an attempt was made to pump it out, it became contaminated with salt water and the well was abandoned. There were many other schemes to provide ample water. One was to dam a ravine that crossed the island, and another was to cement a 40-foot-wide natural cavity that extended from the top of the island down to the water. These, too, never proceeded beyond the talking stage. Several times both Weather Bureau and Coast Guard dependents had to leave the island because of lack of water. Until 1965, the water pressure was a matter of gravity flow. During that year a pressure water system was installed, and fire hoses could then deliver water to the top of the buildings.

Observations from Tatoosh had been transmitted at various times by telegraph, telephone, and radio. In 1962, a single-sideband two-way radio was installed, and this allowed transmission of all data to the Weather Bureau station at Astoria, Oregon.

Occasionally, earthquakes were recorded on Tatoosh. On June 23, 1946, twenty shocks were felt. The first two were five seconds apart, followed by 15 to 20 shocks five to seven seconds apart. Structural damage was slight, but walls and ceilings were cracked. The brush was seen to sway, tools fell off walls, and an observer outside stated that the lighthouse swayed.

With the great increase in costs of labor and transportation, an experiment was undertaken in 1965 to inflate the balloons with hydrogen generated from anhydrous ammonia. The reactor required technical repairs which personnel on the island could not make, but they did keep the generator working for several months. When it operated for any period of time, a 1200-gram balloon could be inflated for 88 cents.

Increased costs and technical requirements finally forced the closure of the Weather Bureau office on Tatoosh Island. The final observation was taken on July 31, 1966, and the entire organization moved to Quillayute Airport on the mainland 35 miles south-southeast of Tatoosh, 83 years after the Signal Corps took the first observation. □

ESSA probes the secrets of non-seismic creep on

CALIFORNIA'S FICKLE FAULT

BY RUSSELL B. STONER
ESSA Research Laboratories

A DRAGON makes an unwelcome neighbor. Even if he stays within his den and confines his activities to an occasional rumbling and a belch of smoke, a feeling of unease pervades the territory. The best known and largest dragon in California is the San Andreas Fault.

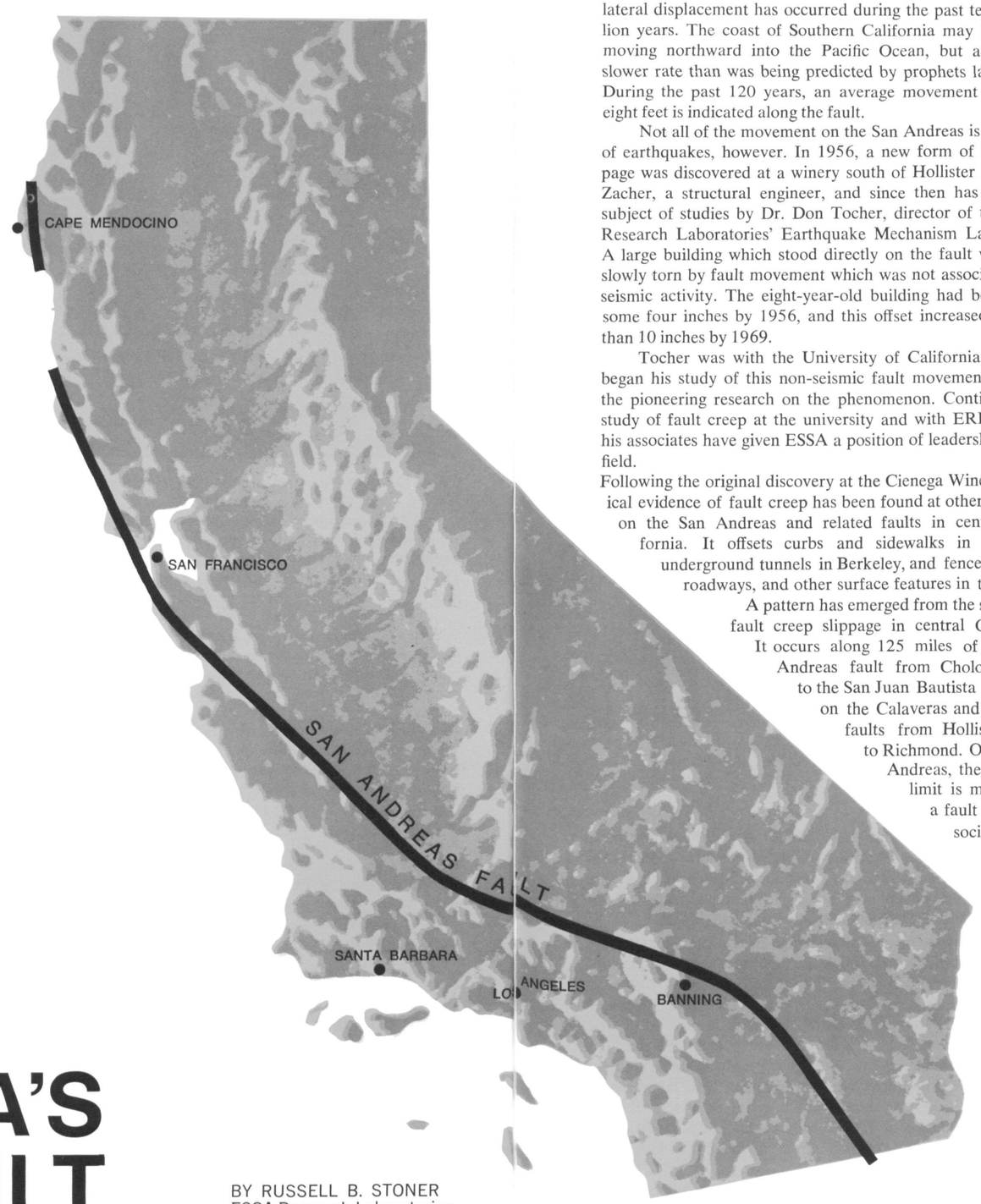
As a continuous feature, this great wound in the earth extends from Cape Mendocino in the north to Banning, 575 miles to the south. Related faults extend the system to the Gulf of California which itself was probably created by a spreading of the fault, separating Baja California from the Mexican mainland, over millions of years. Here the fault system joins the East Pacific Rise, the major feature of the eastern Pacific Basin, associated with the theory of seafloor spreading and the resulting deformation of the earth's crust.

During the past 150 years, several major earthquakes and many lesser tremors have occurred along the San Andreas and associated faults. The San Francisco quake of 1906 is the best known example of this seismic activity.

Surface ground displacement has been noted in connection with many of the California quakes. This is not uncommon, as reports of vertical and horizontal ground movement generally follow large seismic events. Horizontal movements of 50 feet and vertical movements of 30 feet are recorded for the Alaska Good Friday (1964) earthquake, for example.

A fault is a discontinuity in the crustal rock. Different classes of rock oppose each other across stretches of the fault line—in some areas, granite on the west side and sedimentary rock on the east. It is assumed that in the past rock types were probably continuous across the fault line, but that gradual slippage displaced them. This displacement is a possible measure of the movement which has occurred.

In central California, granite formations are exposed west of the fault for 250 miles from Bodega Bay to Cholome. There are no granite formations in the eastern side of the fault in this area, suggesting that more than 250 miles of right-lateral displacement has occurred during the past tens of million years. The coast of Southern California may indeed be moving northward into the Pacific Ocean, but at a much slower rate than was being predicted by prophets last spring. During the past 120 years, an average movement of nearly eight feet is indicated along the fault.



Not all of the movement on the San Andreas is the result of earthquakes, however. In 1956, a new form of fault slippage was discovered at a winery south of Hollister by Edwin Zacher, a structural engineer, and since then has been the subject of studies by Dr. Don Tocher, director of the ESSA Research Laboratories' Earthquake Mechanism Laboratory. A large building which stood directly on the fault was being slowly torn by fault movement which was not associated with seismic activity. The eight-year-old building had been offset some four inches by 1956, and this offset increased to more than 10 inches by 1969.

Tocher was with the University of California when he began his study of this non-seismic fault movement and did the pioneering research on the phenomenon. Continuing his study of fault creep at the university and with ERL, he and his associates have given ESSA a position of leadership in this field.

Following the original discovery at the Cienega Winery, physical evidence of fault creep has been found at other locations on the San Andreas and related faults in central California. It offsets curbs and sidewalks in Hollister, underground tunnels in Berkeley, and fences, bridges, roadways, and other surface features in the area.

A pattern has emerged from the studies of fault creep slippage in central California. It occurs along 125 miles of the San Andreas fault from Cholome north to the San Juan Bautista area and on the Calaveras and Hayward faults from Hollister north to Richmond. On the San Andreas, the northern limit is marked by a fault break associated with the 1906 earthquake, and the southern boundary is a fault break from a large quake in 1857.

The observed rates of creep slippage in the area of activity ranges from a high of more than one inch per year in the center of the slip zone, gradually decreasing to zero on either end. These rates are being closely monitored by the Earthquake Mechanism Laboratory and by groups from the University of California and the U. S. Geological Survey. Regional distortions are being measured by survey parties of the Coast and Geodetic Survey and the State of California.

Robert D. Nason, research geophysicist with the laboratory, conducts an active program of measuring creep at known sites and identifying additional areas where physical evidence of fault creep occurs. These continuing investigations will attempt to solve some questions that cause difficulty in theoretical explanations of fault activity.

Of immediate public interest is the question of the relationship of non-seismic fault creep slippage to future earthquakes. One school of thought suggests that strain along the fault is relieved when creep occurs, reducing the likelihood of major earth tremors in that sector of the fault. This in turn suggests that those areas of the fault where creep does not occur are building up strain rates that might result in a major quake.

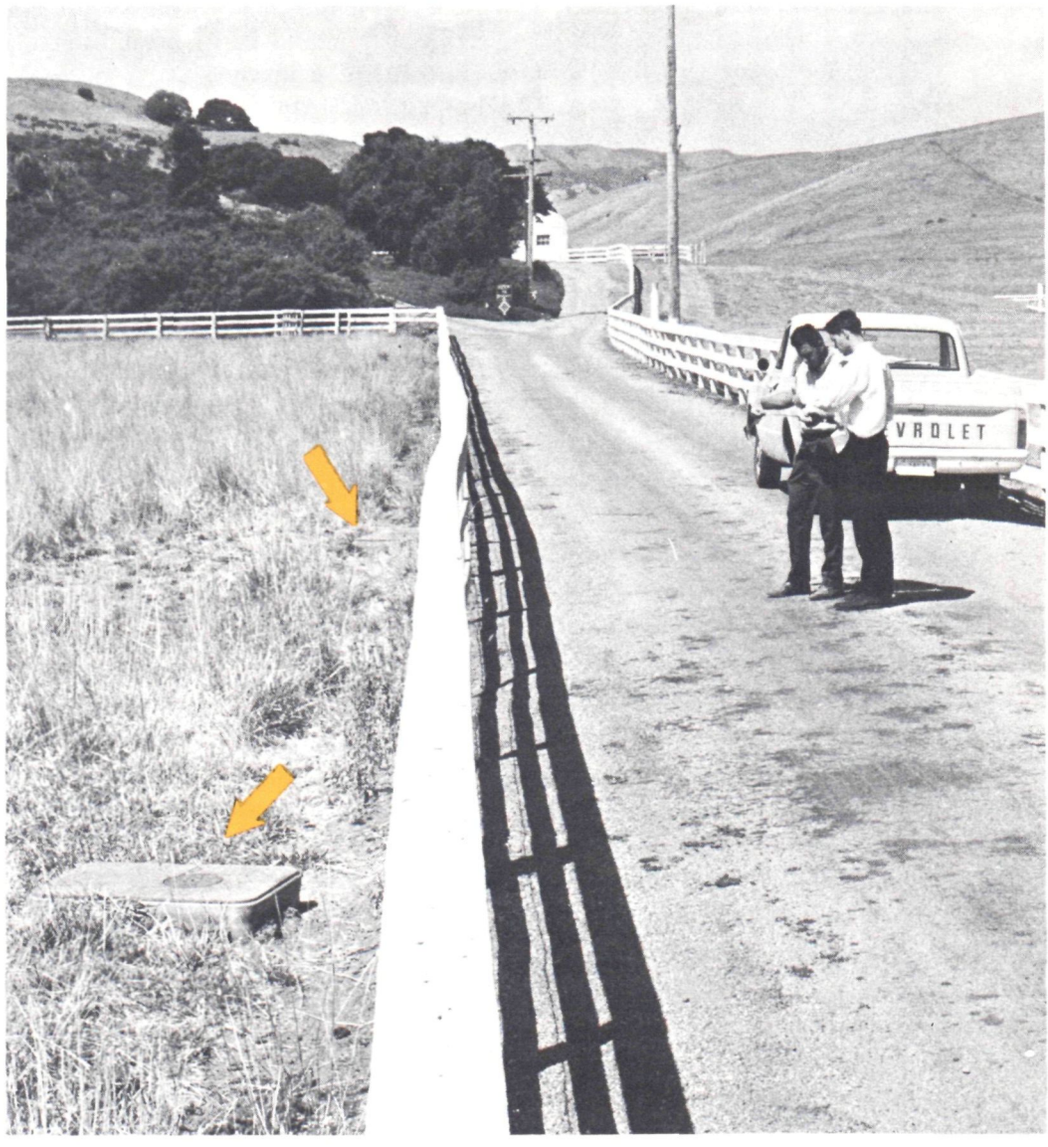
Nason suggests another possibility to this evaluation of fault creep. In the specific case of the San Andreas Fault, he believes "creep occurs where strain has built up. If there is no creep slippage the possibility of major seismic activity is less than if creep were occurring." This theory may be comforting to San Francisco residents since definite physical evidence of creep along the San Andreas Fault has not been observed in that area.

Does fault creep slippage of non-seismic nature occur on the other major fault systems in the world? Movement from earthquakes and aftershocks has been observed, but the non-seismic creep is a newly discovered phenomenon that is difficult to detect. Many of the areas of major seismic activity have few paved roads, established fence lines, or similar features on which the creep is most easily observed. Nor have many trained observers been alerted to look for it. While there is no reason to expect the non-seismic creep to be unique to the California fault system, good evidence of its existence on other fault systems has not been presented, with the possible exception of Japan.

Is there a direct correlation between the slippage and the generally accepted hypothesis of sea-floor spreading? The San Andreas connects with the East Pacific Rise to the south and the Mendocino fracture zone and the Gorda Rise in the north. Some theorists have suggested that the San Andreas is a transform fault or zone of slippage between the two rises. As sea-floor spreading occurs, the old crust is driven along to make way for new material arising from the mantle.

The movement along the rises, as shown by measurement of magnetic anomalies (changes in the intensity of the local magnetic field), is much greater than that observed on the fault. If the two movements are related, the discrepancy in the rates of movement may be absorbed by other features in the California-Nevada-Utah area east of the San Andreas.

continued



(Above) Robert D. Nason, the man in charge of creep field studies, checks the offset of a concrete-lined irrigation ditch at the Cienega Winery, where non-seismic creep was first identified. (Right) Pavement cracks and fence offsets at the Nyland Ranch near San Juan Bautista show where the San Andreas fault runs through the area. The concrete manholes (arrows) are the ends of invar rod measuring devices placed across the fault at different angles. Compression or elongation of the rods, being checked by Nason and Daryl Shelton, indicates the amount and direction of creep.

Since the current non-seismic creep on the fault occurs along approximately 20 percent of the total length, what strains and stresses are applied to the non-moving portions? If strain were uniform along the fault zone before creep occurred, the western side of the fault should be experiencing compression near the northern limit of creep and elongation stress at the southern limit. Another possibility is that the non-moving portions of the fault have effectively relieved this right lateral stress through seismic events, while the shorter creeping zone retains stress that is relieved less dramatically.

Such questions cannot be resolved on the basis of the available data and present knowledge. Some can only be answered with time as future seismic events are recorded and evaluated. Others may yield to the continuing scientific investigations. In pursuit of solutions to answerable questions, the Earthquake Mechanism Laboratory has instrumented a number of sites where non-seismic creep is known to occur.

The Cienega Winery, site of the first identified non-seismic tectonic creep (a concept of the earth's crust as a series of moving plates), has been monitored in the ensuing years by Tocher and his associates. As new locations of the creep were identified, they too were regularly checked to determine the continuing effects of this mechanism. Measuring stations have been located at many of these sites.

In the case of a private garage in Hollister, a relatively simple device is used to measure movement along a rupture in the foundation. Lines of spikes are installed in roadways across the fault in known or suspected creep areas. Some of the newer stations use an installation of long rods across the fault at different angles. As movement occurs, the rods are either elongated or compressed, giving a precise measurement of the amount and direction of movement. This compressing or elongating is registered on calibrated dials which are read at regular intervals or are recorded continuously by electronic devices which allow the time as well as amount of movement to be determined.

Establishing and maintaining this network of sites to monitor movement on the fault has required the friendly

(Left) When you live in earthquake country, evidence of earth movement is never very far away. Here, apparently unnoticed by a passing citizen of Hollister, Calif., the San Andreas fault creeps through a quiet residential neighborhood, producing this classic offset of curb and sidewalk. Elsewhere in this city, Earthquake Mechanism Laboratory instruments measure such motion.

(Above) Pavement cracks across a California highway show the route of the San Andreas fault zone, which emerges to the left of the water towers in the background. A deep fill has transformed the steep, fault-made ravine into a level area where new homes are going up. Although these cracks are probably not due to actual fault movement, they might disconcert new homeowners here.

cooperation of both private and corporate landowners, particularly in the Hollister-San Juan Bautista area where evidence of creep is most common. The Nyland Ranch near San Juan Bautista displays creep evidence in offsets of the fences and roadway leading to the ranch house. Permission was obtained to install creep-measuring rods at this point on the fault. Similarly, Almaden Wineries have cooperated by allowing installations of instruments and by having their foremen record the movements at their Cienega vineyard. At these and other sites where the ESSA scientists have needed to place instruments, the cooperation has been exceptional.

Some preliminary results of the non-seismic fault creep studies have been obtained. In addition to defining the extent of the creep zone and the average rates of creep, Tocher has found that the movement is episodic rather than continuous. Periods of as much as 30 days without appreciable movement have been noted.

After such periods of dormancy, creep starts over a limited portion of the fault and not simultaneously over the entire zone. The ERL researchers found that the creep may spread in either direction along the fault. The rate of spread, according to their data, seems to be less than six miles a day.

While the search for answers goes on, California's dragons occasionally stir within their dens, sending tremors through the countryside. Speculation as to the possibility of major quakes in the future and the degree of danger involved is a popular topic of conversation. Mystics warning of doom and disaster found many willing listeners last spring. But the appointed day dawned and passed without the words of a popular ditty coming true—"Where did California go? Moor your boats in Idaho."

While California did not disappear, the slow, relentless movement of the San Andreas goes on. The forces which move such land masses can be explained in theory. The eventual consequence of the energy transmitted in such a fashion is still a subject for conjecture. The geophysicists and geologists theorize, gather data, and refine their theories as the advance of knowledge moves forward. □

Hawaii's Science Peak

. . .It's wired for practically everything

REPORTING movements of the "phantom dog" of Mauna Loa to the local press is just one of the responsibilities a scientist assumes when he becomes director of the ESSA Research Laboratories' Mauna Loa Observatory on the island of Hawaii.

Lothar Ruhnke, a physicist with the Atmospheric Physics and Chemistry Laboratory who just returned to the mainland from two years as Mauna Loa's director, explains that this high-altitude ESSA observatory is unique both in location and philosophy. "Mauna Loa was designed with a diversified scientific community in mind. All research is welcome at Mauna Loa. Numerous geophysical and meteorological teams have operated successfully from the tropical maritime peak of volcanic Mauna Loa."

While collecting the data that ultimately documented a steady increase in carbon dioxide in our atmosphere, Mauna Loa scientists also became involved in the search for a phantom dog on their desolate mountain. Kilauea, the legendary home of Pele where sulfurous steam rises from deep fissures, is on Mauna Loa. Local legend has it that Pele's pet dog appears to warn of an oncoming eruption.

In 1966, a barkless dog showed up at the Observatory. Hawaiian zoologists had been looking for a dog such as Pele's mythological dog—a descendant of the barkless poi dogs which the early Polynesian settlers brought to Hawaii. Thus, the Mauna Loa dog caught the interest of the newspapers—both because his appearance actually did precede an eruption and because he appeared to resemble a poi dog.

Although the ESSA team tried, it was unable to capture its barkless friend and he remained a "phantom dog" to the Hawaiian press.

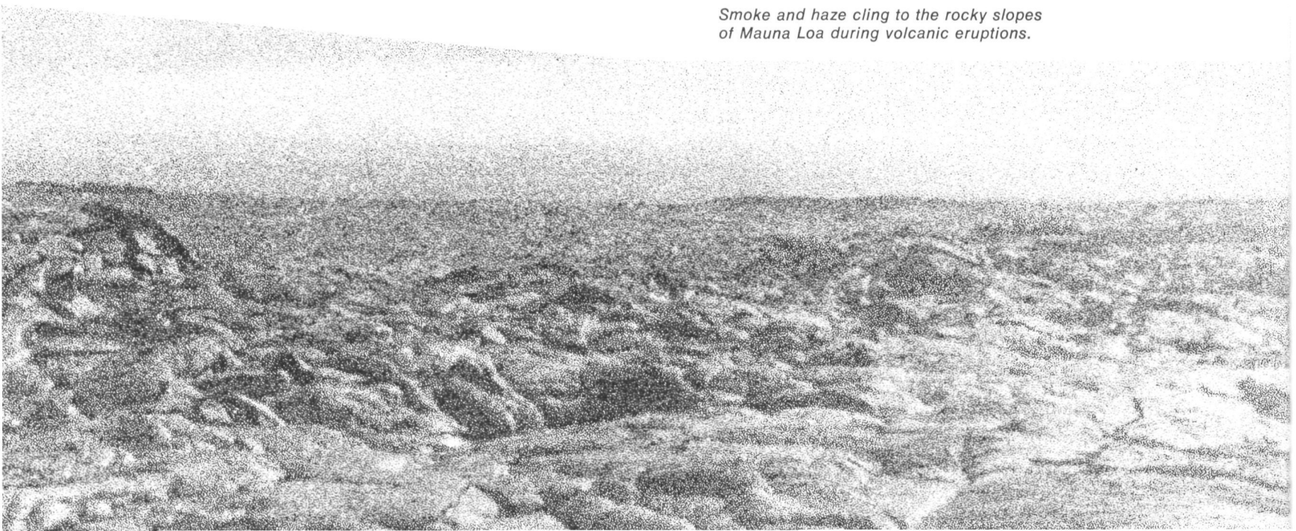
In addition to mythological intrigue and zoological missing links, scientists at Mauna Loa find themselves immersed in the Hawaiian community. Since the Hawaiian Islands provide unique opportunities for many kinds of research, physical scientists are not professionally isolated in Hawaii.

BY JOANN TEMPLE DENNETT
ESSA Research Laboratories

From its beginnings in a small hut, the Mauna Loa Observatory has continued to grow, and now includes seven buildings.

Not until 1950 was a cinder road built across the lava wastes to make the upper reaches of the mountain accessible.

Smoke and haze cling to the rocky slopes of Mauna Loa during volcanic eruptions.



Situated in mid-ocean far from other land, the islands offer a rare opportunity to observe weather and atmospheric phenomena without interfering factors. They further provide an excellent base for research and documentation work on volcanoes, earthquakes, water resources, erosion, and the oceans.

As early as 1921, scientists were proposing more observation work from the Hawaiian Islands. The first Pan Pacific Science Congress, meeting in Honolulu in 1921, adopted a resolution calling for the establishment of a weather station at the summit of Mauna Loa. But it was not until 1950 that this became possible when a cinder road was finally laid across the lava wastes to the upper reaches of the mountain.

Mauna Loa's present complex of sophisticated instrumentation began in 1951 with a small masonry hut 13,400 feet from sea level. This hut, 280 feet below the summit, was designed to house 90-day weight-driven recorders for atmospheric pressure, temperature, relative humidity, wind, sunshine, and precipitation measurements. At the same time, rain gages and instrument shelters with conventional barographs, hygrothermographs, and thermometers were placed along Mauna Loa's gentle slopes at elevations of 5,100, 8,300, and 11,500 feet.

From these small beginnings, Mauna Loa Observatory has grown to be ESSA's principal geophysical monitoring station. The Observatory, a segment of the Atmospheric Physics and Chemistry Laboratory of ERL, now has seven permanent buildings complete with commercial electrical power and telephone service. The National Center for Atmospheric Research (NCAR) has erected a permanent structure there to house instruments for studying the solar corona. In addition, Mauna Loa Observatory has an office and laboratory in nearby Hilo, two hours from the mountain site on an oiled, finished road.

Weather on Hawaii and at the summit observatory are excellent for meteorological research. In its first eleven years of operation, Mauna Loa Observatory logged 3748 days of complete solar radiation records for both normal and horizontal incidence. The observatory site is well within the geographic tropics and, except for its sister peak Mauna Kea, Mauna Loa is a solitary mountain lying more than 2000 miles from the nearest continental land mass. Measured from its roots, 18,000 feet below the sea, Mauna Loa is the most massive mountain on earth. It lies in the midst of a tropical ocean which has a mean annual temperature of 75° F, an annual range of only 5° F, and a daily range of less than 2° F. The prevailing surface wind is the northeasterly trade which flows 90 percent of the time in summer and 80 percent of the time for the year as a whole.

The road up Mauna Loa gradually ascends the northeast face of the mountain passing through a tropical rain forest of trees and ferns. Along the route, the average rainfall increases rapidly from 145 inches annually at Hilo to 250 inches between 2,500 and 3,000 feet and then decreases steadily to less than 15 inches at the summit. A little over a mile high, the forest open abruptly into fields of lava dotted with shrubs and scattered trees. Continuing on, soon even the trees and shrubs are gone leaving only moss and lichens.

This road, opened in April 1963, lays claim to being the highest road in the Pacific. (Colorado still holds the nation's record for the highest highways with the summit road to Mt. Evans reaching 14,260 feet and that to Pike's Peak topping off at 14,109 feet.) The road to Mauna Loa Observatory comes close with a topmost point of 11,150 feet.

Mauna Loa's research and observational studies vary with the season but several current programs are of continuing interest. One of these is the carbon dioxide sampling program. During the IGY, a worldwide effort began to gather benchmark data on the carbon dioxide content of our atmosphere. Since this time, Mauna Loa has documented a steady increase of this byproduct of civilization in our atmosphere. This increase is running about one part per million per year at Mauna Loa—in a tropical maritime region of climatic uniformity far from direct sources of pollution. There is a seasonal change also. The total carbon dioxide concentration in the atmosphere peaks in May around 315 parts per million and falls to a minimum in October of less than 311 parts per million.

Monitoring of such secular changes is one of Mauna Loa's major interests in line with the work of its parent group, the Atmospheric Physics and Chemistry Laboratory. Part of ERL, APCL is the laboratory charged with research on weather modification—both deliberate modification attempts and the inadvertent changes caused by man's own activities.

continued

. . .*It's wired for practically everything*

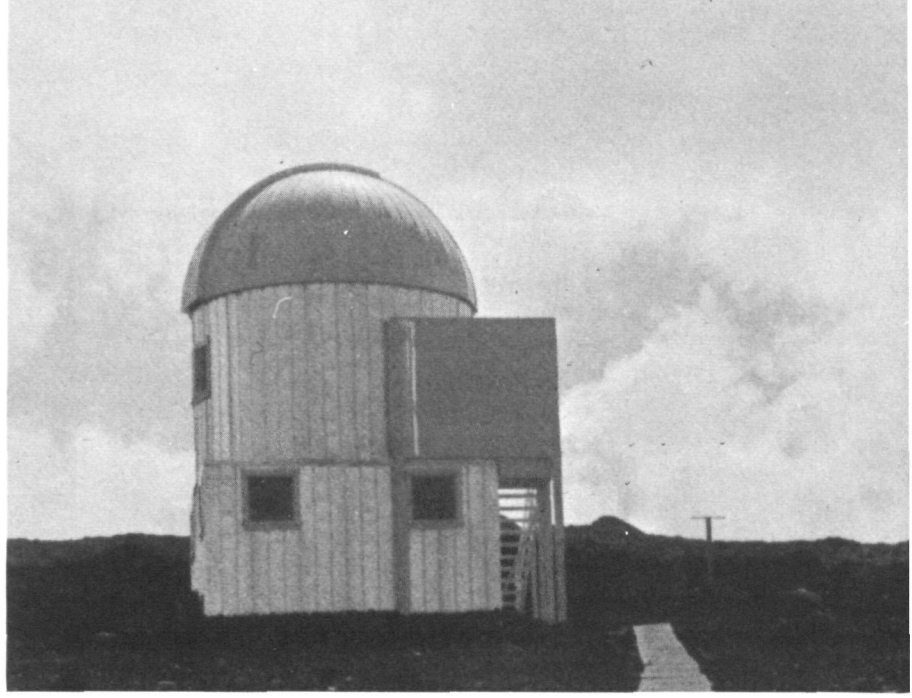
Other measurements are being made to watch for changes in the atmosphere. At Mauna Loa secular measurements are made on solar radiation, fine particle pollution or nuclei populations, the trade wind inversions, ozone, and the atmospheric electric field.

Data from the first measurements of the atmospheric electric field in 1960 were used in correlating the global electrical field with worldwide thunderstorm activity. The second set of benchmark measurements on this environmental factor is scheduled for 1970.

Mauna Loa is also playing a telecommunications role. Since available frequencies in the radio spectrum are being consumed at a rapid rate by modern technology, satellites and ever-expanding communications, the VHF ranges will have to be used more extensively. Very little is known about attenuation at VHF frequencies and the U.S. Air Force, with the help of APCL's meteorologists at Mauna Loa, set out to study the problems it might encounter in routine use of VHF channels. One significant factor is distortion, attenuation, or absorption of VHF signals by heavy rainfalls such as occur in the tropics. At Mauna Loa Observatory's Hilo offices where rainfall is very heavy, the Air Force has installed a microwave radiometer system for studying the effects of rain on signal strength. This is just one of the projects undertaken at Mauna Loa by other agencies, governments, and industrial research units.

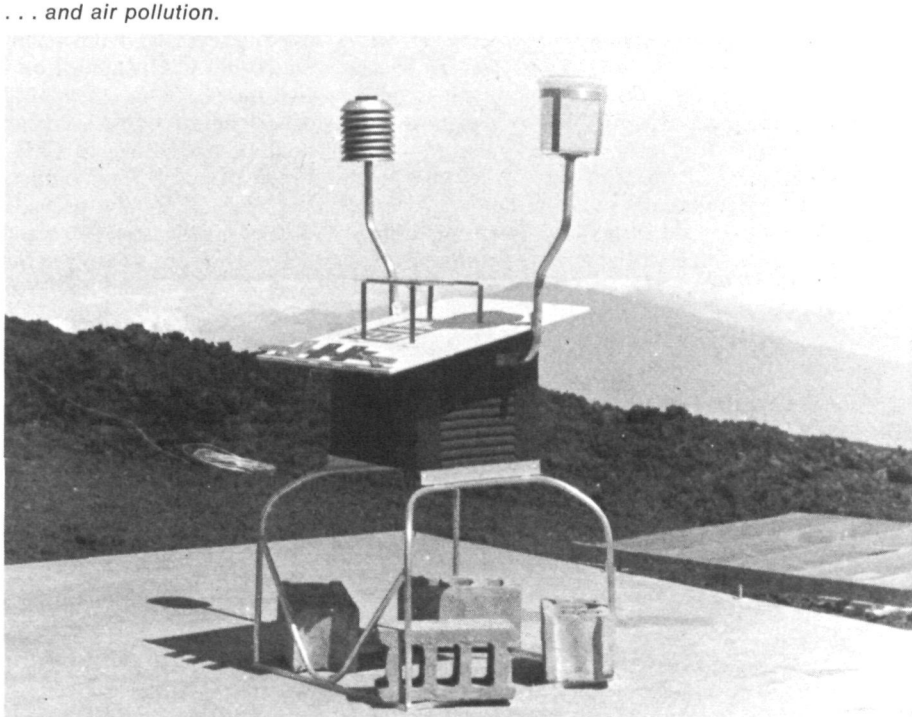
The U.S. Topographic Command (formerly the Army Map Service) timed stellar occultations from Mauna Loa Observatory and used its results to connect the Hawaiian Islands with the North American geodetic datum. NBS and the National Geographic Society took advantage of the low humidity at Mauna Loa to make spectrographic observations of water vapor in the atmosphere of Mars. Hans Pettersson, a Swedish oceanographer, scavenged cosmic dust from equipment based at Mauna Loa. He was looking for a correlation between the deposition rate of micrometeoritic materials and the dating of oceanic sediments. The AEC installed an observation station at Mauna Loa to monitor fallout from the South Pacific nuclear tests, and atmospheric scientists continued with similar work using radioactive products as tracers of large-scale global motions in the atmosphere.

Now in its 12th year of full-scale operation, Mauna Loa Observatory remains ready to offer facilities and housing to visiting scientists and to assist in instrument-reading and servicing aspects of projects which other scientists would like to complete in absentia. □



An excellent base for research.

Weather observations include rainfall . . . and air pollution.



Coils at Fredericksburg Geomagnetic Center can duplicate the magnetic field as it exists anywhere on earth, permitting simulation of any geomagnetic environment in the laboratory.

THE SILENT STORM

After more than a century of study, much remains to be learned about magnetic disturbances

BY J. H. NELSON
Coast and Geodetic Survey

ONE OF nature's strangest forces, the earth's magnetic field, has been under constant study and investigation by ESSA's Coast and Geodetic Survey for some 125 years, yet there is still much to be learned about it.

Many people are acquainted with the term "magnetic storm," not because they can feel or see it, or otherwise detect it with human senses, but because they know it interferes with communications, including their radio reception. Unlike other storms, there is no wind or lightning, no snow or rain, no heat wave or subzero temperatures, and no catastrophic tidal wave or earthquake.

Why then spend time, money, and effort on its study? Because it is important to many people, including engineers, surveyors, navigators, exploration geophysicists, scientists, map makers, and even Boy Scouts. Every plane and ship carries one or more magnetic compasses. While all large ships and many smaller ones are also equipped with gyrocompasses which indicate the direction of true north quite satisfactorily, they sometimes get out of order. When that happens, the old reliable magnetic needle furnishes a reserve guidance system.

For airplanes, there is no such thing as a true gyrocompass for general use. There are gyro-stabilized compasses and direction indicators that employ gyroscopes, but these rely on the magnetic field for basic orientation. The accelerations of an aircraft in flight, both vertical and horizontal, are too large and erratic to permit the operation of a conventional north-seeking gyrocompass.

The compass is often needed also to resolve questions regarding early boundary lines. This is because many early land surveys in the United States, particularly in the eastern part of the country, used the surveyor's compass to determine direction. To reestablish an early boundary line, the old

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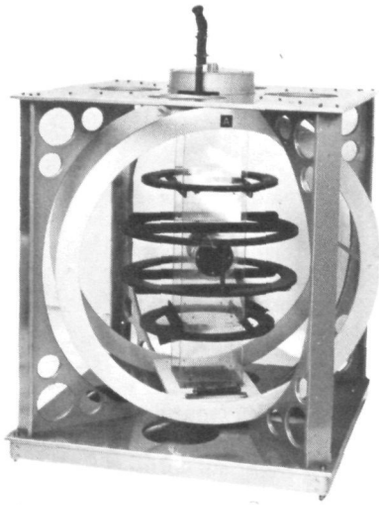
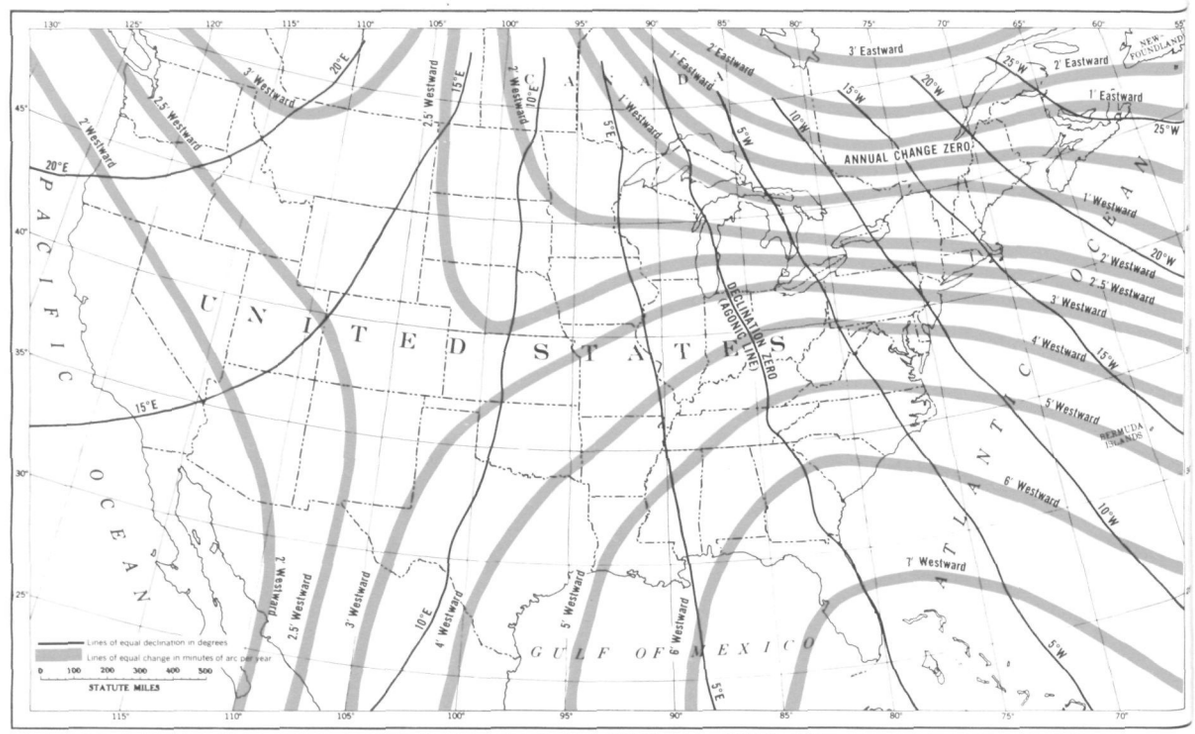


Sensors like the proton vector magnetometer, above, measure the horizontal and vertical components of the earth's magnetic field as well as total field intensity. Data are portrayed on maps like the isogonic chart at right, which shows magnetic declination for 1965 and its annual variation east and west.



Distribution of magnetic declination for 1965 (derived from C&GS Chart 3077)

survey lines have to be retraced and this can only be done with a compass. The Coast and Geodetic Survey answers a small but continuous stream of inquiries from county engineers, registered surveyors, and others asking for the amount of change in magnetic north between some earlier specified date and the present time. This type of information is readily available from the Coast Survey's files.

The Coast Survey's aim, in its continuing study of the earth's magnetic field, is to utilize this field for the greatest benefit of mankind. To do that, it must be measured and charted, its changes recorded, and its relationship with other geophysical sciences studied.

To carry out this task, the ESSA agency operates 14 magnetic observatories. They extend virtually from the North Pole to the South Pole. The northernmost station is at Point Barrow, Alaska; the southernmost at the South Pole. They include those at College (near Fairbanks) and Sitka, Alaska; Newport, Washington; Boulder, Colorado; Castle Rock, California; Tucson, Arizona; Dallas, Texas; Corbin, Virginia; Cayey, Puerto Rico; Ewa Beach (near Honolulu), Hawaii; Guam; and Byrd Station, Antarctica. The two Antarctic stations are part of the U. S. Antarctic Research Program and are supported by the National Science Foundation.

In addition to the operation of magnetic observatories, the Coast and Geodetic Survey carries on field surveys of various kinds —repeat surveys on land, to help define more adequately the pattern of secular change by remeasuring the strength and direction of the field at some 125 points throughout the United States at intervals of some five years; compass rose surveys, to determine the suitability of specified areas at air bases and commercial flying fields for the accurate calibration of aircraft compasses; and marine magnetic surveys for measuring the anomalies in the field in ocean areas, for study and correlation with bathymetric measurements, gravity surveys, and geological fault systems. One of the most important discoveries or developments ever made in the area of marine geology-geophysics is the concept of "sea floor spreading" as derived initially from marine magnetic measurements of the alternating positive and negative anomalies symmetrically located on both sides of a central ridge. This furnishes a powerful support for the continental-drift hypothesis.

The earth's magnetic field is not fixed. It fluctuates. There are some fairly regular oscillations, such as the daily changes that are obviously related to the earth's 24-hour rotation, but others are quite erratic. The periods of fluctuations cover a wide range of values, from perhaps a half second or less per cycle to some centuries per cycle.

The long-period changes, commonly called secular change, are due to slowly shifting pathways of electric currents deep within the core of the earth. Indeed, it is these currents that are responsible for generating and maintaining probably 98 per cent of the earth's field. Faster fluctuations are due primarily to the effects of the sun. Charged particles and electromagnetic radiation from the sun impinge upon the outer layers of the earth's atmosphere, ionizing them and providing pathways of varying degrees of resistance in the ionosphere (that part of the earth's atmosphere, which extends outward into space from about 50 miles above the ground) for electric currents amounting to thousands of amperes. Since an electric current is always accompanied by a magnetic field, the resulting disturbance to the main field is readily seen when the continuous recordings of the strength and direction of the magnetic field are examined. When the fluctuations become very large and irregular they constitute a magnetic storm.

During a severe magnetic storm, the records at a magnetic observatory apparently indicate violent changes in the magnetic field. However, the strength of the magnetic field will seldom vary by as much as two per cent and the direction of the compass during such a storm rarely changes by as much as two degrees. The intensity of magnetic storm activity, and hence the ranges involved, are much greater in the auroral zones in the North and South Polar areas than in other regions of the earth. Despite this, after the storm is over, both the intensity and direction of the magnetic field will return for all practical purposes to the values that existed before the storm.

Since these rapid changes in the magnetic field are caused for the most part by solar disturbances and since long distance radio transmission is closely related to the condition of ionization in the upper atmosphere, it is apparent that there might be some relationship between magnetic activity and radio propagation conditions. Reports of magnetic conditions are transmitted daily to ESSA's Institute for Telecommunication Sciences in Boulder, Colorado, and serve as one form of input in the preparation of

the forecast of radio propagation conditions.

The long-term secular changes, which occur once in an age or century, are certainly less spectacular than those associated with magnetic storms, but their effects are no less important.

The changes in the direction of magnetic north are about a quarter degree or less per year at any location on the earth's surface other than at the north and south magnetic poles. The present maximum rate of change in the United States is only a little more than a tenth of a degree per year. Nevertheless, these changes are great enough so that after a span of only a few years, they begin to become appreciable.

Perhaps the most startling of all changes in the direction of the compass occurred between the years 1600 and 1800 in the general area of the British Isles when the direction changed from approximately 11 degrees east to 24 degrees west, a total change of about 35 degrees. The present value of magnetic declination (or variation of the compass) at London has changed back to about seven degrees west and is approaching zero at the rate of about six minutes of arc per year.

Because the magnetic field is continually changing and because these changes cannot be accurately predicted, it is necessary to reissue magnetic charts every few years. The International Union of Geodesy and Geophysics has adopted as the standard a time interval of five years for the isogonic chart (magnetic declination), which corresponds to the practice followed by the Coast and Geodetic Survey for over 50 years. Charts showing the distribution of magnetic dip (or inclination) and of the intensity components (horizontal, vertical and total) are recompiled at 10-year intervals. In addition to these charts of the United States, the Coast Survey also compiles a similar set of charts for the entire world in cooperation with the Naval Oceanographic Office. The world charts are printed and distributed by the Navy.

Magnetic charts are not seen as frequently as nautical and aeronautical charts. However, the charts of magnetic declination (or variation) serve as the source of data for compass roses which are used by mariners to plot their course. The compass rose, which appears on all nautical charts, shows the magnetic and true (geographical) north and the annual rate of change.

For a hundred years or more there was relatively little change in the design or concept of magnetic instrumentation, except for minor refinements in techniques and construction. Some 10 to 15 years ago, however, the family of nuclear magnetometers was born and this type of equipment now constitutes the principal calibrating instrumentation in all first class magnetic observatories.

The simplest of the newer magnetometers is the proton precession magnetometer. The nucleus of the hydrogen atom, because it is a spinning, electrically charged particle, has some of the characteristics of a microminiature permanent magnet, and it will tend to align itself with any magnetic field that surrounds it. When a measurement is to be made with the proton magnetometer, a strong magnetic field, perhaps a thousand times the strength of the earth's field, is generated by an electric coil, and the protons contained in a few ounces of water located within the coil are subjected to this field, roughly at right angles to the earth's field.

After two or three seconds, the polarizing field is suddenly reduced to zero, leaving only the earth's field to act on the protons. The protons then tend to realign themselves with the earth's field, and because they are spinning they go into a precessional motion which lasts for several seconds. The angular velocity of the precession is directly proportional to the intensity of the earth's field. The precessing magnets (protons) generate an A. C. voltage, and the frequency of oscillation can be detected, amplified, and measured with great accuracy by modern electronic counting methods. Indeed, the accuracy of magnetic measurements in a standard observatory is within a few parts per million.

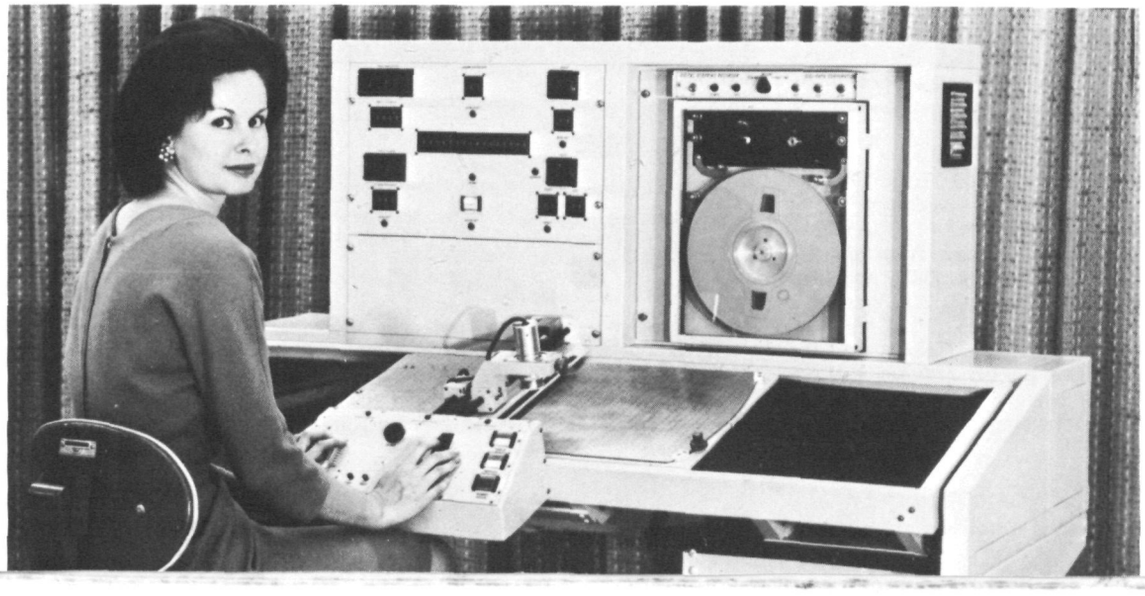
The proton magnetometer is comparatively insensitive to the direction of the field that is being measured since it will measure only the total field that it can "see." However, measurements of the horizontal and vertical components of the field can be made by using biasing coils to reduce the unwanted component approximately to zero. For example, if the horizontal component of the field is nullified, the only part that remains is the vertical component, and this can be accurately measured.

Another type of nuclear magnetometer that is being used more and more is the optical pumping magnetometer in which rubidium vapor, cesium vapor, or metastable helium serves as the active element. Those instruments can operate continuously, not requiring frequent polarizing cycles, and are thus more commonly used for continuous-recording equipment. The sustained radio-frequency oscillations may be accurately counted as often as may be desired and the results recorded on digital magnetic tape suitable for direct input to conventional electronic computing equipment.

In addition to its influence on the compass, the earth's magnetic field has a close relationship with many other aspects of the physical sciences. The field is responsible for trapping charged particles in the Van Allen belts which form layers of high intensity radiation that can be hazardous to space travelers. On the other hand, many of the high energy cosmic rays and ultra-fast charged particles originating in the sun are deflected from the surface of the earth by the magnetic field and the earth's inhabitants are thus protected from their lethal effects.

Magnetic storms, being caused by solar activity, are subjected to the same 11-year cycle that is associated with sunspot activity. Since there is apparently a correlation between the sunspot cycle and rainfall averages, there is a tie-in between geomagnetism and meteorology.

Severe magnetic disturbances are often accompanied by brilliant occurrences of the northern and southern lights. The most intense solar activity cycle on record occurred in 1957-58, during the International Geophysical Year. There were many severe magnetic storms, and displays of the Aurora Borealis were reported as far south as Cuba and Central America. □



This magnetogram scaling machine transforms the analog records of magnetic field changes measured at most of the world's magnetic observatories into a digital form. The machine can convert as many as a hundred scaling points per second, recording the data on computer-compatible magnetic tape. This trend away from tedious and time-consuming hand-scaling of magnetograms is characteristic of most "geosciences."

ESSA NEWS BEAT
U.S. DEPARTMENT OF COMMERCE ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

Gala Banquet, Symposium to Highlight Centennial of U.S. Weather Services

The first major event in the weather services centennial will be a three-day symposium, February 12-14 in Washington, D.C., featuring discussions of future trends in meteorology by leaders in the science from this country and abroad.

Dr. Lee A. DuBridge, the President's science advisor, will speak at a gala centennial banquet February 13 in the International Ballroom of the Washington Hilton Hotel, which is also headquarters for the symposium. A pre-dinner cocktail party/reception is included in the banquet price of $17.50 per person.

The symposium on "A Century of Weather Progress" will open Thursday, February 12, with a keynote address by Dr. Robert M. White, ESSA Administrator.

The roster of scheduled speakers is a virtual "Who's Who" of modern meteorology and related fields. Among those on the program are: B. J. Mason, British Meteorological Office; Erik Mollo-Christensen, MIT; Edward N. Lorenz, MIT; Julian Bigelow, Institute for Advanced Study; V. E. Suomi, University of Wisconsin; Vincent E. Lally, National Center for Atmospheric Research; David Q. Wark, ESSA; John T. Middleton, National Air Pollution Control Administration; George A. Lincoln, Office of Emergency Preparedness; George P. Cressman, ESSA-Weather Bureau; Donald P. Dunlop, Office of the Secretary of the Interior; Thomas F. Malone, The Travelers Insurance Company; Charles Pennypacker Smith, Pacific Gas Transmission Company; Clifton von Kann, Air Transport Association; Paul M. Wolff, Naval Postgraduate School; David M. Gates, Missouri Botanical Garden; William C. Ackermann, Illinois State Water Survey; Roger Revelle, Harvard University; Frederick Sargent II, University of Wisconsin; E. G. Bowen, Division of Radiophysics, Australia; Joanne Simpson, ESSA; and Syukuro Manabe, ESSA.

Dr. Lee A. DuBridge

Session chairman will include: Bernhard Haurwitz, National Center for Atmospheric Research; Morris Neiburger, University of California (Los Angeles); Horace R. Byers, Texas A&M University; F. W. Reichelderfer, former chief of the Weather Bureau; Sverre Petterssen, London, England; Patrick D. McTaggart-Cowan, Executive Director of the Science Council of Canada; and Louis J. Battan, University of Arizona.

A Commemorative Medal marking the United States Weather Services Centennial will be issued early in 1970 by the Treasury Department, and will be available through the American Meteorological Society.

MOST ACCURATE U.S. SURVEY HALF COMPLETED

The most accurate survey ever made in the United States, being carried out by the Coast Survey in cooperation with the U. S. Army Topographic Command, Corps of Engineers, has reached the halfway mark. The 15-year project covering the entire country is so precise that distances are measured with an error of less than one inch every 12 miles.

Almost 7,000 miles have been completed of a 13,760-mile network of the country.

The project was begun in 1961 to meet increased accuracy requirements for tracking satellites and missiles, for detecting and evaluating long-term crustal movements and continental drifts, and for strengthening the agency's national geodetic network used in conducting extensive alignment surveys and in planning urban development.

Work is being conducted now on the part of the network extending between Columbus, Nebr., and Aberdeen, Md., by a C&GS party proceeding eastward along the route in Illinois and by a U. S. Army Party in Ohio carrying the survey westward. Routes already completed extend from Homestead, Fla., to Aberdeen, Md.; from Jacksonville, Fla., to Albuquerque, N. Mex.; from Austin, Tex., to Fargo, N. Dak., and then westerly to Moses Lake, Wash.

Lt. Cdr. John W. Carpenter, head of the C&GS party, said the extensive project requires the use of tall portable steel towers, many nine stories high.

Greeted by snow as they arrive in Fairbanks, Alaska, to tour ESSA facilities and attend a meeting of regional directors were, from left, Dr. Robert M. White, John Eberly, John Connolly, Dan Sala (Fairbanks Weather Bureau), Jack Townshend (College Observatory), Cdr. Gerald Haraden (CGS Alaska Field Director), and Rear Adm. Harley Nygren.

SIRS Data Used For Operational Weather Mapping

Temperature measurements obtained from experimental satellite soundings have proved so valuable that they are being used to prepare the basic maps of Northern Hemisphere weather.

The soundings are made by a device called SIRS—for Satellite Infrared Spectrometer—developed by the National Environmental Satellite Center.

It is one of the instruments aboard the National Aeronautics and Space Administration's Nimbus III, launched April 14, 1969.

Beginning October 21, SIRS soundings were incorporated in the three major analyses of Northern Hemisphere weather prepared daily by computers at the National Meteorological Center.

About six weeks after the Nimbus III launch, the Bureau began using some of the SIRS data in preparing one daily hemispheric weather analysis. The results were so successful that a special computer-to-computer link has been installed between NASA's Goddard Space Flight Center in Greenbelt, Maryland, and the National Meteorological Center to permit regular use of the data in analyses of weather conditions over the eastern Atlantic and most of the Pacific Ocean, from the surface to an altitude of 53,000 feet.

By providing unprecedented coverage of existing conditions over oceans and other areas where few upper-air measurements are made, the SIRS soundings can contribute to better forecasts.

The observations, taken every eight seconds, are used to calculate the vertical temperature distribution—or profile—of the atmosphere beneath the satellite, and also to derive constant pressure heights.

The SIRS on Nimbus III is an experimental prototype of future operational sounding systems. Its soundings present some problems in operational use: the information below clouds is not nearly as good as that in clear air and, because the instrument looks directly downward, there are large gaps in data between orbital tracks.

An improved version of the SIRS, known as SIRS B, is being readied for flight on the next Nimbus satellite, now scheduled for launch in the spring. SIRS B includes six additional sensor channels for measuring humidity. It is also designed to view to the left and right of the orbital track, as well as directly beneath the spacecraft, in order to obtain a broader swath of coverage.

all in the family PERSONNEL NOTES

Capt. William D. Barbee, a member of ESSA's Commissioned Corps, has been named acting director of ERL's Pacific Oceanographic Laboratories. For approximately 19 years, he served with the Corps on geodetic field parties in the United States and on six ships, one of which—the USC&GS Ship SOSBEE—he commanded. In Sept. 1968, he served as chief scientist for the Joint Oceanographic Research Group of the Pacific Oceanographic Laboratories in an experiment to investigate causes and behavior of internal waves.

Capt. Pentti A. Stark, ESSA Commissioned Officer, has been appointed commander of the Coast Survey's Miami Ship Base. The new base commander has been stationed at the Atlantic Marine Center in Norfolk, Va., since 1966. A veteran of 20 years with the Coast Survey, he has served aboard 13 ships, including service as commanding officer of the HILGARD, WAINWRIGHT, SCOTT, COWIE, and EXPLORER.

Donald M. Hanson is now chief of the Systems, Plans, and Design Division in the Weather Bureau's Systems Development Office. Mr. Hanson, formerly the Division's Program Coordinator (World Weather System), joined the Bureau in 1943 at New York and served in St. Louis, Mo., and Kansas City before coming to Weather Bureau headquarters.

Cdr. Ronald M. Buffington is serving as special assistant to Rear Admiral Harley D. Nygren, ESSA Associate Administrator. Cdr. Buffington's previous assignments during his 12 years with the Coast Survey were as officer in charge of the Officer Training Section, Norfolk, Va.; commanding officer of the USC&GS Ship PEIRCE; and instructor and liaison officer at the Naval School, Little Creek, Va.

John Lovkay has been appointed Director of the Equipment Development Laboratory in the Weather Bureau's Systems Development Office. Mr. Lovkay joined the Bureau in 1965 after seven years with the United Aircraft Corp.

Capt. Arthur R. Benton, USESSA, has assumed command of the USC&GS Ship SURVEYOR. A member of the Corps since 1950, he has seen duty on other C&GS vessels, one of which he commanded. His former assignment was as a program planning officer at C&GS headquarters.

Dr. David M. Shaw is serving at the University of Rhode Island as the first Environmental Data Service Regional Oceanographer. Before his ESSA appointment, Dr. Shaw was a lecturer at the City College of New York and a graduate research assistant at the Lamont Geological Observatory at Columbia University.

Bill B. Anderson, former Quality Control Specialist in the Weather Bureau's Western Region, is offical in charge of the Elko, Nev., WBO. Mr. Anderson's other assignments were at Scottsbluff, Nebr.; Santa Catalina, Calif.; and Eugene, Oreg.

George E. Moore, former chief of the Coast Survey's Boston Field Office, now closed, has joined the Program Planning and Coordination Staff of the C&GS Office of Hydrography and Oceanography.

John T. Mosley recently became meteorologist in charge at Alexandria, La. Mr. Moseley began work for the Bureau in 1960 at Midland, Tex., and has been a forecaster at Baton Rouge since 1961.

Robert B. Rollins, a 23-year veteran of the Federal government, has been appointed acting director of the Coast Survey's Executive and Technical Services Staff. Mr. Rollins has served as deputy director of the staff for the past three years.

Claude W. Allen, formerly stationed at the Lake Charles, La., Weather Bureau Office, is now the meteorologist in charge at Pensacola, Fla. A former weather officer with the Air Force, he began his career as an aviation forecaster in 1961. He transferred to Lake Charles as a radar meteorologist in 1963, and became principal assistant at the station in 1966.

Cdr. Ronald L. Newsom has been named special assistant to Capt. John O. Boyer, chief of the Coast Survey's Marine Chart Division. Cdr. Newsom was recently commanding officer of the USC&GS Ship McARTHUR.

Robert M. Ferry is heading the Weather Bureau Forecast Office at Birmingham, Ala. He began his Bureau career at Chicago, and served at Honolulu, Suitland, Md., and Tampa, Fla., before becoming Public Service Operations Meteorologist in the Weather Bureau's Southern Region in 1965.

August W. Roche recently became the new official in charge of the Huntington, W. Va., Weather Bureau office.

Oliver L. Wattenbarger has assumed the post of official in charge at Barter Island, Alaska. Prior to his Alaskan assignment, he held positions in the Weather Bureau's Western, Southern, and Pacific Regions, including a tour of duty in the Arctic.

Cdr. Kelly E. Taggart is the new Program Planning and Coordination Officer for the Coast Survey's Office of Hydrography and Oceanography located in Rockville, Md. Cdr. Taggart has more than 14 years of service with C&GS.

Lt. Roger Kerley has been appointed Executive Officer of the USC&GS Ship PEIRCE. Lt. Kerley joined the Coast Survey in 1964 and has served on the USC&GS Ships PATHFINDER and MARMER, with the National Environmental Satellite Center, as editor of the Mariners Weather Log, and with the C&GS Office of Hydrography and Oceanography.

John A. Mayer has been named meteorologist in charge of the New York Weather Bureau Office, succeeding Anthony E. Tancreto. Mr. Mayer has held several positions in New York City and was formerly meteorologist in charge of the Charleston, W. Va., Weather Bureau Office.

Thomas Morgan has assumed the duties of principal assistant at the N.Y. Weather Bureau Office. Mr. Morgan joined the Bureau in 1947.

57 ESSA Employees Honored by Secretary Stans At Gold, Silver Medal Awards Ceremonies

Fifty-seven ESSA employees were honored by the Department of Commerce during its 21st annual awards program on Oct. 14.

Fifteen ESSA men received the Department's highest award—the Gold Medal—from Secretary Maurice H. Stans.

John H. Eberly, ESSA's Executive Officer, who won the Gold Medal, was cited in part for "capable leadership during the difficult transition period since ESSA's formation in 1965; extraordinary skills in the administration and management affairs of ESSA; a deep awareness and capability in the inter-disciplinary scientific programs of ESSA, and a broad and thorough knowledge of the inherent processes and problems of the agency."

Dr. David Q. Wark, research meteorologist in ESSA's National Environmental Satellite Center, received the award for 'basic theoretical and experimental developments, culminating in the highly successful sounding of atmospheric temperatures from an artificial satellite, a technique of major importance to global weather prediction."

Don T. Hilleary, NESC research meteorologist, was cited for "guiding the development of an important meteorological observing instrument through concept, design, and preliminary test to a brilliantly successful performance aboard the Nimbus III spacecraft."

Four members of ESSA's BOMEX Project Group—**Richard E. Hallgren, William S. Barney, Dr. Joachim P. Kuettner,** and the late **Dr. Benjamin Davidson**—received the award for "outstanding achievement in furthering man's understanding of the relationship between the ocean and the atmosphere."

William L. Tilson, Mobile, Ala., meteorologist in charge, won the award for "his outstanding weather warning service during the approach of Hurricane Camille to the gulf coast in August of this year."

Verne Alexander, Central Region hydrologist; **William E. Hiatt,** WB Associate Director for Hydrology; **Ray E. Johnson,** hydrologist in charge, Kansas City, Mo., River Forecast Center; **Joseph H. Strub,** Minneapolis, Minn., meteorologist in charge; **Herman F. Mondschein,** principal assistant, Kansas City River Forecast Center, were honored for "working as a highly effective team in issuing and coordinating very timely, accurate and highly useful river stage outlooks, forecasts and flood warnings in connection with the widespread Upper Midwest snowmelt floods during the spring of 1969."

Frank W. Burnett, Deputy Director, National Meteorological Center, and **Harlan K. Saylor,** Chief, Analysis and Forecast Division, NMC, were cited for "their work in the development of a new technology, the mixing of man and machine methods to produce central guidance weather forecasts."

The 41 ESSA employees who received Silver Medals were:

Thirteen other members of the BOMEX Project Group: **Capt. Howard S. Cole,** USESSA (Retired), Deputy Project Manager; **Terry de la Moriniere,** Chief, Systems Testing; **Dr. Arnold H. Glaser,** Scientific Coordinator; **Cdr. James G. Grunwell,** USESSA, Logistics Officer; **Capt. Hubert W. Keith, Jr.,** Commanding Officer of the USC&GSS DISCOVERER; **Cdr.. Kenneth MacDonald,** Commanding Officer of the USC&GSS MT MITCHELL; **Capt. Merlyn E. Natto,** Commanding Officer of the USC&GSS OCEANOGRAPHER; **Orville E. Scribner,** Chief, Observations Systems; **Donald B. Seeko,** Administrative Officer; **Cdr. Kelly E. Taggart,** Operations Officer; **Loran A. Weaver,** Aircraft Observing Systems Coordinator; **Cdr. Robert E. Williams,** Commanding Officer of the USC&GSS RAINIER; and **Scott Williams,** Chief, Data Reduction.

Stanley B. Eames, ESSA Director of Public Information.

Morton J. Rubin, ESSA Office of Plans and Programs.

Henry E. Fleming, NESC mathematician.

Alfonso H. Butera, head of the Spacecraft Operations Control Center of NESC.

Barbara McKain, meteorologist in charge of the Norfolk, Nebraska, Weather Bureau Office.

E. Vernon Hendrickson, meteorologist in charge at Fargo, N. Dak.

Charles D. Kearse, electronics development technician, C&GS Office of Systems Development, Miami.

Lockett E. Wood, physicist in ERL's Institute for Telecommunication Sciences.

Russell G. Mann, Robert N. Craig, Dale G. Lillie, Robert H. Dickson, Lewis P. Hahn, Earl A. Johnson, Charles K. Nevins, Delmar J. Taylor, William M. Willard, Dorothy B. Tudor, Marceline L. Mayfield, Elroy C. Balke, Helen L. Berridge of the Kansas City River Forecast Center and regional headquarters staffs of the ESSA Weather Bureau.

Bernard F. Cooke, supervisory cartographer and chief of the Coast Survey's Visual Chart Branch.

Robert C. Baskin, Chief of the Weather Bureau's Weather Analysis and Prediction Branch, Central Region headquarters, Kansas City, Mo.

John D. Stackpole, research meteorologist at the National Meteorological Center.

Jean A. Brown, principal assistant in the Weather Bureau Forecast Office in Redwood City, Calif.

William R. Long, meteorologist at the Pittsburgh, Pa., Weather Bureau Forecast Office.

James F. O'Connor, Chief of the Forecast Branch in the Weather Bureau's Extended Forecast Division, NMC.

Leonard W. Snellman, Chief of the Scientific Services Division, Weather Bureau Western Region headquarters, Salt Lake City, Utah.

H. Dean Parry, meteorologist in the Weather Bureau's Systems Development Office, received the Special Achievement Award.

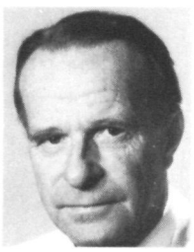
John H. Eberly

David Wark

Don T. Hilleary

Richard E. Hallgren

William S. Barney


Joachim P. Kuettner

William L. Tilson

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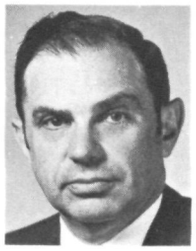
Herman F. Mondschein

Frank W. Burnett

Harlan K. Saylor

Hurricane Debbie's Winds Diminished After Seeding by Project Stormfury

Hurricane Debbie weakened significantly last August 18 and moderately on August 20 after being seeded with silver iodide by Project Stormfury scientists.

Scientists declined to state that seeding weakened the storm, but said preliminary data were so encouraging that the project should be repeated in 1970 with a view to determining cause and effect.

The findings were announced by Secretary of Commerce Maurice H. Stans and Secretary of the Navy John H. Chafee at a press conference December 4. ESSA and the Navy conducted the experiments over the Atlantic several hundred miles northeast of Puerto Rico.

This announcement followed the presentation of a paper by Dr. R. Cecil Gentry, Project Director and head of ESSA's National Hurrican Research Laboratory, at the American Meteorological Society's Sixth Technical Conference on Hurricanes.

Maximum winds decreased by 31 percent for a few hours after seeding on August 18 and by 15 percent after seeding on August 20. On both days, the storm was seeded and monitored by ESSA, Navy, and Air Force aircraft.

Hurricane Debbie was the first tropical cyclone to be seeded in Project Stormfury since 1963. The experiment is based on the hypothesis that conversion of liquid cloud particles to ice will bring the sudden release of the latent heat of fusion of the droplets which, if accomplished in the proper areas of a hurricane, may cause redistribution of the storm's energy and a reduction in maximum wind velocities.

In other years seeding began directly at the eyewall with a single line of 80 large canisters of silver iodide dropped into the hurricane. This year, aircraft penetrated the eyewall to the area of maximum winds before starting to seed. Then, 208 smaller but more efficient silver iodide generators were dropped on a line extending across the outer wall and into the adjacent feeder bands which help fuel the storm, five times at two-hour intervals. The seeded storm was monitored by specially instrumented aircraft at several levels from 1000 to 37,000 feet, from four hours before the first seeding until six hours after the last one. During this period, winds were measured at frequent intervals. Data from the 12,000-foot level, which is considered representative, forms the basis for the conclusions reported.

Secretary of Commerce Maurice H. Stans (left) and Secretary of the Navy John H. Chafee announced the results of Project Stormfury's 1969 seedings of Hurricane Debbie at a Washington, D.C., press conference.

On August 18, before the first seeding, maximum winds at 12,000 feet were 98 knots. After the second seeding and again after the third, measured winds showed a decrease in intensity. Five hours after the fifth seeding, they were 68 knots.

There was no seeding on August 19, and on that day the hurricane reintensified. On August 20 the storm had a double eye structure, something unusual in hurricanes and complicated to handle with present seeding techniques. However, maximum wind speed before the first seeding was 99 knots. After the final seeding, it had dropped to 84 knots.

Project scientists emphasized that much more analysis must be undertaken to determine whether Debbie's temporary weakening was manmade or natural. Toward this end, data from NASA's ATS-III satellite, from radar, from the water content of clouds, and from temperature and pressure readings will be studied. They emphasized also that Stormfury's objective is not to destroy hurricanes (whose force is so great that no tools or techniques now known could dissipate them), but to achieve better understanding and improved prediction.

Overall responsibility for the Stormfury program rests with Dr. Robert M. White, ESSA Administrator, and Captain E. T. Harding, USN, Commander of the Naval Weather Service Command. Associated with Dr. Gentry as Assistant Director and Navy Project Coordinator is Commander L. J. Underwood, USN, Commanding Officer of the Fleet Weather Facility at Jacksonville, Florida. Dr. Pierre St. Amand is Project Manager at the Naval Weapons Center, China Lake, California, where the silver iodide pyrotechnics used for seeding were designed and developed.

Marker Embedded On 86th Floor of N.Y. Skyscraper

Something new has been added to the Empire State Building.

It is a geodetic marker pinpointing the precise geographical position of the world's tallest building. The marker is embedded in the floor of the Observation Deck.

The marker, on the 86th floor, was placed there by a field party of the Coast and Geodetic Survey. It resulted from a request to determine the geographical position of a site at the Brooklyn Navy Yard.

To accomplish this, measurements had to be made from a three-point triangulation net in the area.

The sites used were the 80th floor of the Empire State Building, the roof of the new 46-story Federal Office Building at 26 Federal Plaza, and the site within the Navy Yard (Pier J), whose latitude and longitude was being determined.

After the survey was completed, a point was also determined on the Observation Deck, so that a bronze marker could be placed there to denote the building's geographical position for the millions of tourists who visit the structure. The coordinates of the site on the Observation Deck are Latitude 40° 44′ 53″.997, Longitude 73° 59′ 10″.812.

BOMAP Succeeds BOMEX Operation

There's a new acronym in ESSA, Bomap, for the Barbados Oceanographic and Meteorological Analysis Project.

It is ESSA's operation to realize the scientific significance of the Barbados Oceanographic and Meteorological Experiment, executed in the Caribbean from May through July 1969. It is headed by Dr. Joshua Holland, formerly of the Atomic Energy Commission and, during Bomex, chief scientist for the sea-air interaction program. His deputy is Dr. Arnold Glaser, who served in Bomex as a consultant for coordination of experiments.

Bomap is organized into three main task areas: the Bomex Data System; the Core Experiment; and the Bomex Investigators Information Exchange.

Bomap is responsible for carrying on ESSA's responsibility as lead agency in Bomex.

NASA has an important contribution in data reduction, and is running preliminary data analyses at the Mississippi Test Facility, Bay St. Louis, Mississippi. A crew of Environmental Data Service personnel has moved temporarily from the National Weather Records Center, Asheville, N. C., to MTF to work for Bomap in the preliminary data runs. National Hurricane Research Laboratory and Research Flight Facility personnel are collaborating on reduction of aircraft data at Miami.

Among those detailed to Bomap are: Valti Powell, Administrative Officer; Diane Smith and Patricia West, secretaries; Bomex Data System, Terry de la Moriniere; Data Reduction, Technical Support, Calvin Anderson; Ship Data Reduction, Scott Williams and Ray Joiner (MTF); Aircraft Data Reduction, Robert Reeves and James McFadden (Miami); Island Radar and Satellite Data Reduction, Vance Myers; Core Scientific Design, Dr. Eugene Rasmusson; Bomex Investigators Information Exchange, DeVer Colson; Dr. Ted Horner, Booz-Allen Associates, is working in Core Statistical Design.

At MTF, Harold Craddock, Frank Quinlin, John Shelton, Mortimer Buchwald, Warren Wisner, and William Hodge are working in data reduction with Ray Joiner. Harry Hawkins and Billy Lewis are working in Aircraft Data Reduction. Neil Frank will work in Synoptic Analysis at Miami.

At Boulder, Dr. Pete Kuhn (radiation) and Dr. Brad Bean (eddy flux of moisture) are sharing part of Bomap analysis while Dr. Jose Colon, MIC from San Juan, will participate in the physical interpretation of the energy budget.

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