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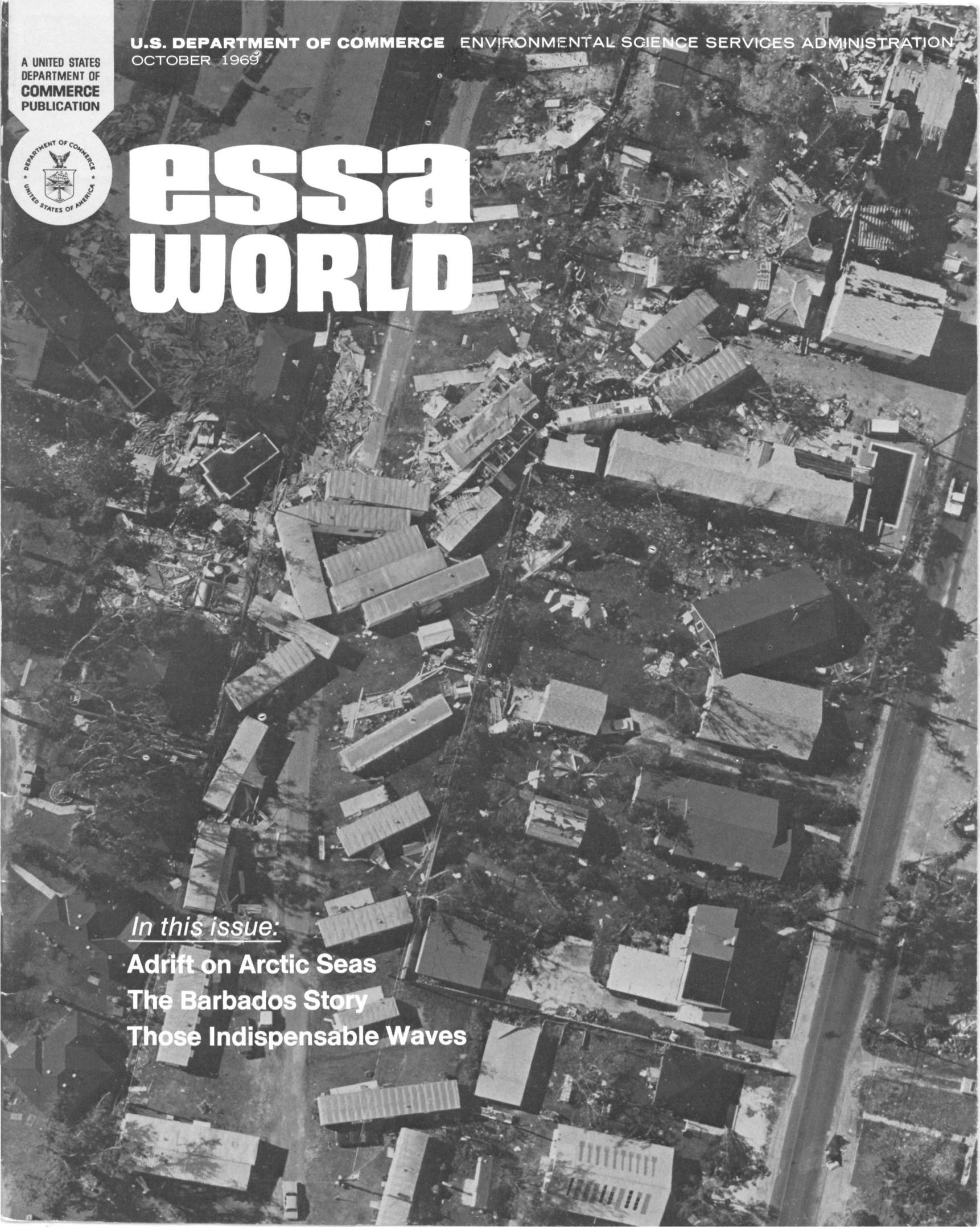
U.S. DEPARTMENT OF COMMERCE ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
OCTOBER 1969

essa WORLD



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Adrift on Arctic Seas
The Barbados Story
Those Indispensable Waves

National Oceanic and Atmospheric Administration

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OCTOBER 1969 VOLUME 4 NUMBER 4

U.S. DEPARTMENT OF COMMERCE, MAURICE H. STANS, Secretary
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION, Dr. Robert M. White, Administrator
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COVER
Camille was the most vicious hurricane ever to hit the U.S. mainland. A Coast Survey aerial photograph of the damage to Biloxi, Miss., shows house trailers overturned and thrown together.

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ROBERT M. WHITE
ADMINISTRATOR

A Message from the Administrator

The operational phase of the Barbados Oceanographic and Meteorological Experiment has ended. Now the findings of approximately 100 separate projects performed by many Federal and private agencies within the grand design of Bomex await evaluation.

There is no doubt in my mind that these results will be exciting and valuable. But even before they have been analyzed one fact emerges clearly: the Bomex approach can provide a blueprint for science in government, in projects of a great nature.

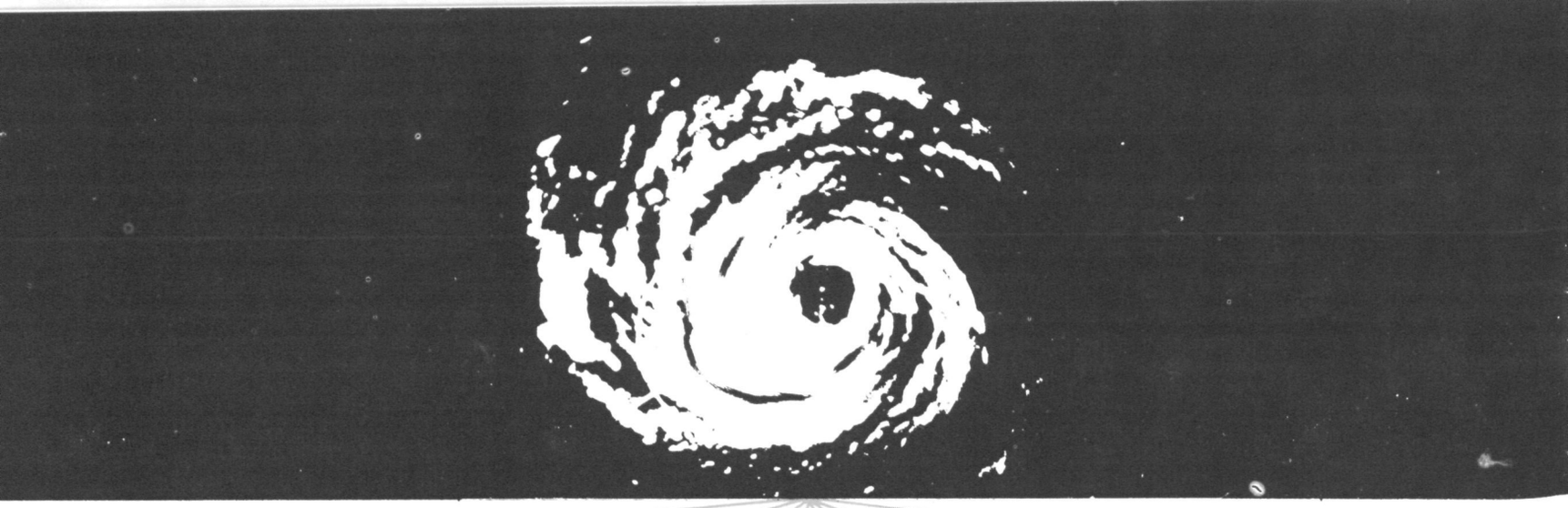
Bomex proved that men of infinitely diverse temperaments, interests, and loyalties can put these things aside for a common cause and, in doing so, can accomplish major achievements. Bomex was big; it was complex; it demanded the best that everybody could bring to it. No part of it was simple or easy, either in the scientific or the operational sense. And the men and women of Bomex performed with rare dedication and selflessness.

Once upon a time, when it was more or less tacitly agreed that the environmental sciences had certain built-in limitations, life was more comfortable, the horizon nearer. Today it is clear that we cannot regard any environmental problem as insoluble, and that many of them constitute vital national needs. In our specific area, the challenge is compounded by the awesome scope of the individual problems of land, sea, and air and the fact that, in an indivisible, interacting environment, they must be attacked from a total rather than a piecemeal viewpoint.

Let us face the fact, too, that the solutions to our environmental problems and knowledge gaps are rendered more distant by the limitation of resources imposed by national priorities. The Nation obviously cannot afford duplication and competition among Federal agencies.

Bomex eliminated duplication, produced a rich cross-fertilization of disciplines, and enabled environmental science to accomplish things that no one agency, university, or corporation could possibly have done by itself. If we are to solve the great and pressing problems posed by our environment, something on the order of Bomex must become a life style of science, Federal and private, in the future. The Nation will be better off for it.

R M White



COUNTLESS LIVES WERE SAVED WHEN SUPERB WEATHER
BUREAU WARNINGS KEPT THE GULF COAST

AHEAD OF A KILLER

Hurricane Camille, the most vicious storm ever to strike the United States mainland, slammed into the Mississippi coast on Sunday, August 17, with winds measured at 190 miles an hour and tides up to 20 feet.

The death toll was over 200 persons; the devastation over a 600-square-mile area of the gulf coast was incredibly awful, with thousands homeless and damage estimated to rise as high as $1 billion.

It was a time of unprecedented testing for the hurricane warning service. The measure of its effectiveness was the fact that an estimated 200,000 persons took advantage of the Weather Bureau's early warnings to take safe shelter inland, and to save what valuables they could carry.

The *U.S. News and World Report* headlined its story: "Hurricane Camille would have killed thousands, instead of hundreds, if there had been no advance warning."

And the *Philadelphia Inquirer* pointed out in an editorial: "It is to the credit of the Weather Bureau and other civilian and military agencies engaged in the business of spotting the storms and tracking their courses that the death toll wasn't much greater."

When Camille was still a quickly forming tropical storm in the Caribbean south of Cuba, the Weather Bureau's first advisory was before the public—a public which had, from that time, days in which to watch the progress of the storm and make preparations.

Some, sadly, did not. "Hurricane parties" heightened the death toll. Some remained in their homes from stubbornness, although early in the course of the storm its amazing intensity was widely broadcast.

Key figures in the early and accurate prediction and warning of Hurricane Camille were Dr. Robert H. Simpson, Director of Miami's National Hurricane Center, and his staff; Stephen Lichtblau, head of the New Orleans office, and his staff; William Tilson, head of the Mobile, Alabama, office and his staff; Terrence Kable and Joe Pope at Pensacola, Florida. Dr. Gordon Dunn, retired Director of the National Hurricane Center, volunteered his services and aided in the effort.

At Boothville, La., where the Meteorological Observatory already was 10½ feet above sea level, waters rose 4½ feet in the station, trapping its occupants and causing the equipment to fail. Official-in-charge Gerald O'Donnell, Douglas and Marion Grantham, Thomas Craig, and Virgil Coludrovich issued observations as long as the equipment functioned. They were not rescued until an Army amphibious vehicle arrived 24 hours later. Their personal property was swept away.

Radar, satellite, and air reconnaissance experts and equipment all played major roles in the tracking of the storm. Air Force, Navy, and ESSA Research Flight Facility planes flew dangerous missions to bring new information to forecasters.

After the storm, the Coast and Geodetic Survey's Air Photo Mission was on the scene, performing a two-day reconnaissance over the hurricane-devastated coast, photographing damage to harbor facilities and shorelines. Their striking photos, some of which accompany this article, will provide a preliminary look at areas which may require extensive resurveying. After water conditions returned to normal, further photography was planned.

The story of the Weather Bureau's participation in the effort to help save life and property in an hour of grave crisis along the gulf coast is told in the sheaves of advisories and bulletins issued every few hours from the moment the gathering storm was spotted. The material in those warnings, summarized here, tells the story of a warning service to the nation which saved many lives.

On Thursday, Aug. 14, a Navy reconnaissance plane reconnoitering a tropical wave in the Caribbean encountered a fast-developing depression which reached storm intensity while the aircraft was still in the area. Advisory Number One on the new storm, to be known as Camille, was issued at 1 p.m. EDT that day by the Weather Bureau's National Hurricane Center in Miami.

At that time, Camille was located near latitude 19.3 North and longitude 82.3 West or about 60 miles west of Grand Cayman or 480 miles south of Miami. Camille was moving west-northwestward at about 13 miles per hour with strongest winds about 60 miles per hour over a very small area near the center. A bulletin was issued at 3 p.m. Advisory Number Two was issued at 6 p.m. on Aug. 14, saying indications were that the storm would pass near the western tip of Cuba that night or early the next morning, moving northwestward at 10-12 miles per hour. It was forecast that the storm would go into the Gulf of Mexico.

Another bulletin was issued at 9 p.m. EDT on the 14th, indicating no important change.

At midnight Thursday, Aug. 14, Advisory Number Three was issued. It stated that Camille took a more northerly course. This was based on a Navy reconnaissance flight report. At that time, there was no significant change in intensity.

A bulletin was issued on Friday, Aug. 15, at 3 a.m. stating that Camille was "plodding" toward the Isle of Pines. At 6 a.m., on Friday, Aug. 15, Advisory Number Four was issued, stating that Camille was still heading toward extreme western Cuba with indications that hurricane force would be reached that morning and hit extreme western Cuba around noon or a little later. It forecast a slight turn to more northerly movement after Camille passed Cuba and would enter the Gulf of Mexico later that day. At 9 a.m. that day, a bulletin said Camille had become a full-fledged hurricane. An ESSA reconnaissance plane found Camille had highest winds estimated at 90 miles per hour. Advisory Number Five, issued at noon Friday, Aug. 15, indicated that Hurricane Camille was centered near latitude 21.2 North, longitude 83.9 West, or about 400 miles southwest of Miami. It stated that Camille would reach western Cuba around noon or a little later and precautions should be taken immediately for rapidly increasing winds reaching hurricane force by early afternoon and tides up to eight feet on Cuba's southwest coast.

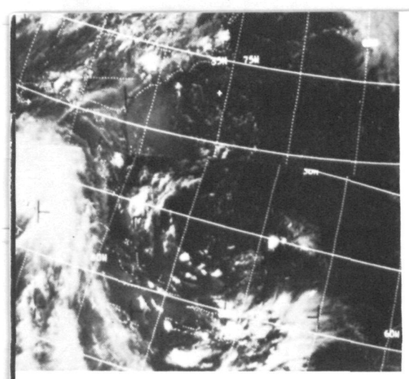
It forecast a turn to a more northerly course, and an increase in forward speed which would bring the storm into the Gulf of Mexico by evening. It pointed out that small craft around the Florida keys should not venture far from shore and those around western Cuba should be in safe harbor. A bulletin issued at 3 p.m. on Friday, Aug. 15, said that an ESSA reconnaissance plane reported steady intensification, and somewhat slower movement as it approached southwest Cuba coast. The eye of the hurricane was clearly in view of the weather radar in Havana, which was supplying regular reports to the National Hurricane Center. This bulletin said Camille, while still an immature young hurricane with a very small intense core, was nevertheless the most intense hurricane since Beulah of 1967. Maximum winds were at least 115 miles per hour and over water areas gale force winds extended outward into the eastern Florida strait area. At 6 p.m. on Friday, Aug. 15, Advisory Number Six was issued, stating that the storm was at latitude 21.5 North and longitude 84.4 West or about 270 miles southwest of Key West. This position was based upon Air Force reconnaissance, land-based radar, ship and island reports. It said the hurricane was expected to enter the Gulf of Mexico early Saturday morning, Aug. 16, and proceed north over the eastern gulf at a slightly increased forward speed. It stressed that all interests along the eastern Gulf of Mexico should remain in close touch with all future advisories and bulletins. A bulletin was issued at 9 p.m. Friday, Aug. 15, stating the eye was over extreme western Cuba and was under surveillance of the Key West and Havana radars. Another bulletin, citing no change, was issued at 11 p.m.

At midnight Friday, Aug. 15, Advisory Number Seven was issued. It stated that small craft around Florida should observe caution. It called Camille "a dangerous hurricane" entering the east portion of the Gulf of Mexico and said it "poses a great threat to the United States mainland." It urged all interests along the eastern Gulf of Mexico to keep in close touch with advisories. It stated that a hurricane watch probably would be issued for a portion of the coastal area of the northeast gulf by or before noon Saturday, Aug. 16.

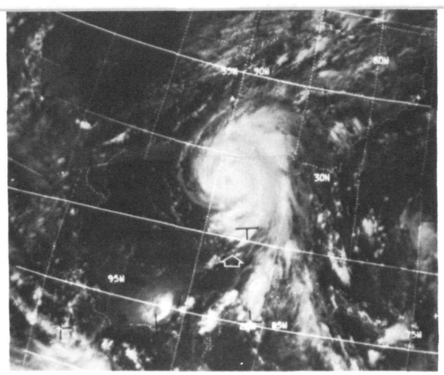
A bulletin issued at 3 a.m. Saturday, Aug. 16, located Camille near latitude 23.2 North and longitude 85.0 West or about 220 miles west-southwest of Key West, moving north-northwest at ten miles per hour, with winds estimated at 100 miles per hour near the center. At 6 a.m. Saturday, Aug. 16, Advisory Number Eight said the hurricane threatened northwest Florida. It said that small craft along the northwest Florida coast and as far west as Mobile, Alabama, should seek safe harbor that night. It added that a hurricane watch "undoubtedly" would be needed over most of that area later that morning, and warnings for a portion of the area that afternoon.

Advisory Number Nine, issued at 9 a.m. Saturday, Aug. 16, said "a hurricane watch is in effect from Biloxi, Mississippi, to St. Marks, Florida, at 8 a.m. CDT. Specific hurricane warnings will be issued for portions of this coastline at noon today following receipt of further reconnaissance information from the center of Hurricane Camille." It stated that the strongest winds were expected to remain not less than 100 miles per hour, with further intensification expected. It said Camille was "potentially a very dangerous hurricane. All interests in the watch area and adjacent coastlines should remain in close touch with later advices today and be prepared for fast protective action when warnings are issued."

At 11 a.m. CDT on Saturday, Aug. 16, Advisory Number Ten was issued from the New Orleans Weather Bureau office. It stated that hurricane warnings had been issued on the northwest Florida coast from Fort Walton to St. Marks and gale warnings elsewhere from Pensacola to Cedar Key, effective at 11 a.m. that day, CDT. It added that "preparations for hurricane force winds and five- to ten-foot tides in the area from Fort Walton to St. Marks should be started immediately and completed tonight." At 11 a.m., she was centered near latitude 24.5 and longitude 86.0, or about 380 miles south of Panama City, Florida, moving north-northwestward about 10 miles per hour. It added the hurricane was expected to continue that movement that day, with a gradual turn to the north that night. A slight increase in speed was said to be likely that night and the following day. Highest winds were estimated at 115 miles per hour near the center, with gales extending out about 150 miles from the center. Conditions were said to be favorable for further increase in intensity that day. A bulletin was issued that day at 1 p.m., repeating the information. Another bulletin was issued at 3 p.m., stating Camille had stalled temporarily, but was expected to resume its north-northwestward movement at about 10 miles per hour that night. At 5 p.m. CDT the bulletin said the hurricane had become very intense and repeated safety precautionary information, along with the area watch and warning. A bulletin at 7 p.m. CDT repeated the information and called Camille "a very intense and dangerous storm." At 9 p.m. CDT on Saturday, Aug. 16, Advisory Number Eleven was issued. It gave the location as latitude 25.4 North and longitude 87.3 West, or about 350 miles south of Pensacola, Florida, moving north-northwestward about twelve miles per hour, with highest winds estimated at 150 miles per hour near the center. At 11 p.m. CDT that night, Advisory Number Twelve was issued, stating that Camille was "extremely dangerous," repeating the watch-and-warning area and predicting little intensity change over the next twelve hours. A bulletin at 1 a.m. CDT Sunday, Aug. 17, continued to call the storm extremely dangerous, and repeated the watch-and-warning area. A 3 a.m. bulletin said that the hurricane was located by a Navy reconnaissance plane near latitude 26.7 North and longitude 86.7 West or about 260 miles south of Pensacola, Florida, moving on a course a little west of north at about twelve miles per hour. A slight change to a more northerly course was said to be indicated with little change in forward speed. The plane found Camille still well organized, with a small compact eye. Highest winds were estimated at 160 miles per hour near the center.



August 13



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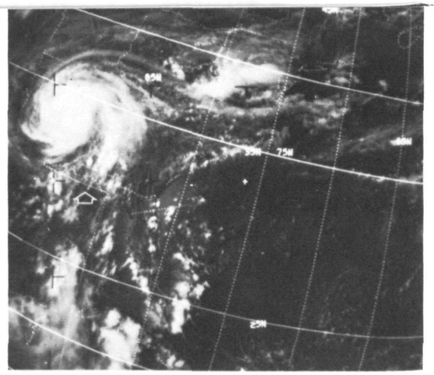

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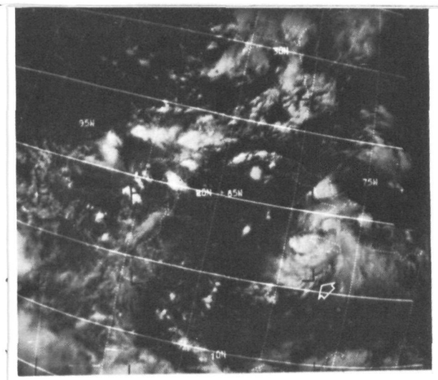
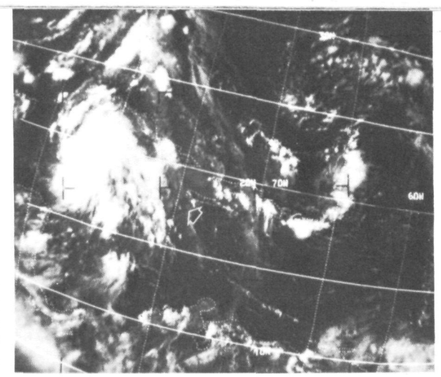
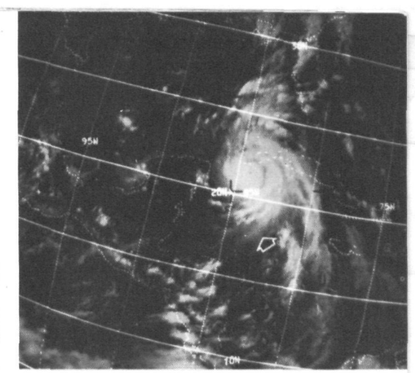


August 16

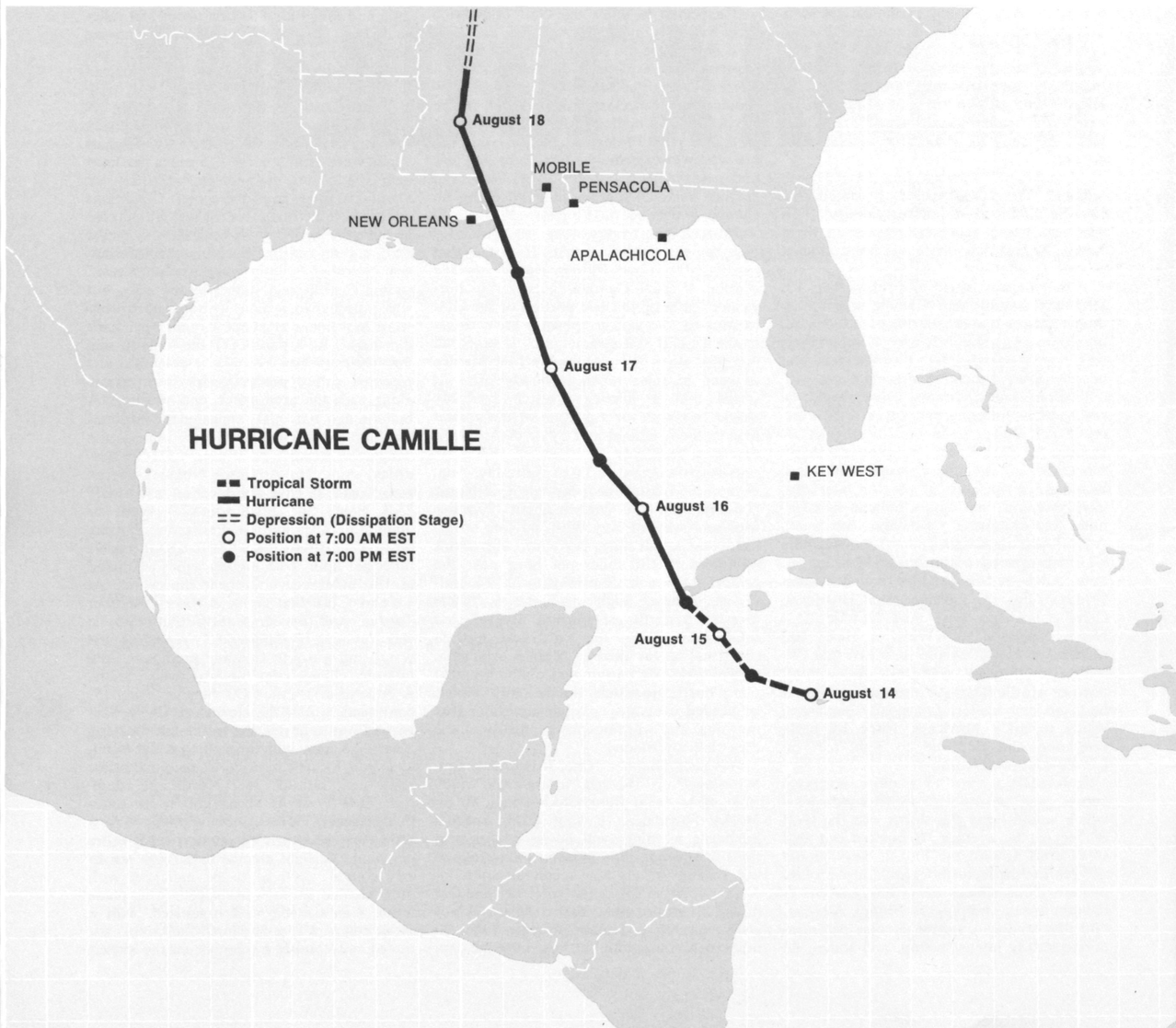


August 17



August 18

ESSA 9 track of Hurricane Camille, August 13-18, 1969. National Environmental Satellite Center, Suitland, Maryland



At 5 a.m. CDT Sunday, Aug. 17, Advisory Number Thirteen was issued. It called Camille "extremely dangerous" and said that she had shifted a little westward, threatening Mississippi, Alabama, and the northwest Florida coast. Hurricane warnings were extended westward to Biloxi, including the Alabama coast and the Pensacola area of northwest Florida. Hurricane watch and gale warnings were extended westward to New Orleans and Grand Isle, Louisiana.

It said: "Hurricane warnings are now in effect from Biloxi, Mississippi, to St. Marks, Florida, and gale warnings elsewhere from New Orleans and Grand Isle to Cedar Keys, Florida." It said preparations should be completed as early as possible that day in the area of hurricane warnings and persons in the area of hurricane watch should be prepared to take quick action if necessary. It called for winds to increase and tides to start to rise along the northern gulf coast from Grand Isle eastward. It forecast tides up to 15 feet in the area where the center was to cross the coast and up to five to twelve feet elsewhere in the hurricane warning area. "Evacuation of the low-lying area that would be affected by these tides should be done as early as possible today before escape routes are closed. The center is expected to move inland near Mobile tonight." A bulletin issued at 7 a.m. CDT Sunday, Aug. 17, stated that the movement of Hurricane Camille during the past few hours had been generally toward the mouth of the Mississippi River and "unless the anticipated turn to a more northerly course occurs within the next few hours, it will be necessary to extend hurricane warnings into the area of hurricane watch."

Advisory Number Fourteen issued at 9 a.m. CDT on Sunday, Aug. 17, extended warnings westward to include all of the Mississippi coast and southeastern Louisiana as far west as New Orleans and Grand Isle.

It stated: "Gale warnings have been extended westward to Morgan City, Louisiana. Hurricane warnings are now in effect from New Orleans and Grand Isle, Louisiana, eastward across the Mississippi, Alabama, and northwest Florida coasts to St. Marks. Gale warnings are now in effect elsewhere from Morgan City to Cedar Keys, Florida. Preparations against this extremely dangerous hurricane should be completed within the next few hours.

"Winds are increasing and tides are rising along the northern gulf coast from Grand Isle eastward. Gales have begun a short distance offshore and will be spreading inland over the warning area today and will reach hurricane force from southeast Louisiana across coastal Mississippi, Alabama, and extreme northwest Florida by late this afternoon or early tonight. Tides up to 15 feet are expected in the area where the center crosses the coast and tides of five to 12 feet elsewhere in the hurricane warning area. Evacuation of the low-lying area that will be affected by these tides should be done as early as possible today before escape routes are closed. Present indications are that the center of Camille will pass close to the mouth of the Mississippi River late this afternoon and move inland on the Mississippi coast tonight." At 9 a.m., the hurricane was located near latitude 27.4 North and longitude 88.4 West or about 200 miles southeast of New Orleans, moving north-northwest at about twelve miles per hour. Highest winds were estimated at about 160 miles per hour near the center. Hurricane force winds extended outward 50 miles, gales 150 miles from the center. Camille then was under the surveillance of radars at New Orleans, Pensacola, and Apalachicola.

A bulletin issued at 1 p.m. CDT on Sunday, Aug. 17, repeated the fact that Camille was extremely dangerous and moving toward the mouth of the Mississippi River, repeated the areas of watch and warning, and stated that "several tornadoes are likely over extreme southeast Louisiana eastward to Fort Walton, Florida, and up to 100 miles inland this afternoon and tonight." Advisory Number Sixteen, issued at 3 p.m. CDT Sunday, Aug. 17, discontinued warnings east of Apalachicola and continued warnings at New Orleans and Grand Isle, Louisiana, eastward across the Mississippi, Alabama and northwest Florida coast to Apalachicola. It pointed out that winds were increasing and tides rising along the northern gulf coast from Grand Isle eastward. It urged immediate evacuation of areas affected by tides, and repeated the other warnings. An Air Force reconnaissance flight into Camille Sunday afternoon, the advisory stated, estimated the winds at 190 miles per hour near the center with hurricane force winds extending outward 60 miles and gales outward 180 miles from the center.

On Sunday, Aug. 17, at 5 p.m. CDT Advisory Number Seventeen was issued. It stated:

"Hurricane warnings are in effect from New Orleans and Grand Isle, Louisiana, eastward across the Mississippi, Alabama, and northwest Florida coast to Apalachicola. Gale warnings are in effect from Morgan City to Grand Isle. Preparations against this extremely dangerous hurricane should be completed before dark.

"Winds are increasing and tides are rising along the northern gulf coast from Grand Isle eastward. Hurricane force winds are now occurring at the mouth of the Mississippi River. Gales in squalls are spreading inland over the warning area and winds will reach hurricane force over much of the area from southeast Louisiana across coastal Mississippi, Alabama, and into extreme northwest Florida later this afternoon or by early tonight. The following tides are expected tonight as Camille moves inland: Mississippi coast, Gulfport to Pascagoula, 15 to 20 feet. Pascagoula to Mobile, 10 to 15 feet. East of Mobile to Pensacola, six to 10 feet. Elsewhere in the area of hurricane warning east of the Mississippi River, five to eight feet. Immediate evacuation of areas that will be affected by these tides is advised.

"The center of Camille is expected to move inland on the Mississippi coast near Gulfport early tonight. Several tornadoes are likely over extreme southeast Louisiana eastward to Fort Walton, Florida, and up to 100 miles inland through tonight. Any flood statements needed will be issued by the local Weather Bureau offices. . . ."

A bulletin issued at 7 p.m. CDT on Sunday, Aug. 17, added that heavy rains with local amounts eight to ten inches would spread into southeast Mississippi, southwest

continued

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3

A Coast and Geodetic Survey aerial reconnaissance mission photographed the hurricane-devastated gulf coast. 1, 2. At Biloxi, Miss., Camille tossed buildings from their foundations and left yards and streets strewn with rubble. 3. At Gulfport, Miss., three freighters were beached by the storm.

Alabama and the Florida Panhandle that night. At that time, the center of Hurricane Camille was located by New Orleans and other land-based radar near latitude 29.5 North, longitude 89.1 West, or about 70 miles east-southeast of New Orleans and 60 miles south of Gulfport, Mississippi, moving north-northwest about 15 miles per hours. Highest winds were estimated at 190 miles per hours with hurricane force winds extending outward 60 miles and gales 180 miles from the center.

Advisory Number Eighteen was issued at 11 p.m. CDT on Sunday, Aug. 17. It reported Camille moving inland near Gulfport, Mississippi. It repeated the hurricane warnings and urged precautions be continued. It stated that hurricane force winds were then occurring over most of the warning area. It again forecast heavy rains and tides.

It said that "those in the path of the eye are reminded that the winds will die down suddenly if the eye passes over your area but the winds will increase again rapidly and from the opposite direction as the eye moves away. The lull with Camille will probably last from a few minutes to one-half hour and persons should not venture far from safe shelter. Hurricane Camille has begun to fill and will weaken quite rapidly as it continues northward through Mississippi at about 15 miles per hour tonight and Monday. Winds and seas will gradually diminish Monday as Camille moves away from the coast. Warnings will be discontinued Monday."

At 1 a.m. CDT on Monday, Aug. 18, a bulletin was issued at the time when Camille was battering the Mississippi coast and heading inland. It reported that hurricane winds were occurring from extreme southeast Louisiana eastward across the Mississippi coast with a few squalls to hurricane speed likely across coastal Alabama into northwest Florida. Tides were running ten to 20 feet above normal on the Mississippi coast and five to ten feet elsewhere from southeast Louisiana to northwest Florida. It cautioned that several tornadoes were likely that night within 100 miles of the coast in the area of southeastern Mississippi eastward to Fort Walton Beach, Florida.

At 1 a.m., the center of the hurricane was located by New Orleans and other land-based radars near latitude 30.6 North, longitude 89.5 West or 10 to 15 miles east of Picayune, Mississippi. Highest winds were estimated at 140 miles per hour near the center along the Mississippi coast. Keesler Air Force Base at Biloxi reported 20-foot tides and 125- to 150-mile-per-hour winds at 10:30 p.m. CDT the previous evening. A 3 a.m. bulletin repeated the advisory.

At 5 a.m. CDT, Monday, Aug. 18, Advisory Number Nineteen was issued. It found the hurricane continuing to weaken, and predicted a more rapid weakening as the storm moved northward through Mississippi at about 15 miles per hour. An 8 a.m. bulletin said warnings along the northern gulf coast would be discontinued at 11 a.m. CDT. Highest winds at that time were estimated at 80 miles an hour, tides were falling along the coast, and many areas were still inundated. Winds and tides were forecast to continue diminishing through the day. Heavy rains with local accumulations of five to eight inches were expected in northern Mississippi that day and evening, and heavy rain was predicted to spread into western Tennessee and western Kentucky that night and the following day.

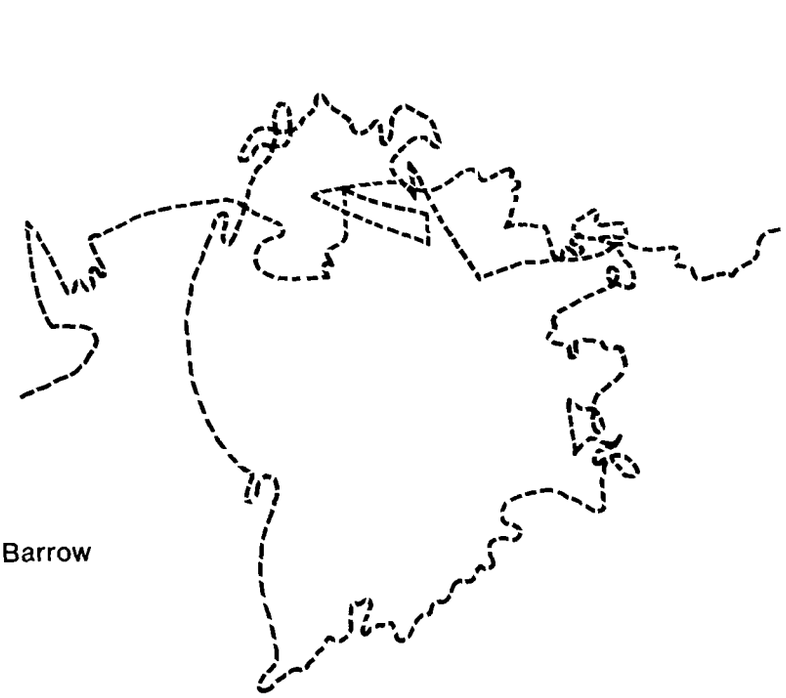
Advisory Number Twenty was issued at 11 a.m. Monday, Aug. 18, CDT. It was the final advisory on Camille. It reported the storm continuing to weaken as she moved northward through central Mississippi.

Warnings were discontinued along the northern gulf coast at 11 a.m. CDT. It reported tides falling along the coast, with many areas still inundated. It stated that winds and tides would continue to diminish that day and night. □

ANADYRSKOYE OSKOGORYE

Weathermen work on an island of ice

ADRIFT ON ARCTIC SEAS



Ice island T-3 has wandered erratically around the Arctic Ocean since 1952, when it first became a floating platform for geophysical studies.

ARCTIC OCEAN

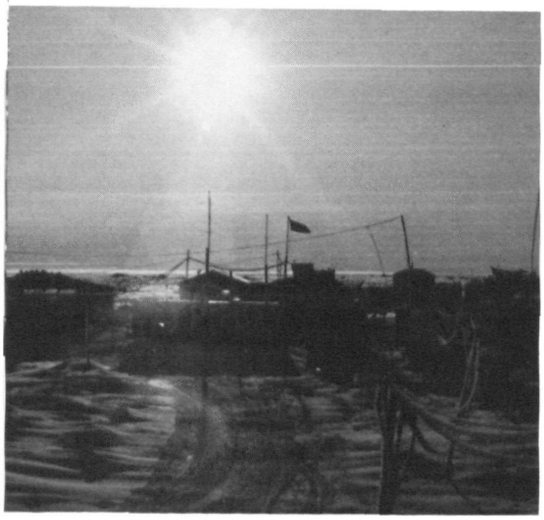
ELLESMERE ISLAND

GREENLAND

ALASKA

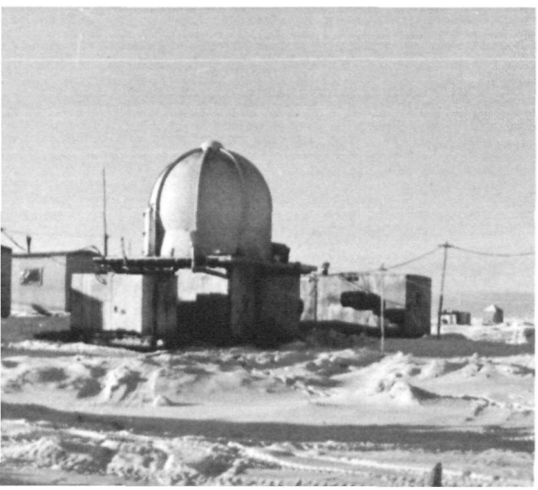
BAFFIN BAY

In summer patches of ice dot the sea.



The scientific base near T-3's coast.

Melting snow leaves buildings high and dry.



Weather facilities on the island.

ADRIFT ON ARCTIC SEAS

It drifts along, spinning slowly, crashes into land and frees itself, tearing itself to pieces bit by bit as it travels a tortuous path near the North Pole. That's T-3, a floating ice island.

On this 22½-square-mile chunk of drifting ice, 23 men divide their time between scientific missions and basic survival in one of the most inhospitable climates on earth.

The Weather Bureau is there.

Three members of the Bureau's Overseas Operations Division are among the scientists, technicians, and other station personnel who live and work on T-3. The program they conduct isn't particularly unusual for Weather Bureau employees. They make and record surface and upper-air observations, just as it's done at hundreds of other Weather Bureau stations. They also take special ozone soundings and measure surface ozone and radiation. What *is* unusual is T-3 itself and the reasons why these men are, even now, floating through the Arctic night on an iceberg.

There is evidence that T-3 was once a part of an ice shelf which juts from the northernmost part of Ellesmere Island in Canada's Northwest Territories. When it broke away from the ice shelf (probably not before 1935), it was about seven times larger than it is today. Constant erosion has shaved it to its present 3 by 7½-mile dimensions.

T-3 was photographed from the air in 1947, but for all practical purposes was "lost" until 1949 when, on systematic Air Force weather reconnaissance flights, it became a common enough landmark on radar to earn the designation "T (for Target)-3."

In 1952, a camp was set up on the island under the direction of Lt. Col. Joseph O. Fletcher (T-3 is often referred to as Fletcher's Ice Island), to learn more about the nature of the island and the area through which it would drift.

The Air Force conducted geophysical investigations and upper-air weather studies on T-3 until 1954, when the island was abandoned because it had drifted close to the continental weather stations of the Canadian Arctic. A small scientific party (including a Weather Bureau observer) reoccupied T-3 during the summer of 1955; then it was again abandoned.

With the International Geophysical Year, T-3 again became a floating platform for scientific investigations in the Arctic. Two other ice stations were established for the IGY, but both broke up (one so suddenly that all equipment was lost). During this period (1957-1959), T-3 was known as Station Bravo.

After a brief suspension of operations, T-3 was again occupied, but only for a little more than a year. This time, T-3 was abandoned because the ice island had been grounded off the Queen Elizabeth Islands. There it sat until 1962.

T-3 was stuck, but Arctic research continued. In 1960, the Arctic Research Laboratory (ARL), a research and logistic support activity of the Office of Naval Research, established the first of four drifting stations in the Arctic. These were identified as ARLIS (for Arctic Research Laboratory Ice Station) I, II, III, and IV. ARLIS I, III, and IV were placed on ice floes for special short-term investigations. ARLIS II was on an ice island which was continuously occupied from 1961 to 1965, when it was abandoned after drifting out of the Arctic Basin almost to Iceland.

In 1962 T-3, as if tired of being out of the action, began to move again. The Navy obligingly came aboard and used the island primarily as a forward staging area for the flights supporting operations on ARLIS II.

In 1965, the ARL shifted operations from the southbound ARLIS II to T-3 and invited the Weather Bureau to carry out various research programs there. The Bureau accepted, and in 1966 the Overseas Operations Division began its present program.

What's it like on T-3 weatherwise?

Well, it's cold, naturally. Temperatures seldom are above freezing and can go below −60°F. Surface winds are usually gentle, but the prevalence of comparatively light winds is deceptive. At the low temperatures on T-3, any wind over five miles an hour can cause considerable discomfort to personnel engaged in outdoor activity. Polar explorers have regularly commented on the persistent, dark, low-overcast skies found during the summer months, and T-3 is no exception. Precipitation is light but quite frequent on the island. Snow blowing into collectors makes it hard to measure actual falls. Winter snows may be as little as two inches.

Weather Bureau tours on T-3 are for six months. The living isn't easy, but there are compensations. For one thing, pay is good.

With 25 percent "differential" and the 16 hours' overtime allowed per pay period, an electronics technician at the Grade 9 level could make about $6,500 during his six-month stay on T-3. Food, quarters, and polar clothing are provided at no expense.

(Left) An aerial view of the base camp. In winter the coast is hard to distinguish from sea ice. (Above) When melting left it perched on a block of ice, the operations building at T-3 International Airport was relocated.

Weather Bureau personnel on ice island T-3 take surface and upper-air observations, as well as special ozone soundings and surface ozone and radiation measurements. (Above) Preparing to launch a balloon.

There's not much to spend your money on up there, so a man could salt away a pretty good nest egg for his return to the States.

Indoors, things are made as comfortable as possible. There are books, games, and movies. Navy chow is famous, of course, and the best frozen and, when possible, fresh foodstuffs are provided.

A man earns his board and keep on T-3, though. Along with the fierce Arctic cold, which limits outdoor working time no matter how well a man is bundled up, the island itself can be treacherous.

Radio message from Station Manager, T-3, August 2, 1963—

I regret to report that Weasel #490 was lost this morning at 1030 ADST. I was driving through a melt pond just off the Island on Colby Bay—a pond that only two days ago was 18 inches deep. The bottom of the pond simply gave away, sucking the Weasel and me down with it. When the water level got to my chin, I figured it was time to give up efforts to save it, and I bailed out. My thumb was broken in the process, but Damon put a cast on and it feels o.k. No other personnel were with me.

What the Station Manager, John Barwis didn't say in this laconic message to his boss, Dr. Max Britton of the Office of Naval Research, was that the windshield of his oversnow vehicle (Weasel) collapsed in on him and, with his feet mixed up with the pedals, he came very close to a nasty death on the floor of the Arctic Ocean.

While T-3 is more than 150 feet thick in some places, the scientific party is based on relatively thin ice near a coast (the island revolves so there is no north end or west side).

During the same month that Barwis broke his thumb, the T-3 operations building had to be shifted to firmer ice because of rapid melting conditions.

Whether it's money, the lure of adventure, scientific curiosity, or some other attraction, there isn't too much trouble recruiting personnel for this exotic assignment.

Weather Bureau men currently serving on T-3 are:

Bennie P. Lightsy of Louisville, Ky., is technician in charge of the meteorological program. Along with administrative duties, he helps take the surface and upper-air observations.

Lynn J. Winans of Montrose, Pa., is a meteorological technician. His job is to make the weather observations, which consist of three- and six-hourly observations and upper-air soundings with rawinsondes. He may also carry out special studies such as radiation investigations.

Domingo A. Gomez of San Antonio, Tex., is in charge of maintaining the Weather Bureau's equipment. An electronics technician, Gomez must install, calibrate, and repair equipment ranging in complexity from standard weather observing instruments to the GMD-1A, the radio-direction-finding system used to obtain data from balloon-borne rawinsondes. He also assists with the upper-air observations.

These men, together with everyone else at at the station, participate in such camp chores as snow removal, cargo handling, and kitchen chores (KP!).

The living isn't easy on an ice island, but today's science is seeking answers to questions that weren't even thought of 20 years ago. With men attempting to live on the bottom of the sea or flying around the moon, perhaps T-3's Arctic odyssey isn't so strange after all. □

The search is on for

The Lost Maps of the American Coast

An 1855 engraving depicted the discovery of North America by John and Sebastian Cabot.

BY FERGUS J. WOOD
Coast and Geodetic Survey

DURING the summer of 1856, Dr. Johann Georg Kohl, world traveler, geographer, cartographer, historian, and German *savant extraordinaire*, on a visit to America, wrote for the edification of Washingtonians an article entitled, significantly, "Lost Maps." It described, in a fascinating and authoritative fashion, the great missing maps of history—documents that had turned the course of human events but which were lost to mankind.

His treatise appeared in the *National Intelligencer* on September 9 of that year, obscure among news of territorial war in Kansas, a circus "Apollonicon" drawn by 40 horses collapsing a bridge in Fort Wayne, Indiana, and a letter to the editor advocating standard time.

Ironically, certain of Kohl's own monumental contributions to geographic knowledge, prepared between 1855 and 1857 for the Coast Survey, today constitute a magnificent, missing cartographic prize—a prize which has become the object of an intensive search spearheaded by the Coast and Geodetic Survey and actively supported by learned societies, museums, academic institutions, libraries, and individual scholars across the nation.

Born in 1808, Kohl was brought up in Bremen, Germany, and attended the Universities of Göttingen, Heidelberg, and Munich. He traveled widely over the continents of Europe and Asia and wrote extensively concerning their geography. For some five years, during his visits to the large libraries and museums of Europe, he investigated the historical aspects of knowledge relating to the exploration of the New World, with special attention to the history of discovery of the North American continent.

A man to whom the search for new geographic knowledge was synonymous with pure exhilaration, Dr. Kohl realized that his project of five years in the investigation of the historical geography of North America could only be met by travel in the region he was studying. Accordingly, on September 7, 1854, he embarked aboard the steamer *City of Manchester* for Philadelphia—a voyage which in those times consumed 19 days.

After traveling to Canada along the shores of Kitchi-Gami (Lake Superior) and to the Far West, he returned to Washington in late 1854. Culture seeks culture and knowledge courts knowledge, and Kohl made the friendship of Dr. Alexander Dallas Bache, the first president of the National Academy of Sciences, Superintendent of the Coast Survey, founder of Girard College in Philadelphia, and great-grandson of Benjamin Franklin.

Professor Bache persuaded Kohl to lend his services to the Government's survey organization, then known simply as the U. S. Coast Survey, in a project for assembling all existing knowledge on the history of the exploration of the west coast of the United States. In his characteristic meticulous fashion, Kohl subsequently augmented this project to include, in addition to a historical account of early exploration, a large-scale descriptive map showing progressive states of cartographic knowledge of the west coast, a catalog of all known maps of the coast, an assembly of notes describing these maps, a description of all bays, harbors, channels, inlets, coves, and estuaries along this coast, a descriptive orthography of the names given to points along this coast, a catalog of all known historical charts relating to this area, and a complete bibliography of books relating to discoveries along this coastline.

So useful was this cartographic and hydrographic endeavor covering the west coast that he was subsequently requested by Bache to prepare similar compilations for the gulf and east coasts. The general title of these three works was "History of the Discovery and Exploration of the Coasts of the United States."

Dr. Kohl was admirably well prepared. During the years of his previous travel and study, he had painstakingly handcopied—from original sources in the largest libraries and museums of Europe—numerous very early maps showing the gradual development of knowledge of the North American coastline. This collection of hand-executed maps he had brought with him to America. They greatly facilitated the preparation of his historical manuscripts dealing with the exploration of the coastlines of the United States.

In payment for his studies for the Coast Survey, Dr. Kohl received $1,000 for the preparation of the west coast manuscript, $1,000 for the gulf coast manuscript, and $2,000 for the east coast manuscript. Recognizing the value of his cartographic collection, the Congress in 1856 appropriated $6,000 to establish copies of these maps in America, a munificent sum in those days. The payment was authorized for the further hand-reproduction of 474 maps from his European collection.

The maps were originally secured for the State Department at the instance of William Learned Marcy, Secretary of State. During the Civil War, the entire collection came temporarily under the custody of the War Department, was stored in a troop billet, and came very close to being destroyed. On July 17, 1903, they were transferred from the Bureau of Rolls and Library, Department of State, to the Division of Maps and Charts, Library of Congress.

Plans had been made by the Superintendent of the Coast Survey to publish Kohl's manuscripts. But the financial panic of 1857 intervened, the annual appropriation by Congress to the Coast Survey dropped by $20,000 between fiscal years 1857 and 1858, and publication plans fell by the wayside. Dr. Kohl managed to secure the publication of minor portions of his original manuscript in the *National Intelligencer* for September 22 and 24, and October 8, 14, and 20, 1857, but these represent the only parts of his original manuscripts ever reproduced intact.

Twenty-seven years later, in 1884, the then Assistant to the Superintendent of the Coast and Geodetic Survey, and editor of the *Annual Report of the Superintendent*, Edward Goodfellow, partially discharged a debt to history by retrieving Kohl's manuscript from oblivion. He prepared a vastly abridged version of the historical portion of Kohl's total ten-part memoir on the west coast, and published this segment, and similarly abbreviated sections on the gulf coast and east coast, as Appendix 19 of the *Annual Report of the Superintendent* for 1884. Not one of Kohl's original maps which had been especially prepared to accompany his reports was ever reproduced.

For another 81 years, the voluminous three memoirs lay dormant, their carefully drawn group of maps unused and almost forgotten. This situation continued until 1965, when several inquiries were almost simultaneously received in the Coast and Geodetic Survey from interested persons in New Jersey, motivated in part by historical projects in connection with the 300th anniversary of the first permanent settlement in the State of New Jersey in 1664. Several historians noted the reference to the Kohl manuscript in the *Annual Report of the Superintendent* for 1884 and wrote to the Coast and Geodetic Survey regarding the availability of those portions of the Kohl report dealing with the historical origins of the names of bays, harbors, rivers, and inlets of New Jersey.

The search to locate and assemble the very numerous components of the missing manuscript commenced—and ran headon into problems presented by the passage of years. Clues were sought on every front to the location of the individual parts of the manuscript, which had apparently become separated over the years. The original archive records of the Coast and Geodetic Survey were thoroughly searched. Related library-archive references to subsequent official loans and temporary dispositions of parts of the manuscript were followed to their nonproductive conclusions. Kohl's publications in German after returning to his homeland were scrutinized for possible mention of any later disposition of the manuscripts. His published letters to the editor of the Washington *National Intelligencer* over subsequent years were similarly studied. Memorials to his cartographic achievements and writing efforts, published by various geographic societies after his death in 1878, were scanned for possible clues. Inquiries were directed to historical and cartographic societies, universities, and Government agencies to which portions of the manuscript might subsequently have been loaned. Bibliographies listing the holdings of geographic research libraries were systematically scanned.

Progress was discouragingly slow at first, but bits and pieces of a jigsaw puzzle already more than 110 years old began to fall into place—culminating in some interesting findings during this past year.

The initial discovery of the historical portion of the west coast report in the C&GS library-archives was followed by location of the gulf coast historical narrative and miscellaneous other sections of the Kohl report in the Manuscript Division of the Library of Congress. Thus far, however, the corresponding east coast historical section and nine additional portions of the total report have not been recovered. With the full cooperation of the Library of Congress, other missing segments of the total report were unearthed among the collections of the Geography and Map Division.

One of the most interesting disclosures from the latter search endeavor resulted in an entirely new concept in connection with Kohl's productive work. It had been generally accepted that the maps officially designated as the Kohl Collection of the Library of Congress contained, and represented a more substantial collection of, the maps which Kohl had intended should accompany his manuscript report for the Coast and Geodetic Survey.

Now came the revelation that there existed a second set of historical maps compiled by Kohl, rivaling the first for the neatness of their presentation and the accuracy of their cartography. In a drawer among the rare map files of the Library of Congress, quite distinct from the official Kohl Collection, were found the miniaturized maps Kohl had prepared as part of his definitive study for the Coast and Geodetic Survey. A direct comparison with corresponding items in the official Kohl Collection reveals the particular value of the smaller collection. The latter maps represent enlarged sections (pertaining only to the American coastlines) hand-copied from the same original sources used in construction of the original State Department maps.

Various stages of map preparation, showing the perfection of this cartographer's endeavors—and the similar efforts of the C&GS map draftsmen with whom he worked—were also found with this collection. These include several unfinished drafts containing pencil sketches, sample cartouches, vignettes, and rough notes.

Up to the present, the portions of the Kohl manuscript located from various sources comprise over 3,000 handwritten folio pages, stacking nearly two feet tall, and equivalent to more than a million words—all completed in less than two years.

Unquestionably, the lapse of time since Kohl prepared his various manuscripts has dimmed their substantive value in terms of subsequently derived knowledge. It is not, however, the weakness (seen in the light of today's knowledge) of Kohl's often only-intuitive interpretations that should be considered, but rather the strength of his factual contributions to the geography and cartography of his period. For only through such pioneering effort could our present awareness of geographic discovery have evolved.

From a historical standpoint, his contemporary information on the early settlement of the American coastlines—together with his research into the then more readily available origins of their geographic names—offer an invaluable contribution to learning. From the viewpoint of hydrography, his faithful descriptions of harbors and coastal features are, with a few exceptions, such as Blunt's *Pilots*, without contemporary parallel. His compilations of bibliographies relative to the history of discovery of the

continued

coastlines, his catalogs of maps, and the comprehensive notes on his own collections of maps, provide limitless resource material. Added to all this is the fine accuracy of his cartographic representation in the historic maps he so carefully reproduced.

The great value of Kohl's reproduced maps lies not alone in the fact that they were assembled from widely scattered original sources, but that they were made available in this country at all. In 1856, the Kohl Collection of historical maps represented the only really comprehensive collection of hand-copied or facsimile maps which existed in America derived from original sources in the leading libraries and museums of Europe. Their existence filled a gap in available reference information for American geographers, historians, and cartographers of the late 19th century. This consideration bears an appropriate place in any assessment of the pronounced increase in the development of geographic knowledge and the much more detailed representation of the cartographic features of the United States which occurred during this period and the one immediately ensuing.

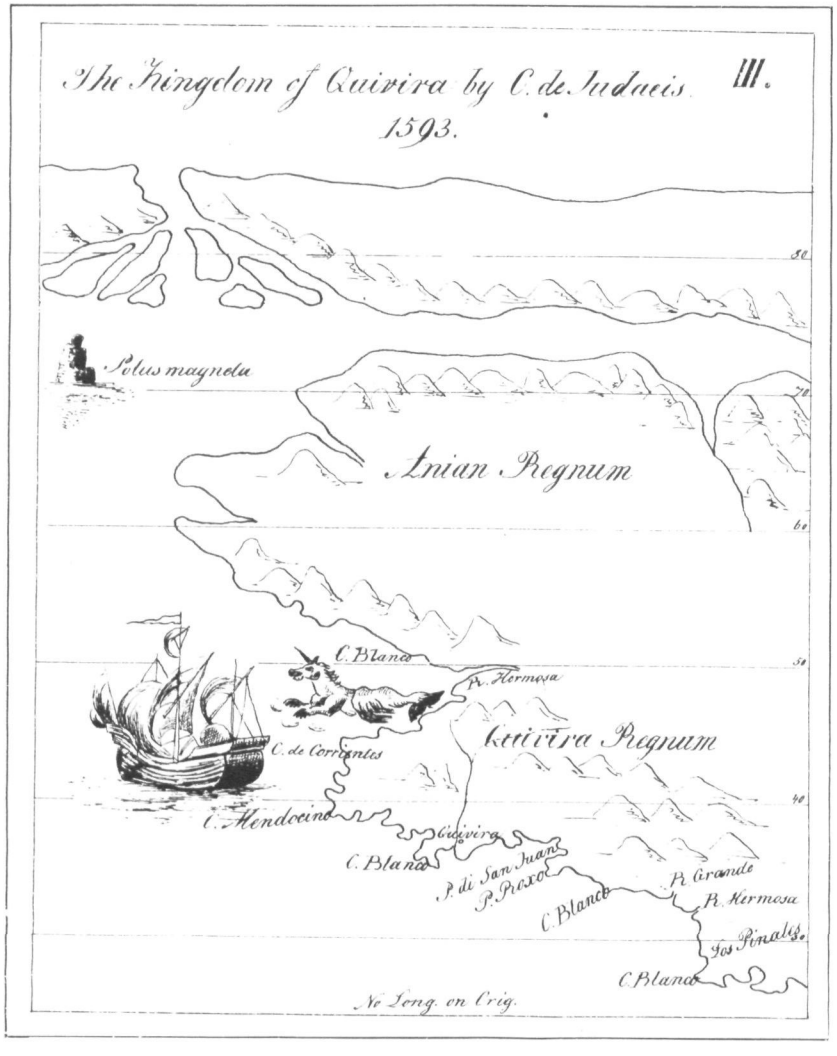
A critical comparison of Kohl's maps with facsimile copies of some of the original manuscript maps which, over the intervening years, have reached this country from the libraries of Europe reveals the painstaking accuracy with which he depicted geographic features and the integrity of his cartographic endeavors. This attention to detail included the reproduction of even such minor map elements as vignettes which appeared on the original charts.

DR. JOHANN GEORG KOHL

Before coming to the United States, Kohl hand-copied many historical maps of the North American coastline. (Left) Cornelius de Judaeis' 1593 map of the west coast of North America. (Right) Kohl outlined the principal features of de Judaeis' map.

One of the great geographic controversies which raged throughout the 17th century and into the early 18th century was whether California was a peninsula or an island. In his famous world map of 1560, Jacobi Gastaldi had depicted California in its correct relationship as a peninsula, although he also connected North America directly with Asia. Kohl copied the west coast portion of this world map accurately as one of the maps in his series. On the other hand, in Nicolas Sanson d'Abbeville's map of 1656 California was represented as an island.

The Office of the Director, Coast and Geodetic Survey, plans to reproduce, by microfilm and xerographic means, the available portions of Kohl's historical account of the explorations of the coasts of the United States. All of Kohl's original maps prepared for the Coast Survey are being photographically copied.



(Below) In Nicolas Sanson d'Abbeville's map of 1656, California was represented as an island. (Above) Kohl copied a portion of Sanson's map. Illustrations courtesy of the Library of Congress.

In replying to letters of inquiry from the Coast and Geodetic Survey regarding the worth of this endeavor, thirty-nine persons representing a wide segment of the geographic, historic, and scientific communities—including research scholars at Yale, Harvard, Princeton, and Columbia universities—have variously endorsed the aims of the project. The project has also received encouragement and cooperation from the Library of Congress.

A complete catalog of the 29 portions of the original Kohl memoirs, and a collation of his maps with original sources both in manuscript form and in print, will form a part of this effort—as well as a critical comparison of representative Kohl maps with original source materials from which they are derived. Also included will be a detailed summary of his life and accomplishments which, although recounted in German professional journals, never have been definitively treated in American reference sources.

In keeping with the strong principles of accuracy and professional integrity in presentation which Kohl himself adopted, it has been decided that—except for necessary changes to make the German idiom intelligible, and certain interpolations made necessary by fading of the original pen-and-ink manuscript over the course of 112 years—the substance of Kohl's memoirs will be preserved intact, with explanatory footnotes only where necessary.

Dr. Kohl was fiercely devoted to his task, and completed the entire 29-part handwritten manuscript in English—together with three parts comprising 144 reduced maps—in 22 months of tenure with the Coast Survey. In addition, he finished an entire book titled *Travels in the Northwest of the United States* during three months in New York after he had finished the west coast report for the Coast Survey and before he was asked to undertake the gulf coast and east coast portions. While in Washington, he prepared numerous popular articles on geographic and cartographic subjects for readers of the *National Intelligencer* and became a principal party in a newspaper debate on the true origins and orthography of the name "Maryland." In 1856, he presented a strong verbal plea for the establishment of a national "Chartographic Depot" to serve as a repository for all maps on the discovery and exploration of the United States. The plan for this national facility was described before a receptive audience at the Smithsonian Institution, and was subsequently published in the *Annual Report of the Smithsonian Institution* for 1856. His book on *History of the Discovery of the East Coast of North America,* published in 1869, was referred to in 1886 by Justin Winsor, the eminent historian of Harvard University, as "the most important single contribution to the history of the discovery and cartography of our Eastern coast." □

The weatherman gets invaluable assistance from

THAT GALLANT BAND OF TWELVE THOUSAND

BY CHARLES G. THOMAS
Weather Bureau

(Left) The weather station and a few sheds are all that remains of Fremont. (Above) Mrs. Branch carries on the observing program.

No one lives in Fremont, Oregon.

There's no post office, no school, no store; in fact, only a few outbuildings remain where once a small community of homesteaders struggled to farm the thin surface soil.

If one stands on the site of the last home in Fremont, which was destroyed by fire in 1962, there is no sign of human habitation as far as the eye can see. Fremont, the town, is no more.

But it still exists. The Environmental Data Service can tell you what the average temperature was there last month. It can tell you how cold it was on January 15 and how hot it was on July 4. It knows how much rain fell there on March 27 and will be able to tell you how much snow falls there next Christmas.

For Fremont, Oregon, is not totally desolate. There, perched near the flame-charred ruins of the last house, is a Weather Bureau instrument shelter enclosing several thermometers. Close by is a rain gage. Why these instruments are there and how they mark the past and perhaps the future of Fremont is part of a much bigger story . . . the story of more than 12,000 citizen weather observers whose work provides a detailed description of the nation's climates.

In the early 1900's, Fremont was a small farming community of homesteaders. There was a school, a post office, a store, and a cluster of houses. Nature was harsh to the little group of farmers. There were only nine or ten inches of rainfall each year—and most of that was in the winter. Temperatures could go as low as 15 degrees above zero in mid-July. A plentiful supply of water was available, but it was underground —as far as 250 feet straight down through solid lava rock.

One of the early leaders of the Fremont settlement was William Dehne, a veteran of the Spanish-American War who had been wounded in Cuba but recovered in time to fight in the Philippines. The Dehne family eked out a living with the rest of Fremont. They built their cabins, dug their wells by hand, and tried to raise crops. But Fremont couldn't make a go of it. One by one the settlers gave up and moved away until, in 1939, only the Dehnes were left.

As early as 1918 Mr. Dehne, realizing the need of weather records to appraise better the type of agriculture that might succeed in the area, asked the Weather Bureau if he might set up a cooperative weather station at his home. The Bureau gladly agreed, and Dehne operated his station from March 9, 1918, until 1962, when a combination of fire and ill health forced him to retire.

This was the end of Fremont, the town, but not Fremont, the weather station.

Dehne's daughter, Venita, had inherited her father's love for this ruggedly beautiful country. She had married and, with her husband, Floyd Branch, lives in Fort Rock, a tiny village some seven miles from the site of her father's Fremont farm. Six days a week she carries mail from Fort Rock to the scattered ranches in the area, and her route takes her by the old Dehne ranch site.

Each month a complete, neatly kept weather record for Fremont goes forward to the Portland River Forecast Office, where the data necessary for the water-supply forecast is extracted before the form is sent on to the National Weather Records Center in Asheville, N. C., for publication in the Oregon Climatological Data sheet.

Thus, the name of Fremont still survives, and month by month it is documented in the official publications of ESSA.

Oregon State Climatologist Gilbert L. Sternes, who tells this story with some pride, looks to the future of the Fremont area saying, "Today land-hungry people from the south and east are again looking at that part of Oregon as a potential for development. It is quite possible in the near future that the dream of Mr. Dehne and the other homesteaders of a permanent and prosperous community will be realized. If it is, the need for a well-documented climate of the area can be met because of William Dehne and his daughter, Mrs. Venita Branch."

The story of Dehne and his daughter and the town that isn't there illustrates why phrases like "dedicated," "devotion to duty," and "public-spirited" keep cropping up when the Weather Bureau's cooperative observers are discussed.

From earliest times, man has always observed and commented on the weather around him. Anyone who has ever said "It looks like it's going to rain" is practicing meteorology and, on a personal scale, imitating the Weather Bureau's major functions—observing, forecasting, and disseminating weather information.

Success in weather forecasting, however, is enhanced by systematic observations. Also, you can't describe the climate of a place from casual observations. (For example, in June 1915, the temperature at Fort Yukon, Alaska, reached 100 degrees. Fort Yukon's climate, therefore, is not unlike that of West Palm Beach, Florida.)

The first systematic weather observations in the New World began only 24 years after the signing of the Mayflower Compact when, in 1644 and 1645, the Reverend John Campanius Holm kept a diary of the daily weather at Fort Christina near the present site of Wilmington, Del.

Now, 325 years later, there are 12,000 weather "diarists" whose work, it has been said, is one of the most extraordinary services ever developed anywhere and probably nets the public more per dollar expended than any other government service in the world. These are the Weather Bureau's cooperative observers who, in exchange for instruments and guidance from the Weather Bureau, take and record daily observations.

They are from all walks of life. They are farmers, bankers, storekeepers, ministers, newspapermen, chemists, postmen, teachers, retirees—it would be difficult to find an occupation not held at one time or another by these volunteer weathermen.

Take Leslie J. Anderson, the cooperative observer at Manti, Utah. He's the town's mayor. He's an active churchman. He's County Civil Defense Director. He's a member of the Governor's Planning Committee. He's County Democratic Chairman. A busy man, to be sure, but the records show that throughout 61 years of weather observations, begun in 1908 by his father, J. M. Anderson, there never has been a missing month of record—a total of 736 continuous months of weather observations completed by this father-and-son team.

A long record, indeed. But the histories of these "substations," as the Weather Bureau calls them, abound in long periods of record.

The Rev. C. F. Williams started making unofficial weather records at Ashwood, Tenn., in 1856. (The "unofficial" status of his records is not surprising; the national weather service would not be established until 14 years later.) His records became official in 1883. In 1893, is son, C. D. Williams, took over the observer duties. In 1896, the Rev. Williams' daughter, Mrs. Myrna Fleming, became the observer and served until 1939. Mrs. Fleming's son, Thomas, took over in 1939 and has been the Weather Bureau's observer since then. One hundred and thirteen years of weather records from the same home site!

Weather records, like antiques, tend to become more valuable the longer they're kept, and it's understandable that special appreciation is given the work of volunteers who have served for many years.

But the oldtimers have to share credit for the program's success down the line. The incredible record of Father Adelhelm Hess, who at the time of his death at 90 in 1964 had been the observer at Conception, Mo., for 70 years, is intrinsically linked to that of James H. Caldwell, for 15 months the observer at Tilford, Ky., who turned 12 last March.

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1. Leslie Anderson, observer at Manti, Utah, is mayor, civil defense director, and county Democratic chairman. 2. Mr. and Mrs. Thomas Fleming continue a 113-year family tradition. At right, Tenn. climatologist John Vaiksnoras. 3. William L. Groene, Scottsdale, Ariz., has equipment seldom found in substations. 4. Mrs. Emma Leach holds the record for service in Alaska. 5. 12-year-old James Caldwell, Tilford, Ky., may be the youngest observer.

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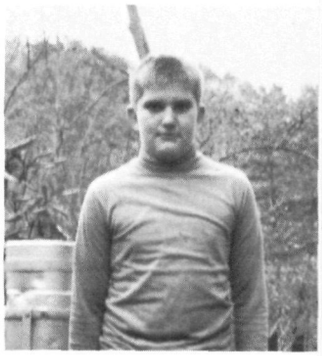


(In contrast to Father Hess' long service, one observer's career was cut short after only six months when he was caught stealing hogs. The pork rustler did not volunteer to take up his duties again after his debt to society was paid.)

Practical examples of how these observers' records are used range from multimillion dollar projects such as studies of snowmelt rates over a watershed for which dams are planned, to determining the need for company salesmen to have air conditioners in their cars. On a more personal basis, the records may help a couple select a retirement location or assist in the selection of a climate favorable to a particular health problem.

Most of the volunteer observers record daily temperature ranges and each day's precipitation—rain or snow. Others are asked to read river gages or make other special measurements. All observations are entered on a log and sent to the National Weather Records Center, where they are processed and become permanent records of the nation's climate.

Thermometers and a rain gage are not enough for Willard L. Groene, the observer at Scottsdale, Ariz. In addition to his regular weather observations, Groene is a member of the National Air Sampling Network for which he takes special observations on air pollution. He mans the Coast and Geodetic Survey's Mummy Mountain Seismological Station where earthquakes throughout the world are recorded. He also runs the Mummy Mountain Astronomical Observatory, recognized by the U. S. Geological Survey and the U. S. Naval Observatory in Washington, D. C.

Groene has had a consuming interest in the natural sciences for many years and most of his observations can be taken indoors with indicators remoted to the instruments themselves, as he has acquired (at his own expense) some rather sophisticated equipment.

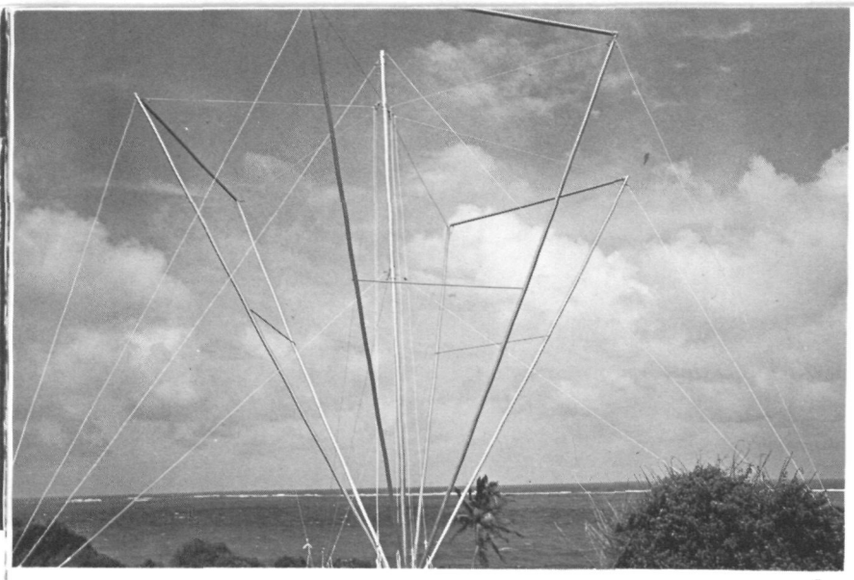
On the other hand, many stations are composed just of an instrument shelter containing a maximum-minimum thermometer set and a simple rain gage. (One observer, solicitous of his instruments—or perhaps his health—wrote the Weather Bureau a short note as follows: "I brought the gage in the house—will use it again as soon as weather conditions permit.")

The great majority of observers leave their instruments outside and tramp out in the most appalling weather conditions to read them.

Mrs. Emma B. Leach of Circle Hot Springs, Alaska (just 75 miles south of the Arctic Circle), has the longest length of service of any Alaska observer. Her records are remarkably complete in spite of below-zero temperatures seven months of the year. Her thermometers have fallen to minus 60 degrees.

The cooperation of individual observers is matched by other Government agencies and many firms and corporations which maintain substations for the Weather Bureau. A considerable proportion(perhaps 30 percent) of the cooperative weather stations are run by organizations such as radio and television stations, schools, the U. S. Forest Service, and public utility agencies.

Even with such modern technological tools as radar and weather satellites, the Weather Bureau has found that there is no substitute for the human observer. Multiply the individual by 12,000, and you have an invaluable network of dedicated volunteer weathermen from Alaska to the Virgin Islands—the Weather Bureau's Cooperative Observers. □



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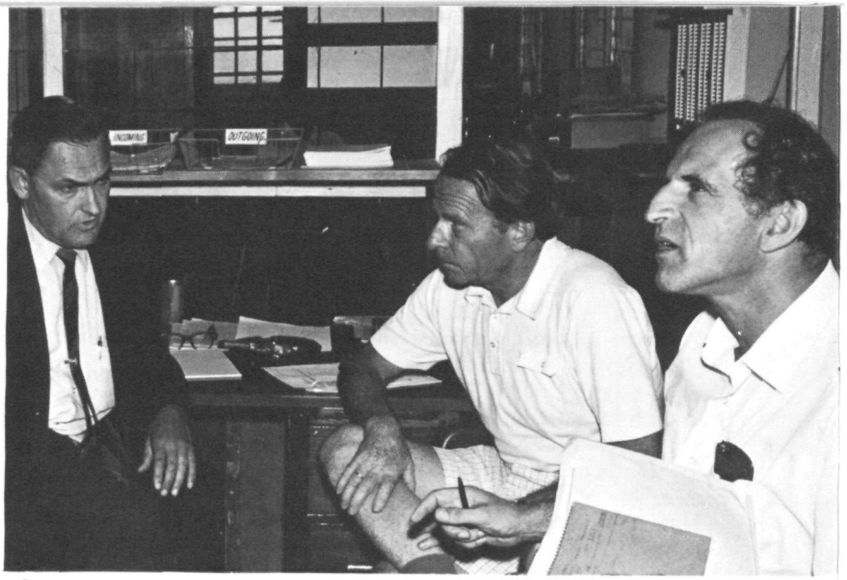

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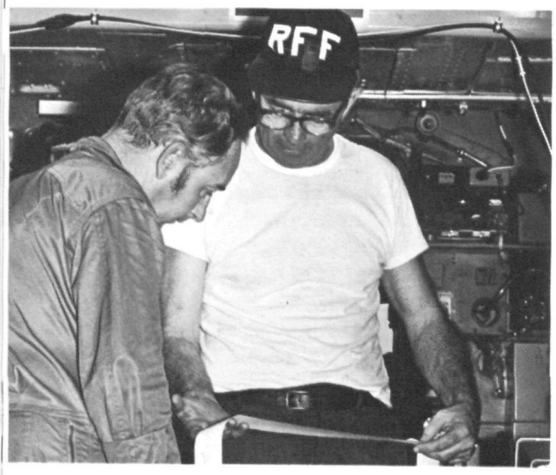

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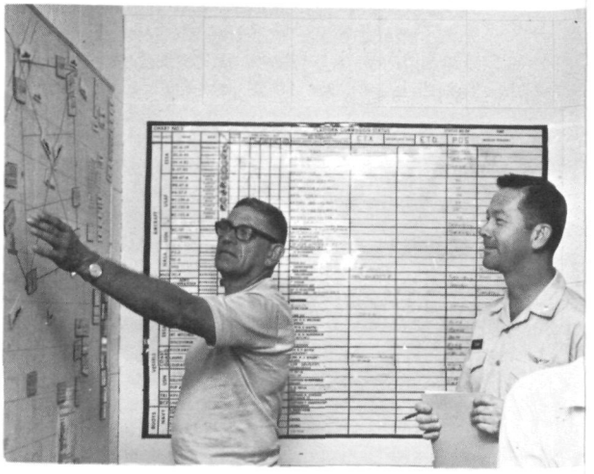

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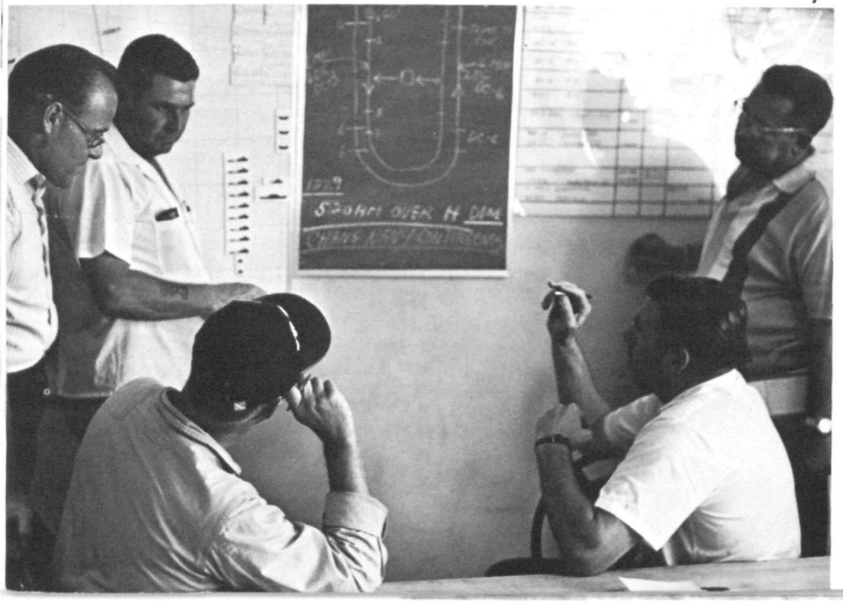
One phase ends, another begins in one of the most fascinating annals of science

THE BARBADOS STORY

BY ANN K. COOK



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THE FIRST CHAPTER in one of modern science's most exciting adventures ended on July 28.

For three months, a parcel of tropical sea and air was transformed into a scientific laboratory, as 1500 persons, fleets of ships and aircraft, several satellites, a dozen buoys, and a fantastic variety of instruments on land gathered data in the operational phase of the Barbados Oceanographic and Meteorological Experiment (BOMEX).

The most intensive scientific investigation ever made over a large ocean area, BOMEX is a national program made possible by the participation of seven Federal departments and independent agencies, 22 universities, and six industrial laboratories, and by the cooperation of the Government of Barbados. It was planned and coordinated by the Commerce Department's Environmental Science Services Administration, with Dr. Joachim P. Kuettner serving as BOMEX Director and William S. Barney as Project Manager.

From May 3 to July 2, the project took detailed measurements of the energy exchange between sea and air in a 90,000-square-mile area over the Atlantic east of Barbados. Dr. Joshua Holland of the Atomic Energy Commission was chief scientist for this aspect of the program.

In July, the emphasis shifted to a wide-ranging airborne investigation of tropical cloud systems, directed by Dr. Jule G. Charney of the Massachusetts Institute of Technology.

Now, a new chapter begins. For many months, the results of close to a hundred experiments included in the BOMEX program will be analyzed, to learn how energy enters the air from the tropical oceans and is dispersed throughout the global atmosphere. Ultimately, the knowledge of these physical processes acquired through the project will be applied to improving computer weather forecasts.

The volume of data to be analyzed and correlated is prodigious. Instrumented aircraft of the U.S. Air Force, U.S. Navy, Environmental Science Services Administration, National Aeronautics and Space Administration, National Center for Atmospheric Research, Colorado State University, Scripps Institution for Oceanography, and Woods Hole Oceanographic Institution flew more than a million miles on 509 research missions, continuously recording observations of a variety of weather elements.

The five primary vessels in the BOMEX ship array carried out 1316 soundings of ocean temperature and salt content. The ships and an island station operated by the Air Force's Air Weather Service launched and tracked 2367 upper-air sounding balloons to gather information on temperature, humidity, air pressure, wind speed and direction, and solar radiation to altitudes as high as 100,000 feet.

Already, preliminary examination of the BOMEX data is giving hints of significant additions to man's store of knowledge about the tropical air and sea.

According to Dr. Holland, leader of the sea-air interaction program: "It has become apparent that many concepts concerning the physical processes at work near the sea-air interface in the tropics will have to be revised."

Oceanographers found strong eastward-moving currents in the Atlantic off Barbados, where ocean atlases show predominantly westward flow.

Measurements of radiation taken at several levels revealed that perhaps twice as much incoming solar radiation is absorbed in the tropical atmosphere as had been believed. Thus, the amount of solar radiation available to heat the oceans is less than previously estimated.

The exploration of tropical convection systems produced evidence that the Intertropical Convergence Zone — the region where the northeast trades meet the southeast tradewinds—is probably the governing force in the tropical atmosphere and is closely linked with the development of tropical disturbances. On the other hand, the large cloud clusters appearing in satellite pictures, which scientists had assumed to be a major vehicle for upward transport of energy in the tropics, were found sometimes to be merely fields of high cirrus.

During the first two months of BOMEX, the project sought to trace the movement of energy through the air-sea interface into the tradewind layer of the atmosphere, by taking concentrated measurements in a fixed ocean square. The U.S. Coast and Geodetic Survey ships OCEANOGRAPHER, DISCOVERER, RAINIER, and MT MITCHELL were stationed at the four corners of the square, with the Coast Guard Cutter ROCKAWAY in the center position. Other vessels participating in this aspect of the program were the Coast Guard Cutters LAUREL and COURAGEOUS, the U.S. Navy Ship GILLISS, and the Cape Fear Technical Institute's SS ADVANCE II.

The 17 planes gathering data for the sea-air interaction study were the ESSA Research Flight Facility's two DC-6's and DC-4; four Navy C-121's; a Queen Air from the National Center for Atmospheric Research; Colorado State University's Aero Commander; Scripps Institution for Oceanography's DC-3; a C-54 from Woods Hole Oceanographic Institution; NASA's Electra P3A; and from the Air Force, two WC-130's, two WB-47's, and an RB-57F.

"Operationally, the sea-air interaction study was an overwhelming success," Dr. Holland said. "We had several periods of intensive observation spaced over the two months, which will provide some coverage of seasonal variations in weather and ocean conditions. Our tapes hold a unique and valuable set of data. Final conclusions will have to await reduction, analysis, and study of this data."

During the concentrated four-day observation periods, serial rawinsondes and dropsondes were made every day, and aircraft flew patterns around the ship array on three nights and two days. Boundary layer instrument packages tethered to the ships gathered information at low levels in the atmosphere continuously for two-to-four-hour periods coinciding with the aircraft overflights.

The most effective pattern of aircraft use for atmospheric sampling was developed by Dr. Holland on the scene. In this pattern, six planes took measurements at altitudes of 1000, 4000, 7000, 10,000, 13,000, and 16,000 feet along the borders of the ocean square. Aircraft with speeds under 200 knots flew at the lower altitudes, each covering one side of the box. They flew back and forth several times, changing altitudes at the completion of each leg. The faster aircraft traversed the entire perimeter at higher levels. Each plane had at least two points along its route at which it flew over ships where similar data were being obtained by means of balloon-borne instruments.

The primary objective was to gather the necessary data to calculate the energy budget of this atmospheric volume. By making measurements on all sides of the box, the movement of energy from the ocean surface to the atmosphere, both horizontally and vertically, can be calculated. Data from a cluster of instruments aboard FLIP — the Floating Laboratory Instrument Platform provided by the Navy and the Scripps Institution of Oceanography—produced one of the project's early findings. The instruments detected a previously unrecorded relationship between temperature and humidity under certain marine atmospheric conditions.

Ordinarily, scientists expect that in the tropical marine atmosphere, where both temperature and humidity are generally below those existing right next to the water surface, small-scale temperature and humidity changes are closely linked. When the temperature goes up, the humidity goes up; when one drops, so does the other.

continued

1. A weird antenna array measured sea state out to 100 miles, in an experiment by ERL's Dr. Douglass Crombie and James Watts. 2. William S. Barney, Project Manager, Dr. Joachim P. Kuettner, Bomex Director, and Dr. Joshua Holland, Director of the Sea-Air Interaction Program. 3. Dr. Richard Hallgren, ESSA Assistant Administrator for Environmental Systems, and Cdr. James Grunwell, logistics officer. 4. Harlan Davis, RFF meteorologist, and Dr. Bradford Bean, ERL, examine record of the gust probe and refractometer aboard RFF DC-6 (39C). 5. Dr. Jule Charney, chief scientist for the tropical exploration phase, reviews satellite photographs with Dr. Kuettner. 6. Stanley Ratomsky of FAA, Bomex air traffic control supervisor, and Cdr. Kelly Taggart, supervisor of the Bomex control center. 7. Aircraft operations officer Loren Weaver (left) briefs flight crews. 8. Five Bomex ships.

BOMEX gives promise of significant additions to man's knowledge of the tropical air and sea

However, the FLIP data showed that in small atmospheric "fronts," three to four miles long, sudden temperature and humidity increases are often followed by a rapid temperature drop, while the humidity goes back down slowly over a period of about 10 minutes. This phenomenon suggests the existence of patches of moist and dry air a mile or more in diameter with little variation in temperature.

Observations by ships and buoys during the sea-air interaction study revealed two phenomena that startled project oceanographers.

Although ocean atlases show currents in the ocean off Barbados flowing from east to west, BOMEX sea platforms were at times carried toward the east by currents whose existence had been unknown. The ocean measurements also disclosed a large water mass, probably from the Amazon River, that remains unmixed with ocean water as far as 1000 miles from its source.

During the first half of May, while the winds blew steadily from east to west, the ocean currents behaved exactly as expected, carrying the oceanographic buoys and the FLIP toward the western boundary of the ship array. In the latter half of May, after the winds shifted to the southeast, the floating platforms went into reverse and began to drift eastward. At one point, a tug whose motor was turning at 10 revolutions per minute was required to hold the FLIP stationary. During the same period, dye released on the sea surface by the U.S. Navy Ship GILLISS moved to the east and was separated by the wind into streaks 20 miles apart.

These and other observations, according to Robert Landis of the BOMEX Project Office, indicate that the ocean is more complex than had been thought, and that the atmosphere has less influence on its behavior than oceanographers had believed. If the impact of the wind and other atmospheric phenomena is less than anticipated, BOMEX oceanographers say, then some strong driving force is at work in the deep ocean.

William Maloney of the Naval Oceanographic Office, coordinator of the BOMEX oceanographic program, believes that analysis of temperature and salinity data gathered during the program may reveal the reasons for the eastward drift of the ocean instruments. The configuration of the sea floor in the Barbados area may play a role. Barbados sits on an underwater mountain chain, called the Antilles Arc, which creates mixing and turbulence in the ocean. Another observed phenomenon, probably attributable to the bottom topography, is the unusually large amplitude of the internal waves, both horizontal and vertical.

Like the wrong-way currents, the large mass of Amazon water was not observed until the latter part of May. After the wind shift to the southeast, the water entered the BOMEX array, bringing with it a tremendous drop in salt content and an unstable temperature profile. Normally, the ocean is warmer near the surface; the Amazon water was cooler. The outflowing Amazon water moved north and then veered to the northwest. This unique water mass was 120 feet deep, 270 to 500 miles wide, and traveled 1000 miles before losing its identity.

Because this flow from the Amazon does not occur in a steady stream, the oceanographers theorize that it may be blocked in winter by the normal northeasterly wind pattern. When the stream is present, its coolness should tend to reduce evaporation and convection in the atmosphere. This was confirmed by satellite pictures showing suppressed convection over the Amazon outflow.

Using other data gathered during BOMEX, the oceanographers will prepare vertical temperature profiles of the ocean in the area, and study the deep cold counterflow from polar regions—called the abyssal circulation—which has never before been measured south of the Bahamas.

A vital aspect of BOMEX was computation of the radiation budget from the ocean surface to the top of the atmosphere. Energy from the sun in the form of solar radiation fuels the atmosphere's engine. Incoming solar radiation warms the earth and sea; outgoing infrared radiation causes cooling of the earth and atmosphere.

Measurements taken by satellite, aircraft, balloons, and by island and ship stations recorded radiation moving upward and downward at the air-sea interface, at various levels above the sea, at the top of the BOMEX cube, and along the lateral boundaries of the array. The surface program was coordinated by Dr. Peter Kuhn of the ESSA Research Laboratories, the airborne program by Dr. Stephen Cox of the University of Wisconsin.

In July, radiation missions were flown by vertically stacked aircraft—topped by NASA's Convair 990 at 40,000 feet—to obtain a profile of the radiation at several levels. The aircraft would rendezvous beneath the Nimbus III satellite to provide calibration for the measurements made by the satellite's radiation sensors. In addition to the Convair 990, the planes participating in these flights were the three Research Flight Facility aircraft, NCAR's Queen Air, and the C-54 from Woods Hole Oceanographic Institution.

According to Dr. Cox, the measurements showed that more incoming radiation is absorbed in the tropical atmosphere than had been thought, perhaps by a factor of two.

Dr. Cox will use BOMEX radiation data in a major experiment in which his co-investigators are Dr. Verner Suomi, director of the University of Wisconsin Space Science and Engineering Center; Dr. Thomas Vonder Haar, and Kirby Hanson. Dr. Cox and his team hope to learn whether satellite photographs contain information on incoming and outgoing radiation. Clouds are primarily responsible for changes in the amount of radiation absorbed, emitted, and reflected by the tropical atmosphere. If clues to radiative changes can be found in satellite cloud pictures, the information would have important applications in weather forecasting.

A team of the nation's best-known atmospheric scientists led the exploration of tropical convection systems. Dr. Jule G. Charney, the chief scientist, was a pioneer in the field of numerical forecasting and is a leader in the Global Atmospheric Research Program of which BOMEX is a part.

Other primary scientific participants were Dr. Herbert Riehl of Colorado State University, Dr. Mariano Estoque of the University of Miami, and ESSA's Neil Frank, Harry Hawkins, and Dr. Kuettner, BOMEX Director.

Their targets for study were the tropical cloud formations that carry energy upward from the tradewind layer in the lower atmosphere and distribute it around the globe.

"Eighty percent of the heat entering the atmosphere is latent heat in the form of moisture," Dr. Charney explained. "It is only when moisture condenses that energy is released. Condensation occurs in organized systems, such as the cumulus clouds which normally cover only one percent of tropical regions. Cloud clusters are the cores of larger synoptic systems—the inverted V and the warm-core ITC-originated clouds."

The so-called "inverted V" cloud patterns originate over the African continent and move westward across the tropical Atlantic, occasionally developing into hurricanes. The ITC (Intertropical Convergence Zone) lies about 5 to 10 degrees north of the Equator, and is usually marked by a narrow band of clouds. A similar zone exists in the Southern Hemisphere, with a clear dry band right over the Equator. The scientists set out to explore and understand these weather systems. In addition to the core experiments, 46 other research projects were being conducted during the tropical convection study.

For the cloud chase, the ship array was rearranged to form a giant W, with the open ends to the east and the tips pointed at Barbados. From north to south, the vessels were the USC&GSS RAINIER, the USCGC ROCKAWAY, the USC&GSS DISCOVERER, and —forming the southernmost limb of the W —the USC&GS ships MT MITCHELL and OCEANOGRAPHER straddled the normal seasonal position of the Intertropical Convergence Zone.

Flight information for the airspace over this expanded array is ordinarily provided by the Air Traffic Control Center at Piarco,

Trinidad. From July 11 to 28, Piarco gave BOMEX control over air traffic within an area of more than 150,000 square miles—some 60,000 square miles greater than that of the earlier sea-air interaction study. Still, the search for suitable research clouds took the aircraft out of this enlarged area more often than not.

Planning of aircraft missions usually began at dawn on the day before, when a special ground terminal began receiving photographs from the National Aeronautics and Space Administration's Applications Technology Satellite, ATS-III. To provide continuous daylight photographs for the cloud study, the spacecraft was moved eastward along the Equator to a position south of the BOMEX array. The satellite's hemispheric weather pictures were acquired by the portable terminal, valued at nearly half a million dollars, which had been transported to Barbados for this phase of the project.

The BOMEX forecasting operation was managed by Neil Frank of ESSA's National Hurricane Center. Conventional weather information available consisted of day-old upper-air data from Africa, yesterday's forecast products from the National Hurricane Center, weather reports from BOMEX vessels and itinerant ships in the area, radarscope pictures taken every two hours by the Army weather radar on the island, and upper-air soundings made from Barbados by the Air Weather Service and by the Barbadian meteorological service. Meteorological technicians from the local weather service worked for BOMEX on their time off, plotting surface and upper-air charts, as well as some oceanographic data.

The most vital weather data was the wealth of material from weather satellites which provided continuous, timely information on existing cloud formations and their locations—direct readout APT photographs from ESSA and Nimbus spacecraft, Nimbus infrared nighttime pictures, continuous ATS-III photographs, and digitized mosaics of satellite pictures, received each night from Suitland, Md., through the weather facsimile experiment on ATS-III. In the weather briefing area, these photographs were displayed in a day-to-day sequence, showing the movement of weather systems as the study progressed.

By 2 p.m., plans for the next day's flight operations were completed and instructions issued to participating aircraft. Shortly after noon, the scientists and operations officers met to determine the mission for tomorrow. Neil Frank opened the meetings with a review of the weather situation. "Today we have a system of interest at 41 or 42 degrees West. Tomorrow, it should be between 45 and 50 degrees. That would place it too far east for good operations. On the day after tomorrow, it will be over the ship array. Ahead of this system, the ITC is rather active. The next system that might be of interest is still near the African coast."

Beginning the scientific discussion, Dr. Charney summarized the problems. "The system has not traveled as fast as we expected. Still, the planes are ready to go tomorrow. The question is: Should we fly? Is there something of scientific interest?"

Looking at the possible targets, the scientists would reconcile the BOMEX objectives, their individual experiments, the probable weather patterns, and the capabilities of the available aircraft, into a workable flight plan for the next day.

But the project was hunting unknown atmospheric processes, pursuing very short-lived weather systems. By flight time the next morning, many of the cloud formations observed by satellites the day before had dissipated, and others had developed. Last-minute changes in flight plans—based on midnight infrared pictures from Nimbus III and early morning ATS-III photographs—often were required. To give added flexibility to the operation, the primary investigators themselves flew on many of the missions to guide aircraft to the most desirable weather research targets.

On a typical day, Dr. Sigmund Fritz of the National Environmental Satellite Center was aboard NASA's Convair 990, and Dr. Kuettner was flying on an ESSA DC-6. The flying scientists used a special VHF channel for exchanging information on cloud systems.

"Just south of Barbados," Dr. Fritz noted, "within 30 miles, there are lines of cumulus congestus clouds oriented east-west, spaced about 25 miles apart. They are quite long. They run to the west."

Dr. Kuettner: "Roger. What do you see to the east?"

Dr. Fritz: "Cloud bands."

Dr. Kuettner: "How long are these cloud bands?"

Dr. Fritz: "Ten miles long and perhaps 1½ miles wide."

Dr. Kuettner: "How many parallel lines?"

Dr. Fritz: "Three or four."

Dr. Kuettner: "O.K. We are going to operate farther east in the control area."

The DC-6 headed east to explore cloud lines, while the Convair 990 went south to study cumulus clouds.

Of the 16 planes participating in the tropical cloud study a maximum of eleven was available on any given day. Provided by ESSA, the Air Force, Navy, NASA, the National Center for Atmospheric Research, the Woods Hole Oceanographic Institution, and Colorado State University, the air fleet ranged in size from small planes to the equivalent of a modern jetliner.

Flying on 16 of the 18 days allotted to this part of the experiment, the aircraft completed 152 successful missions, averaging 2000 miles per mission. On eight days, they crossed the ITC. They investigated synoptic-scale systems, cloud streets, and subcloud layer phenomena, and carried out flights for solar radiation and aerosol studies.

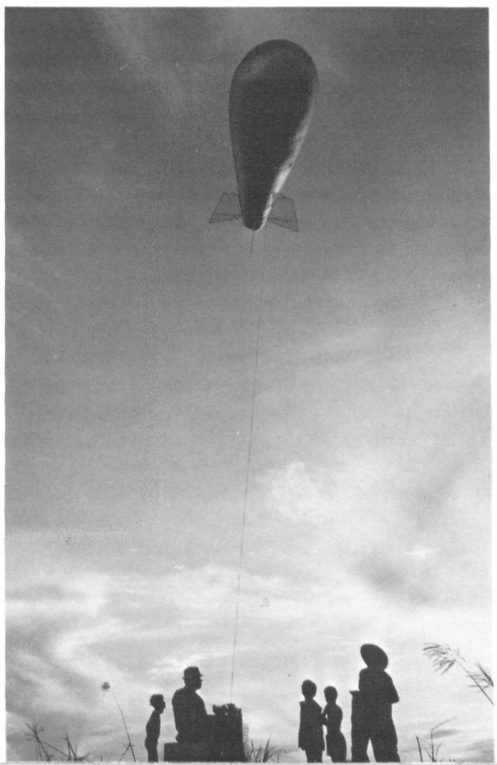
As the study drew to an end, Dr. Kuettner termed it "the most exciting part of BOMEX. The weather cooperated in a marvelous way. We had a wide variety of weather situations in a short period of time."

"We made three flights into the early stages of a system that later developed into a disturbance in the Caribbean," he continued. "The data will be given intensive study and should give us an idea of how these disturbances form.

"As a first impression, I would say that the ITC seems to be easily deformed by weather disturbances farther north. This deformation apparently creates closed circulations which are characteristic of tropical storms. The arrival of an inverted V created a bulge in the ITC and consistently brought disturbances to the BOMEX area."

"We have made the best exploration of the ITC ever conducted," the chief scientist, Dr. Charney, said. "The structure of the normal ITC is of great importance to the general circulation. We have investigated this structure and the way the structure and motion of disturbances are related to it. We already have some rather significant results. One is that the characteristic wind shift pattern at low levels in the ITC is not dependent on any individual cumulonimbus circulation. In other words, the cumulonimbus are embedded in this very narrow band of wind shear and convergence. From a dynamical point of view, one can begin to better understand the interaction between this general zone of convergence and the individual cloud."

Summarizing the tropical convection study, Dr. Charney concluded: "This kind of operation is going to be a way of life. I have been very impressed with the smooth functioning of the operational people. The cooperation and coordination have been remarkable. Out of this should come strategies and methods for using highly instrumented aircraft to study phenomena of a scale which cannot be covered by conventional methods." □



Tethered balloons carried instruments at three levels in the atmosphere.

"They come without warning like the vengeance of a lunatic god"

EARTHQUAKES

EARTHQUAKES make us remember how large and incompletely known our planet is. We inhabit less than a fourth of its surface, and have explored barely a thousandth of its 8,000-mile diameter. Below our shallow grids of cities, roads, tracks, mines, and farms lies the unvisited, inaccessible sphere.

Most natural hazards can be detected before their threat matures. But seisms (from the Greek *seismos,* earthquake) have no known precursors, and so they come without warning, like the vengeance of an ancient, lunatic god. For this reason, they continue to kill in some areas at a level usually reserved for wars and epidemics—the 11,000 dead in northeastern Iran died on August 31, 1968, not in antiquity. Nor is the horror of a lethal earthquake completed with a heavy death toll. The homeless living are left to cope with fire, looting, pestilence, fear, and the burden of rebuilding what the planet so easily shrugs away.

Earthquakes have not been the killers in the United States they have in Eurasia and Africa. Thus far (through 1968) in this century, fewer than 1500 deaths have been caused by earthquakes and tsunamis (so-called "tidal waves") in the United States, and 700 of these came in the April 1906 San Francisco earthquake and fire. Of more than 45,000 deaths from major earthquakes worldwide since 1960, fewer than 200 occurred in the United States.

Property damage is a different story. The San Francisco earthquake did an estimated $24 million property damage, and the ensuing fire $500 million more. Since San Francisco, Americans have paid another $600 million to the earthquake, about $400 million of it to the Alaskan earthquake of March 1964. In this century, the average annual toll has run about $17 million.

A major earthquake in a large metropolitan center could change these figures drastically—and horribly. The 1964 Alaskan earthquake was as close as we have come. There is every reason to believe we have other seismic disasters ahead of us.

The Environmental Science Services Administration, in cooperation with other Federal and private organizations, is trying to change this. Through its Coast and Geodetic Survey and Research Laboratories, ESSA monitors global earthquake activity and crustal movement, detects and warns against Pacific tsunamis, measures earthquake effects on buildings, and seeks to learn what, if any, advance signals an earthquake gives. Work like this is the only avenue to earthquake-resistant cities, more comprehensive warnings against the great waves, earthquake prediction techniques—a lighter seismic burden for mankind.

(This article is excerpted from the ESSA brochure, "Earthquakes," available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, at 30 cents.)

Through much of seismic mythology two ideas recur. The first of these is that something was imprisoned within the earth—a whale, a giant mole, a storm, or the monstrous children of Mother Earth. The second is that earthquakes had something to do with the sea; in Greek mythology, Poseidon, brother to Zeus and god of the sea, is also the "Earthshaker," and devoutly feared.

For many years, geophysicists have attempted to describe the actual counterparts of these mythical animals and storms. At the same time, they have tried to relate these unseeable subterranean forces to their surface manifestations—the building of mountains, the bending of ocean trenches, the tearing of seafloors, the apparent drifting of continents, volcanic eruptions, and earthquakes.

The planet Earth is believed to consist of a thin crust two or three miles thick under the oceans and as much as 25 miles thick beneath the continents that cover the large, solid sphere of the rock mantle, which descends to about 1800 miles. Below the mantle is the fluid outer core, and, at about 3200 miles' depth, the apparently solid inner core. The province of earthquakes recorded thus far is from the crust to a maximum depth of about 450 miles.

Conditions thought to prevail in this hot, dark, high-pressure land cannot be simulated in existing laboratories—at the base of the mantle, pressure is about 11,000 tons per square inch, temperature, 10,000 degrees Fahrenheit. These diamond-mashing pressures produce a rigidity in mantle rock about four times that of ordinary steel, with an average density about that of titanium.

This very solid mantle of rock seems to behave, over periods of millions of years, like a very sluggish fluid. Something, per-

haps the temperature difference between the white-hot region near the core and the cooler region near the crust, drives slow-moving cycles of rising and descending currents in the mantle rock itself.

Evidently, these currents rise beneath the thin-crusted ocean floor, thrust up the mid-ocean ridges, and generate the stresses which produce their spine-like transverse cracks and shallow earthquakes. This is believed to be the force which causes material to well up through the crust, replacing and spreading the old seafloor, and pushing drifting continents apart.

Where the currents begin their descent at the edges of continents, they produce compressive pressures, and massive folding in the form of trenches and mountain ranges. These regions are the sites of the deeper earthquakes, and of most volcanism.

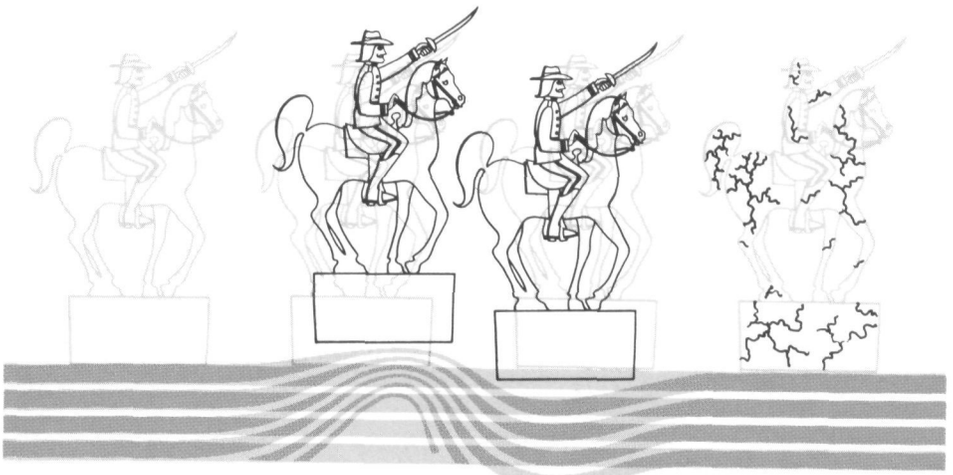
Stresses generated in the crust and upper mantle by convective currents are stored in the form of strain—physical deformation of the rock structure. Under normal circumstances, the "solid" rocks deform plastically, releasing pent-up energy before it builds to catastrophic levels. But, when stresses accumulate too rapidly to be removed by plastic flow, some structural compensation is necessary. Large blocks of material are slowly forced into highly strained positions along faults, and held in place by a supporting structure of stronger materials. These energy-absorbing zones of weakness continue to shift, like longbows being pulled to the breaking point. Finally, more stress causes the supporting rocks to rupture, triggering the "cocked" fracture back toward equilibrium. The sides of the rebounding fault move horizontally with respect to one another (strike-slip), vertically (dip-slip), or in combinations of such motion, as in the large-scale tilting which accompanied the March 1964 Alaska earthquake.

Sometimes all the energy to be released goes out in one large wrench, followed by trains of smaller tremors, or aftershocks, produced by continuing collapse and slippage along the fracture. Sometimes the fault shift is preceded by the small structural failures we detect as foreshocks.

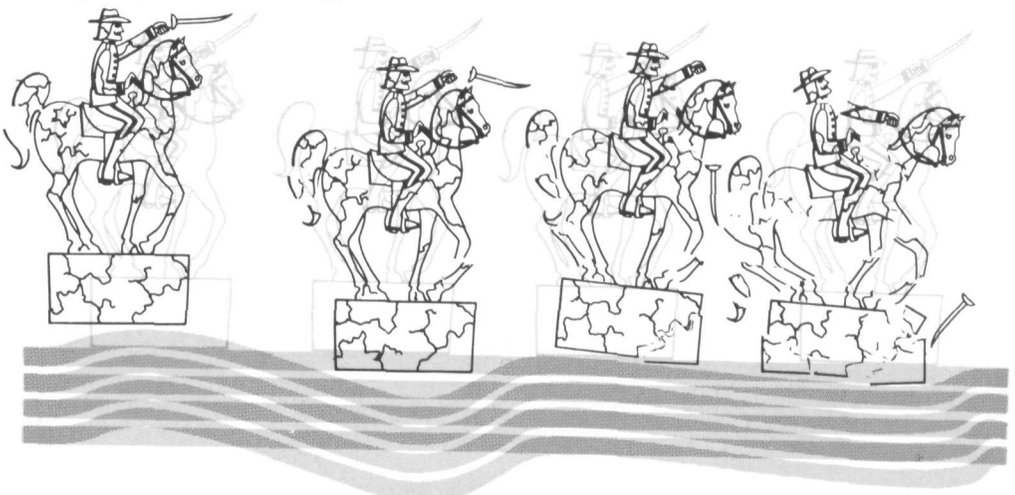
Whatever the time period involved, the energy of strain flows out through the shifted fault in the form of heat, sound, and earthquake waves. These last are the shakers and wreckers, the global messages sent out by earthquakes.

They are also man's only window to his planet's deep interior.

There are four basic seismic waves: two preliminary "body" waves which travel through the earth, and two which travel only at the surface. Combinations, reflections, and diffractions produce a virtual infinity of other types. The behavior of these is well enough understood that wave speed and amplitude have been the major means of describing the earth's interior. In addition, a large earthquake generates



The compressional phase of a **P**-wave train displaces the statue's pedestal away from the earthquake parallel to the direction of wave travel; the rarefactional phase dilates the ground, shifting the pedestal in the opposite direction.



Transverse **S** waves arrive and begin shaking the statue at right angles to the direction of wave travel, completing the destructive work begun a few seconds earlier.

inelastic waves which echo through the planet like vibrations in a ringing bell, and which actually cause the planet to expand and contract infinitesimally.

The primary (P) wave is longitudinal, like a sound wave, propagates through both liquids and solids, and is usually the first signal that an earthquake has occurred. Where the disturbance is near enough or large enough to be felt, the P wave arrives at the surface like a hammerblow from the inside. This is the swiftest seismic wave, its speed varying with the material through which it passes. In the heterogeneous crustal structure, P-wave velocity is usually less than 4 miles per second—nearly 15,000 miles per hour. Just below the crust, at a layer called the Mohorovicic discontinuity (popularly, the Moho), these speeds jump to 5 miles per second and subsequently increase to about 8½ miles per second (more than 30,000 miles per hour) through the core.

As the compressional phase of the P wave passes through the earth, particles are pushed together and displaced away from the disturbance. The rarefactional phase dilates the particles and displaces them toward the earthquake source. For an object imbedded in the ground, the result is a series of sharp pushes and pulls parallel to the wave path—motions similar to those which the passengers feel when a long train gets under way.

The secondary (S) wave is transverse, like a light or radio wave, and travels barely more than half as fast as the primary wave. Because S waves require a rigid medium to travel in coherent rays, their apparent absence below the mantle gives credence to the theory of a fluid core. About twice the period and amplitude of the associated P waves, these shear waves displace particles at right angles to the direction of wave travel. The vertical component of this movement is somewhat dampened by the opposing force of gravity; but side-to-side shaking in the horizontal can be quite destructive. Where the motion is perceptible, the arrival of the S waves marks the beginning of a new series of shocks, often worse than the P-wave tremor.

Surface waves, named for their discoverers, Love and Rayleigh, are of much

continued

greater length and period—e.g., 30 seconds or more, vs. less than one second for P waves. Love waves are shear in the horizontal dimension, and the Rayleigh wave induces a retrograde, elliptical motion, something like that in wind-driven ocean waves. The speed of the Love wave is about 2½ miles per second; the Rayleigh wave is about 10 percent slower. Despite the large proportion of earthquake energy represented by these waves, their long period smooths out the motion they impart, reducing their destructiveness.

Wave motion is not considered in describing the travel of seismic waves through the earth. Instead, the P and S body waves, and their large family of reflected, combined, or resonated offspring, are treated as rays. If the planet were homogeneous, like a ball of wax, these rays would be straight lines. But in the heterogeneous earth the rays describe concavely spherical paths away from the earthquake source, and from points of reflection at the surface.

Because they travel at different speeds, seismic waves arrive at a given point on the earth's surface at different times. Near the source, the ground will shake over a slightly longer interval of time than it took the fault to slip. At great distances, the same energy released by a single event may be detected instrumentally for days.

Seismology is a kind of reverse astronomy that peers into the earth instead of skyward, and depends heavily upon a central instrument: the seismograph is the geophysical counterpart of the telescope.

Seismographs are no longer the fragile, randomly designed affairs they were a generation ago. The Coast and Geodetic Survey, in cooperation with agencies in other countries maintains the Network of Standardized Seismograph Stations—115 installations in 61 countries and territories, using identical systems to obtain the most precise seismic record man has ever had.

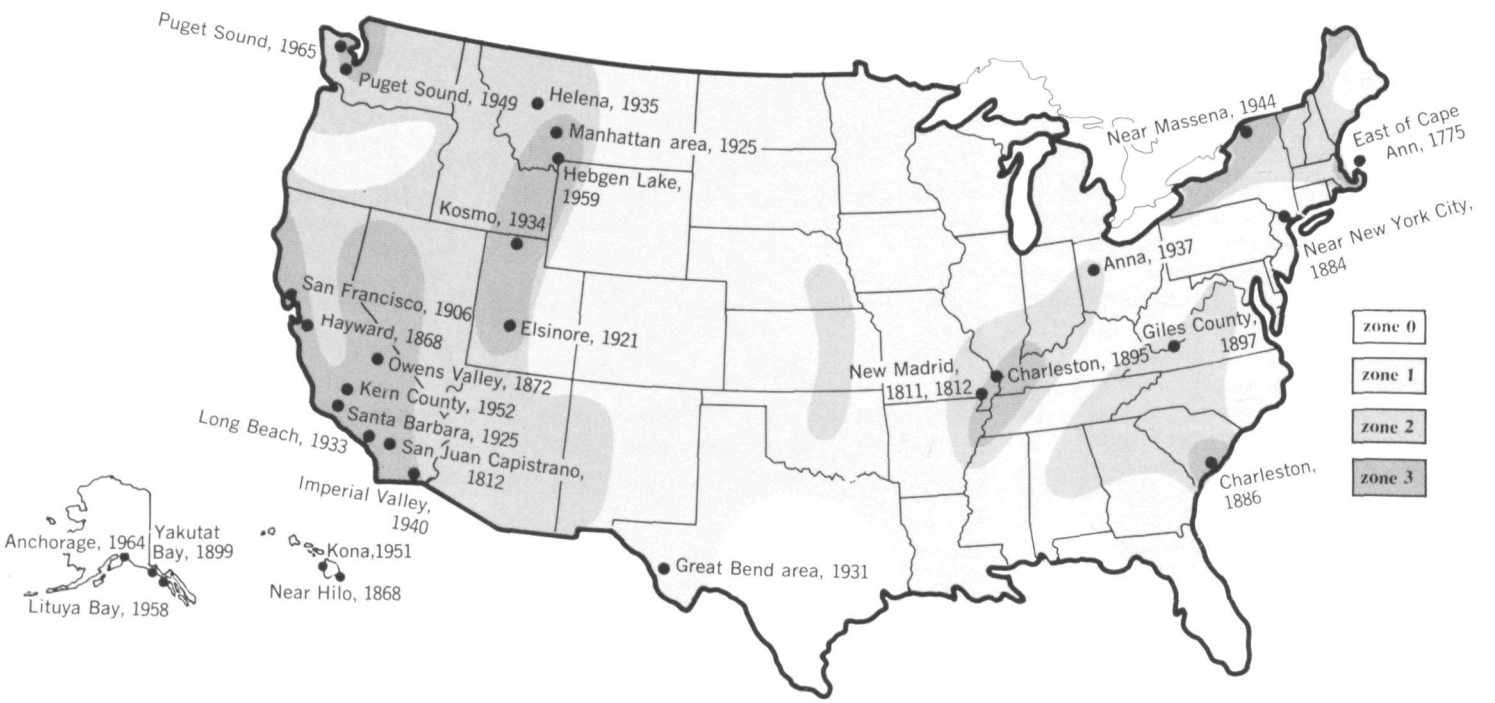
Seismologists once "patched the globe," swinging intersecting arcs of surface distance (computed from P and S wave arrivals) to locate epicenters. The days of hand-positioned epicenters have virtually ended at the Coast and Geodetic Survey, which uses the computers at ESSA's National Meteorological Center to move the mountain of global seismic data. It is an appropriate use of equipment, for the Coast and Geodetic Survey is to seismology what the Weather Bureau is to meteorology.

The computer can handle as many as 800 seismic events simultaneously, providing date, epicenter location, origin time, P-wave arrival, region name (one-degree square), depth of focus, magnitudes determined from body and surface waves, and the number of stations used in the computation. To make this comprehensive response, the computer must sort through incoming data, associate various wave arrivals with appropriate seismograph stations, and check itself for impossible combinations. The earthquake information "floats" in the electronic memory; seismic data and seismologists' comments can be added or subtracted until the description of a particular event is as full and accurate as men and machines can make it.

Epicenter determinations run about 6,000 per year at the National Earthquake Information Center, in Rockville, Maryland, where yearly summaries of global and United States earthquake activity are compiled. The millions of additional microtremors detected are not included except where they appear to be part of more significant seismic activity. At the Environmental Data Service archives in Asheville, North Carolina, nearly half a million seismograms are photographed and stored per year, and retrieved for analyses of particular seismic events.

Earthquakes are not now predictable, but the tsunami, their destructive and far-ranging oceanic side effect, can be detected in time to give early warning. The Survey's Honolulu-based Pacific Tsunami Warning System and its Alaskan counterpart in Palmer monitor seismic activity with special urgency, to detect tsunami-generating earthquakes as soon as they occur, and flash the watch and warning ocean-wide.

Strong-motion instruments emplaced by the Seismological Field Survey measure significant movements in buildings and in surface soils and rocks. It is a waiting game, begun in 1932. Installed in tall buildings, in some dams and bridges, and



Epicenters of damaging earthquakes are superimposed on this seismic risk map, which divides the conterminous United States into four zones: **zone 0,** where there is no reasonable expectance of earthquake damage; **zone 1,** where minor earthquake damage can be expected; **zone 2,** where moderate damage can be expected; and **zone 3,** where major destructive earthquakes may occur. Maps for Alaska and Hawaii are under development by ESSA's Coast and Geodetic Survey. If you live in a high-risk area, check your home's construction against your city's earthquake construction codes; build on solid ground, not fill; and use earthquake-resistant design.

at nuclear reactor sites, the instruments are triggered by earthquake-generated motion above a given amplitude. Strong-motion data obtained in the devastating 1933 Long Beach, California, earthquake and more than 100 records taken since, have been applied to writing building codes in many earthquake-prone areas.

Along California's slowly moving San Andreas fault system, ESSA's Research Laboratories have set up instruments to measure strain, earth movement, and changes in magnetic and gravity fields. This is an effort to obtain a comprehensive understanding of the rate of strain accumulation, and what signals, if any, precede a major shock. Studies of continental drift, interaction between the earth's rotation, fields, and seismic activity, and other fundamental studies are being carried out to reduce the amount of supposition in man's view of his restless planet.

The analogy between astronomy and seismology does not end with the emphasis on particular instruments. The two sciences must describe their subjects both as they seem and as they are. Stars are described in terms of apparent size and brightness, which is what we see, and in the much larger terms of their actual dimensions. Seismologists make similar distinctions in describing earthquakes.

Intensity is an indication of an earthquake's apparent severity at a specified location, as determined by experienced observers. For seismologists and emergency workers, intensity becomes an efficient shorthand for describing what an earthquake has done to a given area.

The Modified Mercalli Intensity Scale generally used in the United States grades observed effects into twelve classes ranging from I, felt only under especially favorable circumstances, to XII, damage total. The older Rossi-Forel Intensity Scale, or R.F., has ten categories of observed effects, and is still used in Europe. Still other intensity scales are in use in Japan and the U.S.S.R.

Rating earthquakes by intensity has the disadvantage of being always relative. In recent years, intensity ratings have been supplemented by an "objective" scale of earthquake magnitude.

Magnitude expresses the amount of energy released by an earthquake as determined by measuring the amplitudes produced on standardized recording instruments. The persistent misconception that the "Richter Scale" rates the size of earthquakes on a "scale of ten" is extremely misleading, and has tended to mask the clear distinction between magnitude and intensity.

Earthquake magnitudes are similar to stellar magnitudes in that they describe the subject in absolute, not relative, terms, and that they refer to a logarithmic, not an arithmetic, scale. An earthquake of magnitude 8, for example, represents seismograph amplitudes ten times larger than those of a magnitude 7 earthquake, 100 times larger than those of a magnitude 6 earthquake, and so on. There is no highest or lowest value, and it is possible here, as with temperature, to record negative values. The largest earthquakes of record were rated at magnitude 8.9; the smallest, about minus 3. Preliminary magnitude determinations may vary with the observatory, equipment, and methods of estimating—the Alaska earthquake of March 1964, for example, was described variously as magnitude 8.4, 8.5, 8.6 by different stations.

Magnitude also provides an indication of earthquake energy release, which intensity does not. In terms of ergs,* a magnitude 1 earthquake releases about one billionth the energy of a magnitude 7 earthquake; a magnitude 5, about one thousandth that of a magnitude 7.

Our planet's most active earthquake-producing feature is the circum-Pacific seismic belt. The Mid-Atlantic Ridge, with its fish-skeleton figure of transverse cracks, is also quite active. Other major seismic belts branch from the circum-Pacific system and arc across southeastern and southern Asia into southern Europe, through the Indian Ocean up through the eastern Mediterranean, and up through southern Asia into China.

In an average year, these belts will generate several million tremors, ranging in severity from barely detectable wiggles to great earthquakes of the size which ravaged San Francisco in 1906, and tilted a third of Alaska in 1964. □

** In the centimeter-gram-second system, an erg is the unit of work equal to a force of 1 dyne acting through a distance of 1 centimeter; a dyne is the force required to accelerate a free-standing gram mass 1 centimeter per second.*

PLAY IT SAFE

Earthquake Safety Rules

An earthquake strikes your area and for a minute or two the "solid" earth moves like the deck of a ship. What you do during and immediately after the tremor may make life-and-death differences for you, your family, and your neighbors. These rules will help you survive.

During the shaking:

1. Don't panic. The motion is frightening but, unless it shakes something down on top of you, it is harmless. The earth does not yawn open, gulp down a neighborhood, and slam shut. Keep calm and ride it out.

2. If it catches you indoors, stay indoors. Take cover under a desk, table, bench, or in doorways, halls, and against inside walls. Stay away from glass.

3. Don't use candles, matches, or other open flames, either during or after the tremor. Douse all fires.

4. If the earthquake catches you outside, move away from buildings and utility wires. Once in the open, stay there until the shaking stops.

5. Don't run through or near buildings. The greatest danger from falling debris is just outside doorways and close to outer walls.

6. If you are in a moving car, stop as quickly as safety permits, but stay in the vehicle. A car is an excellent seismometer, and will jiggle fearsomely on its springs during the earthquake; but it is a good place to stay until the shaking stops.

After the shaking:

1. Check your utilities, but do not turn them on. Earth movement may have cracked water, gas, and electrical conduits.

2. If you smell gas, open windows and shut off the main valve. Then leave the building and report gas leakage to authorities. Don't reenter the house until a utility official says it is safe.

3. If water mains are damaged, shut off the supply at the main valve.

4. If electrical wiring is shorting out, shut off current at the main meter box.

5. Turn on your radio or television (if conditions permit) to get the latest emergency bulletins.

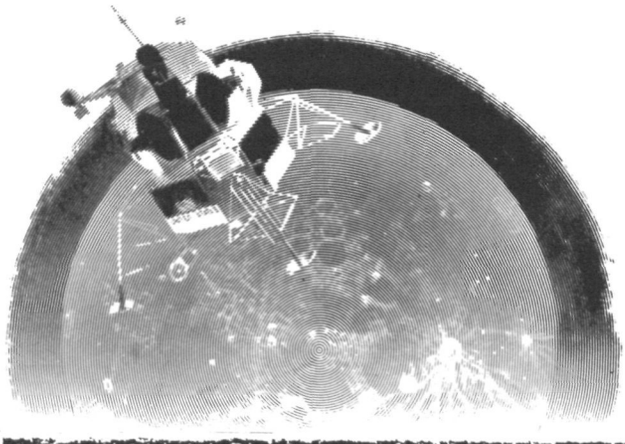
6. Stay off the telephone except to report an emergency.

7. Don't go sightseeing.

8. Stay out of severely damaged buildings; aftershocks can shake them down.

An earthquake's worst killer may come from the sea

If you live in low-lying coastal areas, an earthquake may be your only warning that a tsunami is about to strike. As soon as the shaking stops, start for high ground and stay there until officials have sounded the all-clear. For more information on the great waves, see "TSUNAMI!—The Story of the Seismic Sea-Wave Warning System," an illustrated 48-page brochure from the Superintendent of Documents at 35 cents. A leaflet, "Tsunami Watch and Warning," is available free from the National Earthquake Information Center, ESSA, Rockville, Md. 20852.



ESSA found clear skies for the astronauts when they came

BACK FROM THE MOON

APOLLO 11 was a textbook flight—except for a last-minute detour. After going to the moon and back, the fabled astronauts splashed down to glory in the Pacific 200 nautical miles northeast of their planned landing.

Their personal weathermen—wisely, it developed—so ordained it. As in all the other manned spaceflights by the National Aeronautics and Space Administration, ESSA, in the form of the Weather Bureau and its Research Laboratories, was part of the team, protecting Apollo 11 not only against the foibles of the atmosphere but the solar weather.

They were watched all the way, and more. At Kennedy Space Center in Florida, the weather had to be carefully predicted well before the launch because of possible thunderstorm hazards to their space vehicle or to the men working on it. The launch and the landing were the two most weather-sensitive parts of the mission, but throughout man's greatest adventure, as well, weather forecasts were being made for possible emergency landing sites.

Primary forecast guidance was provided to NASA by the Weather Bureau's Spaceflight Meteorology Group, led by Alan Sanderson, with headquarters at NASA's Manned Spacecraft Center in Houston, Texas. It is part of the Office of Meteorological Operations, Space Operations Support Division, of which Kenneth Nagler is chief.

The planning began long before the flight, as it had since those days in 1960 when NASA first requested that the Weather Bureau form a group to support Project Mercury. Then, Apollo was a distant dream. Now, it was here.

A July launch for Apollo 11 could have occurred only during about a four-hour period on the 16th, 18th, or 23rd, if one of the selected moon landing areas were to be hit with the proper sun angle. Even with such limitations, however, the July weather was likely to be good for the launch. Climatological records showed that the weather most likely to cause a postponement—thunderstorms at the site during the eight hours before launch—had only about a five percent chance of occurrence for the scheduled 9:32 a.m. liftoff. Strong surface winds produced by systems other than thunderstorms are infrequent in summer, and clouds are even less likely to be low enough to delay a launch.

With nearly a million persons crowded at the Kennedy Space Center to view the launch, however, a low overcast would have been a great disappointment and as the hour approached, excessive cloudiness was a real concern for spectators. Just how much cloudiness to forecast for the launch was a problem for J.R. Gulick and the Miami Section of the Spaceflight Meteorology Group, which provides the primary forecast guidance for the launch and the Atlantic Ocean areas of concern, and for Ernest Amman and his colleagues at the Kennedy Space Center, who are responsible for local forecasting and for briefing launch officials.

The 24-hour forecast for the 16th called for an improvement, but still with scattered clouds at 2500 and 15,000 feet, and high thin broken clouds. If launch were delayed, cloudiness was expected to increase.

Launch was precisely on time, and there were scattered clouds at three levels: 2300, 4000, and 11,000 feet, plus high thin broken clouds. Fortunately, the clouds were sufficiently scattered and thin that they had little effect on the view of the rising spacecraft.

Before launch, as has been the custom, a schematic forecast map was prepared for the crew. Executed by Richard Brintzenhofe and his staff at the National Meteorological Center in Suitland, it was sent by facsimile and copied to a smooth chart at the launch center. Nagler, who was at Kennedy for the launch and at Houston later in the mission, discussed the map with astronaut leader Donald Slayton early on the morning of the flight. The astronauts studied it at breakfast that morning to get an idea of the weather systems to be expected that day, and of what the weather would be in possible early emergency landing areas. The team also viewed the ESSA 9 satellite mosaic for the previous day.

Another ESSA unit playing a role in the launch was the Research Laboratories' Air Resources Laboratory. Dr. Isaac Van der Hoven served as the meteorologist at the Radiation Control Center, a joint NASA-Atomic Energy Commission advisory group at the launch control center. Consistent with ESSA's responsibilities to the AEC, he was charged with evaluating and advising on atmospheric transport and diffusion conditions in the Cape Kennedy area, in an unlikely contingency involving the Apollo Lunar Radioisotope Heater. This nuclear energy heat source is being used to protect the moon-based seismometer experiment from the extreme cold of the lunar night, and is part of the growing use of atomic energy in space exploration.

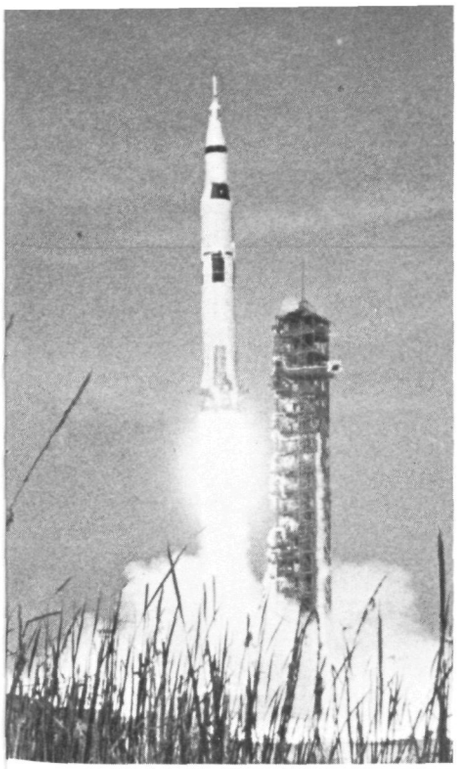
Once the successful liftoff had occurred, forecasts and briefing for the next few days concerned various emergency landing areas in the event of an early termination of the flight.

Meanwhile, another ESSA element was keeping a careful watch on the moon-bound men.

The huge burning mass of the sun, more than 300,000 times that of the earth, can have catastrophic weather. Flares—bright, massive tongues of hot solar plasma—erupt as far as half a million miles from the sun. The x-rays, radio waves, light waves, electron clouds, and energetic, destructive high-energy protons that can accompany these flares continue on toward the earth and into deep space.

In the case of protons, these radiations will ionize and thus potentially destroy anything in their paths from photographic film to sensitive electronic equipment to the cells and bones of an unshielded man. Consequently, accurate forecasting and immediate warnings of solar weather are extremely important during manned space flights. Astronauts outside their spacecraft would have virtually no protection from the lethal radiation that can follow a solar flare.

Robert Doeker, chief of ESSA's Space Disturbance Forecast Center in Boulder,



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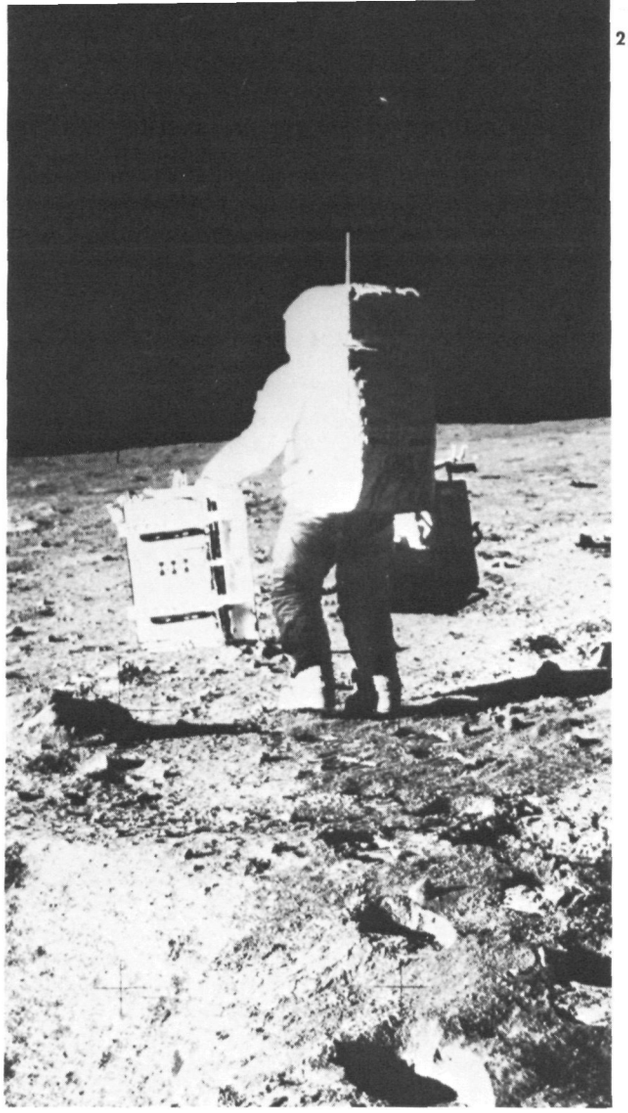

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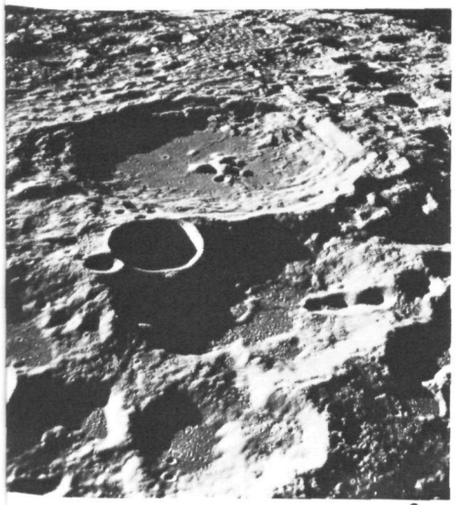

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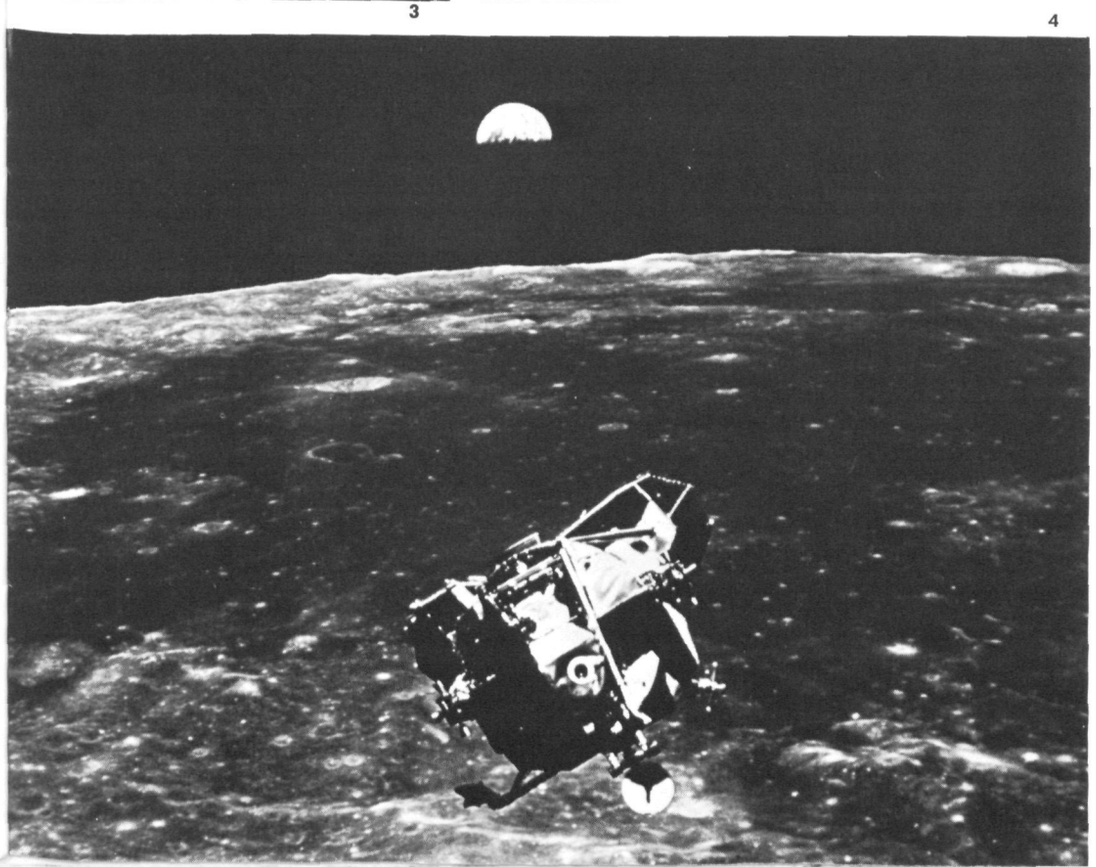
1. Thin high clouds and scattered middle clouds had little effect on the view of the rising Apollo 11 space vehicle. 2. Edwin Aldrin, Jr., deployed experiments on the lunar surface. 3. The back of the moon was photographed from the Apollo 11 spacecraft. 4. The lunar module ascends from the moon's surface, while the earth rises above the lunar horizon.

4



stresses the point that not all flares produce the lethal proton showers. He says: "Protons, which are the chief hazard of solar flares, are relatively infrequent. Solar activity goes through a regular cycle, reaching a peak of activity every 11 years. During the past cycle, we detected protons in only 40 of some 2000 total flares. However, this year is the cyclical peak and the sun has been quite active. Such an active year as this could produce as many as eight proton showers."

ESSA scientists have learned to know each changing phase of the sun. They keep a particular watch on sunspots because of an apparently close relationship between these ever-changing dark spots on the sun's surface and the sudden, fierce brightenings that herald a flare.

During manned flights, ESSA, NASA, and the U.S. Air Force merge all their solar facilities for the mission. Seven solar observatories around the world comprise a NASA project called SPAN for Solar Particle Alert Network. SPAN observatories are located in Houston, Boulder, the Canary Islands, Carnarvon and Culgoora, Australia, Hawaii, and Tehran. The observatories at Boulder and Culgoora are operated by ESSA and the Hawaiian and Iran observatories are operated by the U.S. Air Force. This global ring of observatories assures that the sun's ever-changing face will be under scientific observations 24 hours a day. Scientists from Boulder's ESSA Research Laboratories serve as solar observers at two of the NASA stations, Canary and Carnarvon.

Should a flare erupt, one of the seven SPAN stations sees it within eight minutes, the time it takes for light to travel the distance from the sun to the earth. Getting this initial alert from a SPAN station to the NASA mission director in Houston is a complex process and Boulder's Space Disturbance Forecast Center must operate around the clock to assist in this.

If a flare occurs during Colorado's daylight hours, the first person to see it would be Joseph A. Sutorik. He tends an optical telescope atop ESSA's laboratory in Boulder. This scope tracks and photographs the sun continuously while Sutorik makes visual observations and maps sunspot changes. When Sutorik sees a sunspot begin to brighten, he alerts the Space Disturbance Forecast Center downstairs. There scientists cluster around the remote TV screen leading from Sutorik's telescope and, if the flare develops, it is logged in and one of the SDFC's forecasters takes over.

He quickly analyzes the past history of the flaring portion of the sun, makes a tentative judgment of the magnitude and probable results of the flare and decides whether others need to know about it. If so, he teletypes details of the solar disturbances including information from ground stations on neutrons, protons, and ionospheric data via a special NASA data teletype communications system. This alert on a flare, with

continued

scientific details, reaches the agencies concerned within two minutes. During Apollo missions, the forecaster picks up a "hot-line" phone and gives a fast verbal summary to the Space Environment Console in NASA's Mission Control Center. A team of NASA personnel, composed of space physicists, medical doctors, and flight controllers, is involved in space environment decisions at NASA Houston.

If this group suspects no problem to the Apollo mission from the solar flare, the ESSA information never leaves the console. If, however, it is suspected that the astronauts may be in danger as a result of the sun's most recent action, they will relay the Boulder information and their own warning directly to NASA's flight surgeon.

The flight surgeon and the mission director must then decide what, if any, evasive action to take. They could, for example, call for an immediate change in the mission. An astronaut prospecting on the lunar surface might be ordered back to the shelter of his lunar lander. And, if the flare seemed to be releasing a really excessive amount of ionizing protons, NASA could conceivably tell its lunar explorers to end the mission and get back to the even greater safety of the more adequately shielded Apollo command and service module orbiting the moon.

The logic of this complex warning system for solar flares rests on the fact that it usually takes at least six, and sometimes as much as 12 hours, for significant amounts of radiation from a flare to cover the 90-odd million miles between the sun and a lunar astronaut. Within four hours of a flare, space physics consultants and solar astronomers should be able to gather enough optical, radio, and proton data for the NASA medical staff to accurately evaluate the hazard to the astronauts.

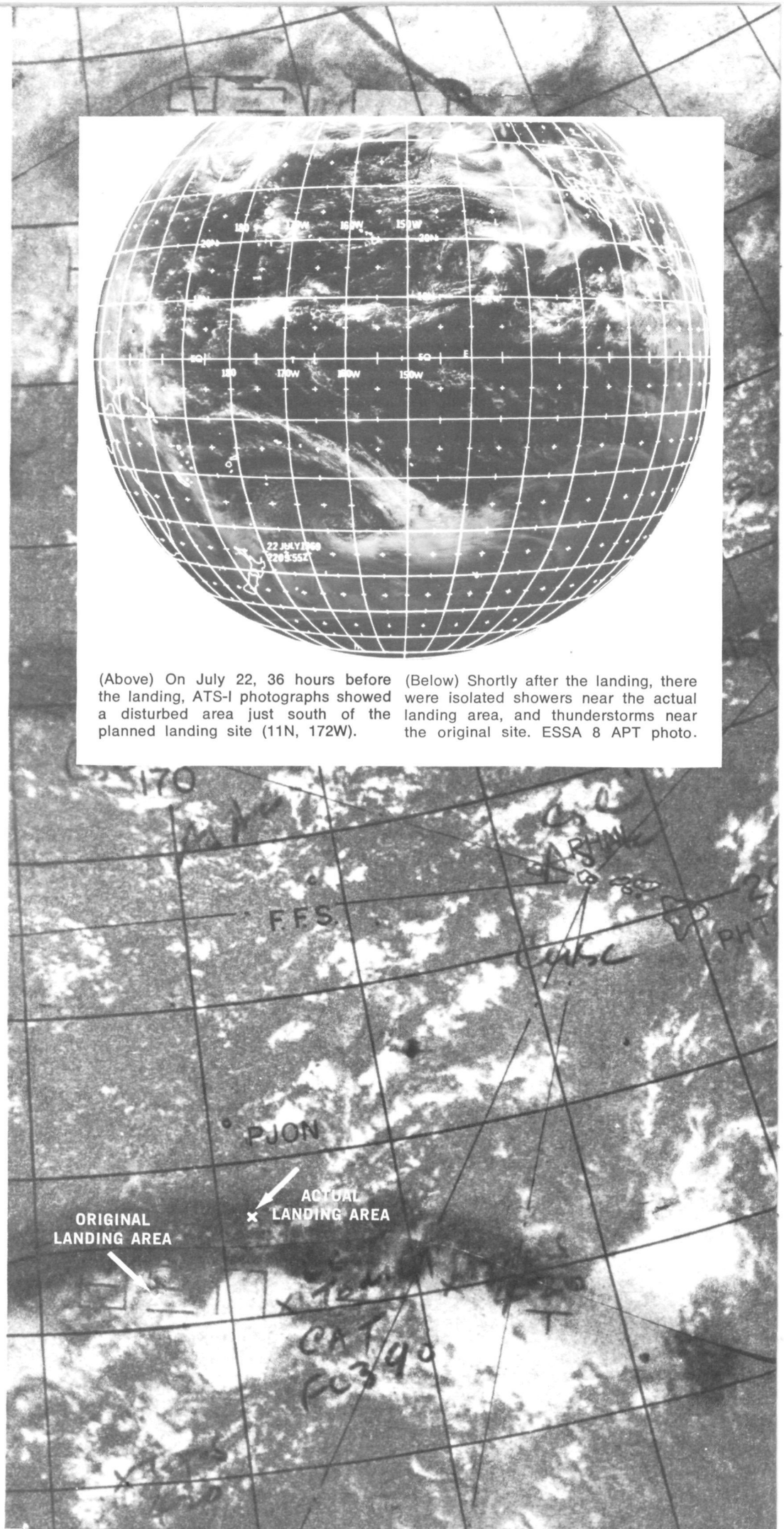
In additional to special alerts or warnings, NASA receives "space weather" information from the ESSA/SDFC on a routine basis four times a day just like other customers. The space environment console at Houston also gets solar data from a number of satellites such as Pioneers, Interplanetary Monitoring Platforms, Applications Technology Satellites, VELA, and SOLRAD.

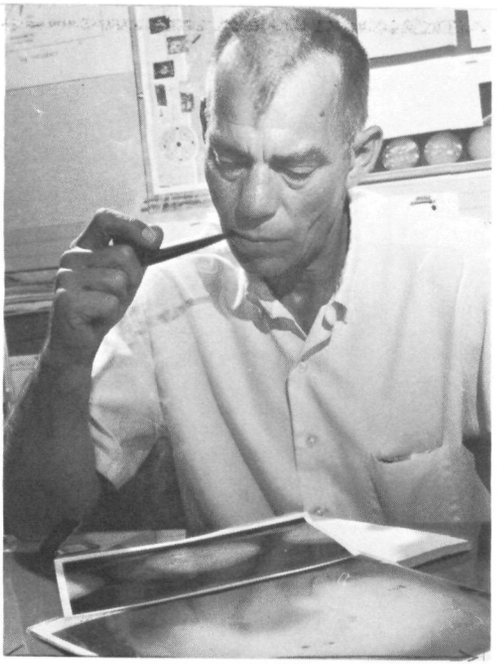
ESSA solar astronomer Patrick S. McIntosh points out that solar prediction is not easy since, apart from its unexplained 11-year cycle, the sun refuses to behave with easily defined logic. At times complex clusters of sunspots are accompanied by interacting magnetic fields that may lead to flares. Prominences or filaments appear head-on viewed from the earth as dark lines which often accompany sunspots. They represent a region of the solar surface where the vertical magnetic field is zero, and more flares seem to occur along this magnetically neutral line.

Flares can erupt continuously from the same region for anywhere from two to four hours. The largest flares extend over as much as two billion square miles of the

(Above) On July 22, 36 hours before the landing, ATS-I photographs showed a disturbed area just south of the planned landing site (11N, 172W).

(Below) Shortly after the landing, there were isolated showers near the actual landing area, and thunderstorms near the original site. ESSA 8 APT photo.





(Left) During an earlier mission, astronauts Aldrin and Armstrong, at right, watched Nagler, second from left, brief flight officials. (Above) Robert B. Doeker, Chief of ERL's Space Disturbance Forecast Center.

sun's surface—that is, ten times the surface of the entire earth. But the size of the flare itself is not a good indication of its hazards. What may appear to be a massive flare through the telescope may really be harmless, while a smaller flare loaded with ionizing proton radiation would be a real hazard.

During Apollo 11, happily, solar flares did not pose a problem. On July 17, the SDFC issued the following forecast: "It is increasingly evident that the radiation hazard the sun poses for Apollo 11 will be minimal. For the past six months major activity has been concentrated within a 10 to 15-degree-wide sector centered at approximately L265 degrees. Presently these longitudes are on the back side of the sun and are not due to return until 29 July. Conditions not unlike those of sunspot minimum will prevail for the next 12 days."

Daily forecasts then proceeded to read: "Solar activity remains at a very low level. The geomagnetic field is quiet." Only three subflares were reported on July 19. On July 21, the sun-watchers located a new dark spot; on the 22nd, a Class C (no geomagnetic effect) flare occurred; and for the rest of the mission, conditions were minimal.

Toward the end of the mission, atmospheric weather—the kind we know—reared its head again. For any launch date, there is only a narrow range of latitudes to which the vehicle can return after a successful mission. For Apollo 11, the optimum landing point was in the mid-Pacific at about 11 degrees North and 172 degrees West. This point is generally some 50 to 100 miles north of the disturbed weather of the intertropical convergence zone. Typically, it has only scattered showers and during most of the mission, fair weather persisted there.

At times, however, disturbed areas form along this zone and extend the area of heavy showers and squally weather a few hundred miles north of the zone's average position. On ESSA weather satellite pictures, these areas appear as blobs of bright, dense clouds. The Spaceflight Meteorology Group's staffs at Suitland and Honolulu watched these areas closely throughout the mission for indications of such developments. At Houston, meteorologists Alan Sanderson, Richard Siler, and Roger Carter kept the NASA staff informed on the intertropical convergence zone and other potential sources of weather—initially for a possible early termination of the flight and later for the planned end-of-mission area.

On July 22, the Weather Bureau group saw an enlarged disturbed area just south of the planned landing site, but a Navy reconnaissance flight found no consequential weather north of 10 degrees latitude. The next day, however, was another story: there were satellite indications that, by landing time, there might be trouble farther to the north. A Navy flight directed to that area found numerous showers and some thunderstorms.

Nagler recounts the tense time that followed:

"At Honolulu, Richard Sasaki of the Weather Bureau forecast office noted these indications of worsening weather and contacted O. A. Gorden Jr., our Spaceflight Meteorology Group representative. Gorden was off duty, but he quickly returned to his post. After conferring with Capt. William Houston, commander of the Fleet Weather Central at Pearl Harbor, he recommended a northward shift of the landing area. At Houston, Roger Carter was on duty. The possibility was discussed with him. He in turn talked it over with James Cox at the Suitland office. Cox examined the film strip showing the successive pictures of cloud cover over the Pacific as taken by NASA's Applications Technology Satellite that day.

"From this and from other indications, the Suitland office forecast 20-knot winds, six-foot seas, scattered showers and isolated thunderstorms with moderate to heavy turbulence."

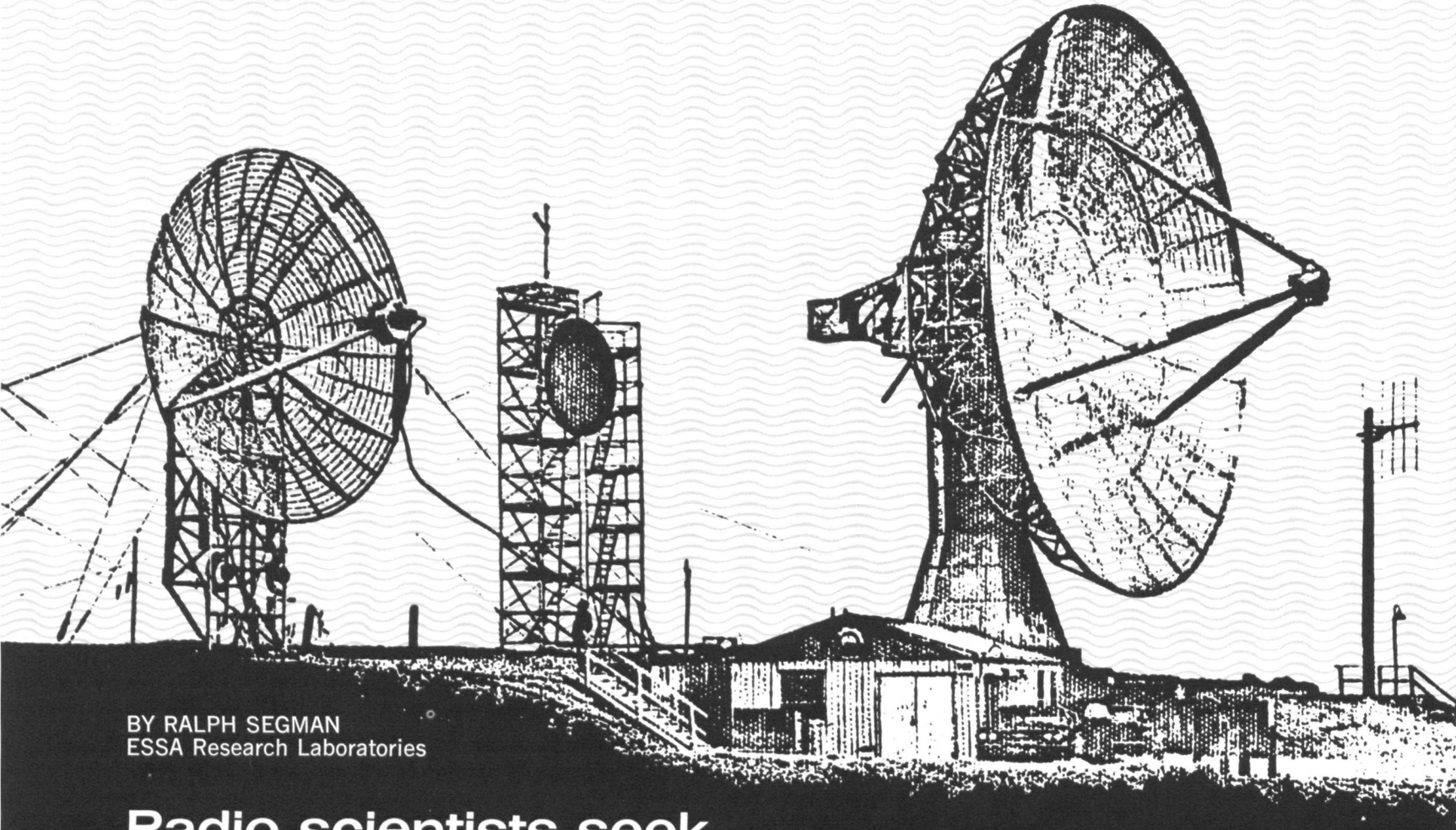
"Winds and seas were acceptable for landing," Nagler said. However, the NASA flight director and his staff did not want to risk the possible effects of turbulence on the Apollo's parachutes should the vehicle happen to come down in an active convective cloud.

"There was the possibility of shifting the landing up to a few hundred miles northeast but, for operational reasons, a reluctance to shift the aiming point very far," Nagler said. "On the basis of the Spaceflight Meteorology Group's forecasts, the end-of-mission point was shifted to 13 degrees 19 minutes North and 169 degrees 10 minutes West. Winds and seas were expected to be about the same at the new as at the first aiming point. At the new location, however, only isolated showers were expected, in contrast to thunderstorms near the original site."

The rest is history. Apollo 11 landed on schedule on July 24, very close to the new aiming point. Winds were 17 knots; waves six feet—and there were no showers.

At the original landing area, rescue aircraft in the region reported considerable shower activity; this was borne out by satellite pictures. The risk would have been materially greater there.

Man's most magnificent adventure had ended safely, and ESSA had made its contribution to the first trip to the moon. □



BY RALPH SEGMAN
ESSA Research Laboratories

Radio scientists seek to expand the utility of a limited resource

THOSE INDISPENSABLE WAVES

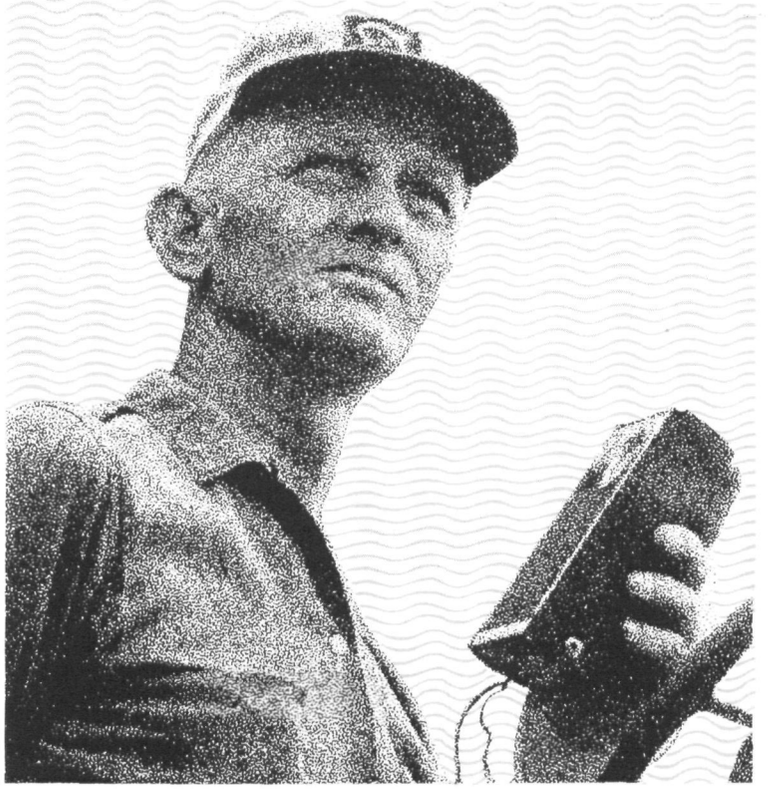
Radio waves are subtle constituents of the environment. They make no noticeable imprint on our senses. They do not splash, crackle, or sing in the pines; nor do they throw shadows or glow red at sunset. They are not hot, cold, dry, or moist. They do not buoy up airplanes or uproot trees and smash homes. But radio waves suffuse the cosmos and are particularly dense in our corner of it. They are, at the same time, a natural and a manmade part of the environment.

Since 1886, when radio waves were first generated artificially, the developing technology has helped bring immense cultural and economic changes to most of the world's people. Telecommunications by radio waves through the atmosphere contributed an estimated $20 billion to the United States' gross national product in 1966.

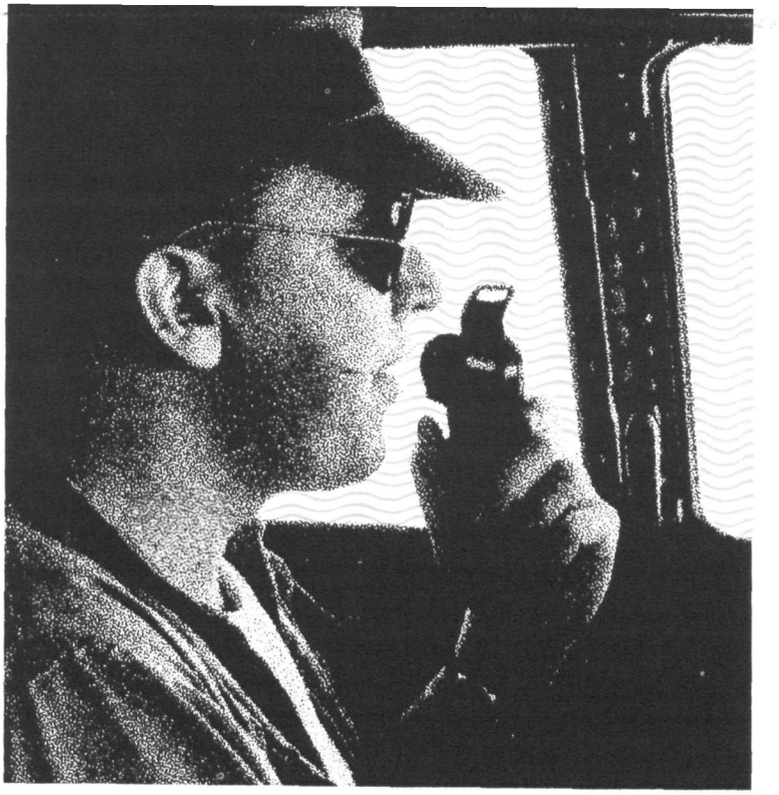
Those who keep eyes glued to the TV and ears tuned to the AM or FM set are aware of the pervasiveness of radio waves in the atmosphere. But the variety of radio telecommunications in this country is startling. In addition to commercial broadcasting, there are mobile land, air, and sea communications; long-distance radio relay of telephone, telegraph, and data; military communications and control; navigation; weather forecasting and warning services; public safety communications; space telecommunications; scientific research; Voice of America broadcasts; citizens' band; amateur radio; and dissemination of time and frequency standards.

If the atmosphere were homogeneous from top to bottom and if it were totally still, radio propagation would be a relatively simple matter. But such an ideal situation can only be simulated in a computer. The real troposphere and ionosphere are in continual motion and have constantly changing properties throughout. Nearly every change in the atmosphere causes radio waves to refract, or change velocity and direction. A radio wave propagated through the atmosphere encounters thousands of eddies and density changes. Sometimes the cumulative effect of all the refraction and attenuation causes fading, or total loss of transmission, or distortion of the wave.

A more thorough understanding of the atmosphere, of its interaction with radio waves, of the interaction between radio waves, and more data on global atmospheric conditions are basic to the design and operation of radio systems, choice of frequency, and efficient sharing of the limited radio-frequency spectrum.



(Opposite page) Twin 60-foot dishes on Colorado's Table Mountain are used by the Institute for studying the effect of the troposphere on radio waves.



Radio waves pervade the atmosphere. Among the variety of uses are commercial broadcasts (left), as well as aviation communications (right).

These are the goals of the ESSA Research Laboratories' Institute for Telecommunication Sciences. The Institute, under Director Richard C. Kirby, has been largely responsible for major atmospheric radio propagation advances, such as long-distance scatter techniques; for advances in radio tracking and very-low-frequency long-range communication and navigation systems; and for predicting performance and working out efficient frequency utilization for many new and established classes of radio systems.

By far the largest of the ESSA Research Laboratories' major components, the Institute has a full-time staff of 216. The most fundamental requirement in ITS' radio-telecommunications environmental research is to know and understand the refraction and attenuation caused by the atmosphere any place around the earth, at any altitude, at any time, for electromagnetic waves of any radio frequency; and to be able to predict the resultant effects on the propagation of radio waves. This enormously complex task comes close to covering the whole range of environmental science, including aspects of meteorology, aeronomy, oceanography, earth science, and space sciences.

Take, for example, the Radio Atmospheric Dynamics Group, headed by Leslie Berry. Berry speaks of electromagnetic probing of the irregularities, movements, and disturbances of the troposphere and the ionosphere, to learn more about their effects on radio propagation and about how these two parts of the atmosphere are physically coupled.

More than 99 percent of the ionosphere is neutral gases and less than 1 percent is ionized. Yet, except for space communications, it is the ionized portion that is utilized in very long-range radio and radar transmission. The radio waves are reflected from various layers of the ionosphere, depending on their frequency and the composition of the reflecting layer. Whether the transmissions return to earth on target depends on the motions of the ionosphere, the altitudes of its layers at the time of transmission, and disturbances in the ionized portion caused by solar activity or by changes in the neutral portion, which may have been influenced by the sun above or the troposphere below.

In one recent study, under Berry's direction, Dr. Thomas M. Georges found a significant connection between the troposphere and the ionosphere. Using three transmitters and a common receiver, they found oscillations in the F-region of the ionosphere that had a period of about three minutes. Georges thought that the oscillations might have been caused by acoustic waves generated by thunderstorms. He studied Weather Bureau radar data and found what seemed to be a close association between thunderstorm activity and the ionospheric waves.

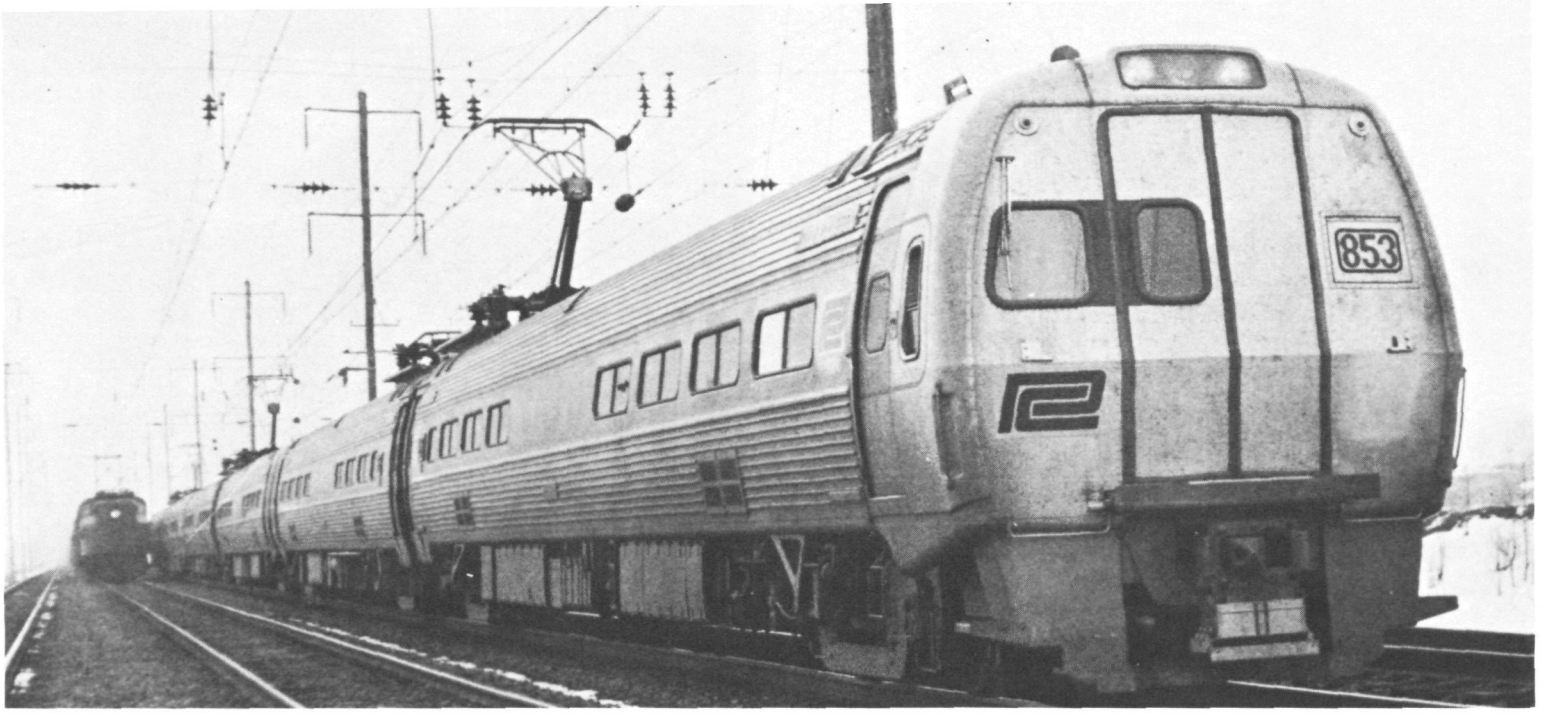
While Georges' work is a telling example of the environmental interrelationships between the troposphere, the ionosphere, and radio waves, another project, funded primarily by the Department of Transportation, shows the importance of considering the radio environment near the ground. The project involves investigation of the feasibility of communicating with high-speed vehicles on railways and highways without interfering with other radio users along the routes. This study is applicable generally to mobile communications problems and may make a significant contribution toward efficient use of the increasingly crowded electromagnetic frequency spectrum.

The work was initiated by Dr. Robert L. Gallawa (who is presently at the University of Toronto for a year of post-doctoral study) and is continuing under Richard G. FitzGerrell, acting chief of the Communication Technology and Systems Group. In undertaking the project, the Gallawa/FitzGerrell group had this to consider:

The purpose for communicating with the high-speed train was for command and control of the train operations and for traveler conveniences such as news service reports, telephone, and television.

Radio-frequency communications had to be transmitted through a tubular conductor, called a Goubau line, paralleling

continued



the train route. The radio signal is guided through the air alongside the line. Coupling devices on the vehicle provide a two-way communications path between the line and the train without physical contact.

They had to achieve the communications capability without a perceptible impact on the operations of other radio users near the railroad.

Early results of the research show that a Goubau line, consisting of a copper conductor 0.94 inches in diameter covered with a 0.2-inch polyethylene jacket, might serve the high-speed train communications needs and overcome the environmental problems. The ITS researchers took advantage of the fact that a good transmitting line is a bad antenna. They found that 99 percent of the energy propagating along this line is confined to within 31 inches of the axis of the line. The power radius varied for different frequencies, the frequency in this case being 750 megahertz (megacycles). At the same time, the radio signal strength drops off rapidly, and it is hoped that other radio users, unless they are within an unlikely three or four feet of the line, will encounter no interference with receiving and transmitting activities.

More than three-quarters of all radio telecommunications depend on frequencies ranging from very-high to super-high using the troposphere for line-of-sight and over-the-horizon transmission, such as Voice of America broadcasts, Federal Aviation Administration radar data relay systems, rocket and satellite tracking, and geodetic measurements. The Tropospheric Radio Group under Dr. Moody C. Thompson works in the radio and optical frequencies at the outermost fringes of the state of the art. Propagation through the troposphere is affected not only by turbulence, which is an oversimplified way of viewing the problem, but also by temperature, humidity, inversions, time of day, season, geographical location, distance, altitude, and type of terrain. The radio waves are refracted, absorbed, scattered, and diffracted, depending on the ever-changing combinations of these factors.

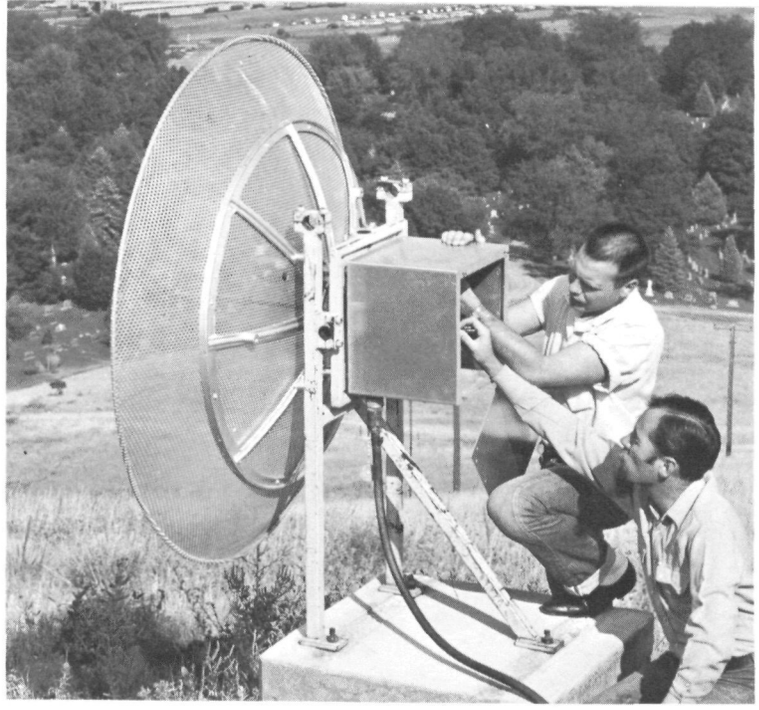
Basically, the work of Thompson's group is to determine errors introduced by the troposphere in distance measurements and to develop techniques and instruments to reduce the errors. Measurements are accomplished by determining the time it takes for an electromagnetic wave to travel the distance under observation. If we lived on an airless planet like the moon, Thompson and his scientific staff would not be in the same business, for the wave-velocity measurements could probably be brought close to the inherent precision of the measuring instruments. Effects of the troposphere presently limit the actual precision to one part per 10 million (a million times less sensitive than the instrument's inherent capability). The working precision of Thompson's instrumentation is sufficient to detect relatively minor earth movements due to seismic activity.

A spinoff benefit of this error-determination work is advancement in remote sensing techniques. The effects of the atmosphere on radio waves can be used to deduce what some of the atmospheric conditions are.

Remote sensing is a primary concern of the ITS Ionospheric Radio group under Douglass D. Crombie and Lowell H. Tveten. In the Barbados Oceanographic and Meteorological Experiment, Crombie has been using high-frequency radar to study sea waves out to distances up to 400 kilometers off Barbados. His technique is to transmit radio ground waves along the sea surface. If the length of the sea waves is half that of the radar waves, a portion of the radar energy is scattered back to the receiver. Using Doppler instruments and two antennas, Crombie is able to measure the wave length of the sea waves, and their energy, amplitude, velocity, and direction. As the technique is further developed, it should contribute to physical oceanography because of the large area coverage that can be achieved from a single point on land, to sea-state determinations for coastal shipping and fishing interests, and to identification of coastal storms and storm surges in time for warnings.

Tveten also uses high-frequency radar for sea studies, but his instrument is located on Table Mountain, Colorado, nearly 2,500 kilometers from the Atlantic Ocean. Using over-the-horizon transmissions, he hopes to develop the technique to the point that he too can determine the sea state and amplitude of the waves. With the great range (about 3,000 kilometers) of his radar, Tveten may be able to locate storms along the entire eastern seaboard and far out in the Atlantic, Pacific, and Caribbean regions. It may be possible also to spot incipient hurricanes and typhoons before they fully develop. And, harking back to the work of Berry and Georges, the technique may be capable of detecting intense land storms through their effects on the ionosphere.

ITS' third general area of activity, improvement of tech-



The Institute has helped to develop communications systems for high-speed trains (left) and for the FBI's National Crime Information Center (above). A small antenna (right) is used to study atmospheric effects on microwave transmission.

niques and systems for data acquisition and transmission in environmental services, is carried out for other government agencies as well as for ESSA. This program is concerned with such areas as ocean and satellite telemetry problems, shipboard communications and radio-navigation techniques, the large ground-communication system for meteorological data, the ESSA Operational Telecommunications System, World Weather Watch, and the Integrated Global Ocean Stations System (IGOSS).

World Weather Watch is an international system which focuses on observing the global atmosphere, and communicating and processing data and weather predictions. IGOSS is a similar international system which deals with the oceans. When viewed together, they constitute a complete atmosphere-ocean system, which by the late 1970's may include as many as 500 ocean buoys and 5000 ships, as well as satellites of different kinds, equipped with automatic oceanographic and meteorological data stations. Both IGOSS and the World Weather Watch came about as a result of the joint efforts of the World Meteorological Organization and the Intergovernmental Oceanographic Commission. The United States is participating in both; and the National Data Buoy System, a project of the National Council for Marine Resources and Engineering Development (chaired by the Vice President) is expected to be integrated with IGOSS in many respects. The council has selected the Coast Guard to manage development of the national buoy system, and the Coast Guard has contracted with ESSA through the Institute to develop a global communications system, which may be adopted by IGOSS.

Even more complex is the job that ITS' Communications Technology and Systems group has in outlining the ionospheric communications system for the colossal environmental data network. Headed by Thijs de Haas, the group is computer-modeling the high-frequency communications system. The system ultimately will be controlled and coordinated by computer. The oceanographic and meteorological data will be automatically recorded and stored. It will be transmitted on interrogation to shore stations in a globally time-synchronous mode. The shore stations will relay the data to an international network of processing centers for analysis and use by various agencies and contractors.

To be of real value, the data must be less than two hours old. The controlling/coordinating computer must be programmed to decide when to order data transmissions, what shore stations should receive data from ships that are constantly on the move, and what conditions are over the radio propagation paths.

Since changes in the ionosphere occur both continuously and abruptly, the need is great for real-time information on radio-propagation characteristics of that part of the atmosphere. Long-range radio users need to know, for example, geophysical disturbances that affect the ionosphere, conditions of specific ionospheric radio propagation paths, and the highest and lowest usable frequencies for ionosphere telecommunications systems. The Ionospheric Propagation Predictions Group under Alfred F. Barghausen has developed a system for rapid dissemination of such information through the ESSA Research Laboratories' computer.

The system's users include the Department of Commerce, National Aeronautics and Space Administration, Department of Defense, Army, Navy, and Air Force.

Ideally, research should be done under well-controlled experimental conditions. This is most difficult to achieve in the unstable ionosphere. Radio propagation scientists have dreamed of being able to simulate accurately in the laboratory radio communications characteristics of the ionosphere. The Communications Technology and Systems Group has developed such a simulator after nearly four years of work.

Under Clark C. Watterson, with a special assist from R. M. Coon, a research team developed and validated an advanced mathematical model for ionospheric radio propagation paths. Based on the validated model, they built a simulator that reproduces fading, multipath propagation (in which the signal takes several paths and interferes with itself), and atmospheric noise. Basically, the simulator is used to test the interaction between the ionosphere and the radio system under study. In its first major assignment, the simulator has successfully evaluated a communications system for the U. S. Air Force.

The earth's surface and atmosphere have many effects on electromagnetic waves. The telecommunications goal is to be able to predict these effects and assess their influence on electromagnetic waves propagated through them. This work is carried on so that the nation will receive the maximum return from its expenditures on telecommunications systems and so that the electromagnetic spectrum, a limited natural resource will be used with maximum effectiveness and efficiency. □

The USC&GSS PATTON, a small vessel which has since been decommissioned, conducted a 19-day hydrographic survey of portions of the Duncan Canal.

Blazing a trail for Barite

BY RAYMOND WILCOVE
Coast and Geodetic Survey

A 19-day hydrographic survey that cost $11,000 made possible the establishment of a new industry in Alaska.

This modest endeavor stands as an example of what cooperation between government and business can accomplish.

The story of this accomplishment began in 1914, when a U. S. Geological Survey geologist, Ernest F. Burchard, discovered a large deposit of barite on an island in southeast Alaska.

Barite's principal use is in drilling oil and gas wells, with more than 900,000 tons consumed annually for that purpose in the United States. The mineral is also used to make numerous heavy chemicals, for paint products, and as an aggregate in high-density concrete. It has some medicinal applications, too.

Annual U.S. consumption of barite from 1954 to 1964 was between 1.2 and 1.5 million tons. Of this, 578,000 tons were imported in 1963. The bulk of domestic production is found in a belt extending from South Carolina, through Georgia, Tennessee, and Arkansas, to Missouri. Total world output is approximately three million tons a year.

Burchard reported that "quarrying of the deposit would evidently be very simple as the material could be blasted from the face of the cliff and a large output obtained in a relatively short time."

Despite the need for barite, little was done about Burchard's discovery for half a century, beyond an announcement of the find in a U. S. Geological Survey bulletin, for it turned out that developing the deposit would be far from simple. The water approaches to the island were dotted with mud flats, rocks, shoals, marshlands, and other impediments to navigation.

In November 1964, however, the Alaska Barite Co., impressed by the high-grade easily mined deposits (the ore eventually turned out to be one of the best grades of barite for drilling mud anywhere in the world) expressed a desire to develop the find. It outlined its plans in a letter to the regional Officer of the Coast and Geodetic Survey in Seattle, Washington.

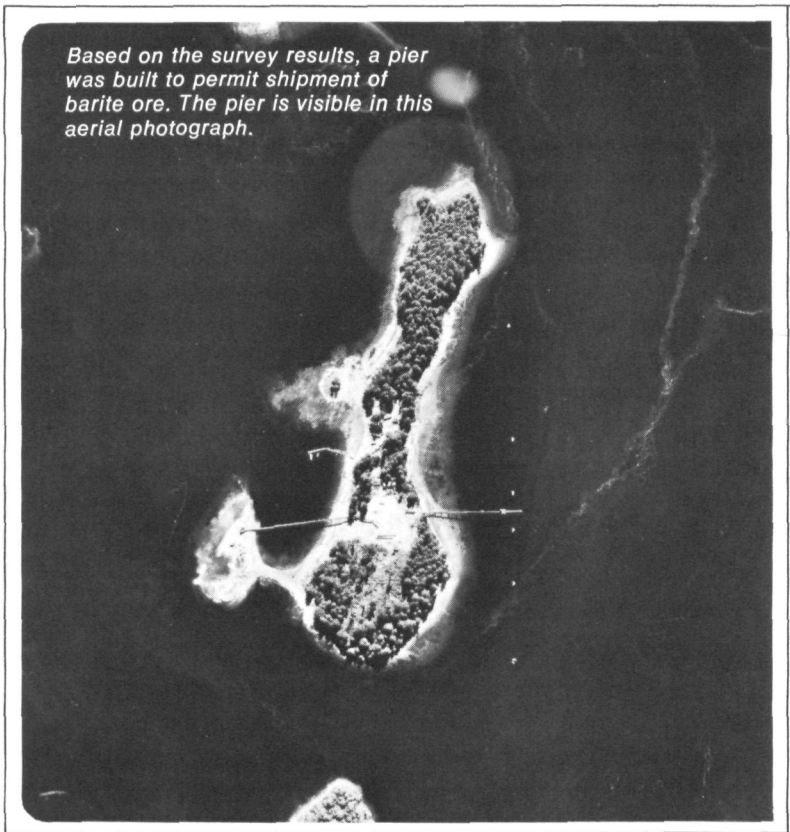
The barite deposit was located in the Castle Islands, which lie in Duncan Canal. The canal, a natural feature, extends northward into Kupreanof Island from Summer Strait, one of the great inlets into southeastern Alaska. The canal is about 20 miles long and 0.8 to 1.5 miles wide. The Castle Islands lie on the western side of the canal about 10 miles from the entrance. The communities of Petersberg and Wrangell are in the general area.

The company proposed to build a deep-sea loading facility in the Castle Island area of Duncan Canal. It emphasized that exploitation of a 20-year lease on the barite deposits would depend on the feasibility of bringing deep-sea vessels of up to 40,000 deadweight tons to a berth alongside the island. If this were possible, the company stated, it would permit the development of an export market for the mineral.

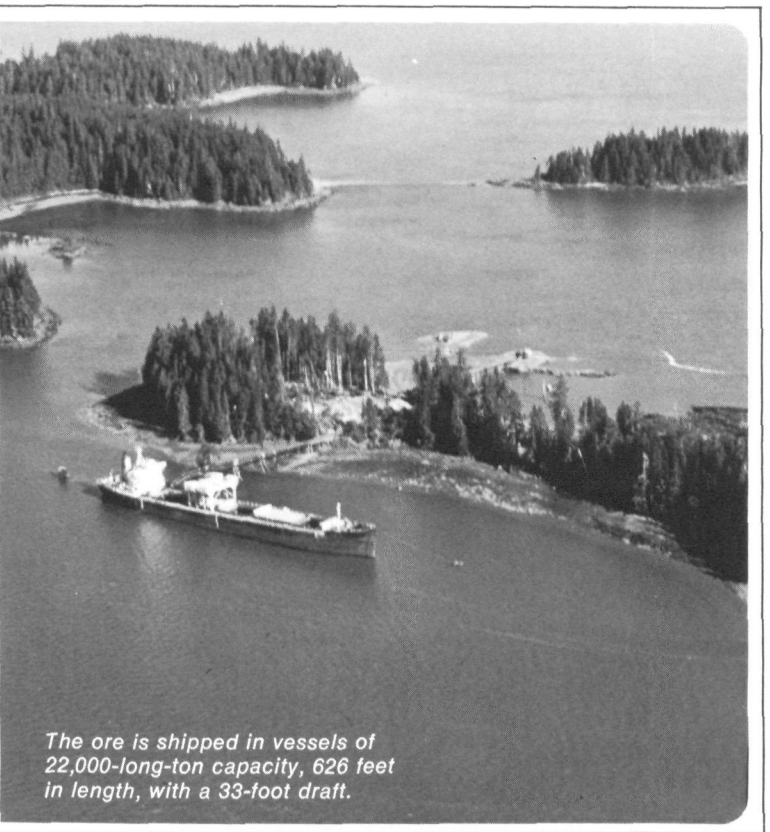
Subsequently, Ray Kelly and John Fleming, two of the principals in the company, disclosed that markets for the Alaskan barite had been found. They proposed to construct a new processing plant in the Cook Inlet area, to which the ore would be barged.

It was essential to the success of the operation, they pointed out, to determine, through hydrographic surveys, the maximum size of ships that could be moored close to the shore. The request for assistance was endorsed by Alaska Governor William A. Egan. The governor wrote the Director of the Coast and Geodetic Survey, in April 1965, that the operation "could contribute substantially to the State's economy and would provide employment not otherwise available.

The ESSA agency had by then been surveying U. S. coastal waters for almost 150 years. Still, it was the professional judgment of the Coast Survey that only half of the area of its charting responsibility was adequately surveyed. But there was a reluctance to expand the rate of progress in the face of competing demands for resources. The agency's Planning Staff proposed that a typical request for surveys be selected from among the large number received each year, and that a simple cost-



Based on the survey results, a pier was built to permit shipment of barite ore. The pier is visible in this aerial photograph.



The ore is shipped in vessels of 22,000-long-ton capacity, 626 feet in length, with a 33-foot draft.

utility analysis be made of this problem.

The request selected was that of the Alaska Barite Co. It was quickly obvious to Coast Survey planners that no competent mariner would risk a large vessel in the area where the company desired to operate without proper aids to navigation—such as buoys and lights—and an adequate large-scale chart.

Before Coast Survey cartographers could compile such a chart, a comprehensive, detailed basic hydrographic survey would have to be made. The survey would have to depict accurately the visible and underwater topography, fix the positions of various landmarks, and clearly show the location of obstructions, shoals, reefs, and other vital features of concern to the navigator.

The existing chart of the area was totally inadequate for navigation there. The Castle Islands region occupied a space of about one square inch on the chart. Furthermore, the previous hydrographic survey had been completed in 1887 and utilized methods long superseded in the Coast Survey. Water depths had been taken with graduated leadlines, and profiles measured across the channel at intervals of about one-quarter mile. This coverage did not permit identification of all possible obstacles to navigation and production of a chart to the large scale required.

Under the Coast Survey's Long Range Plan for Hydrography, a new chart was scheduled for this area sometime after 1972 following a new basic survey. However, in view of the promising aspects of the barite proposal, it was decided to advance the priority for this chart and resurvey part of the Duncan Canal in the summer of 1965. Lt. Cdr. J. K. Richards, commanding officer of the USC&GS Ship PATTON, a small vessel which has since been decommissioned, was directed to conduct a basic hydrographic survey of the area.

The project was envisioned as the first stage of a complete new survey and, consequently, aerial photographic coverage was also scheduled. The assignment was successfully accomplished, and Richards submitted the following report:

1. There were sufficient depths to navigate a deep-draft commercial vessel into the area.

2. In the vicinity of the Alaska Barite Company's proposed dock, 30-foot depths could be carried to within about 240 feet of the high-water line.

3. A pier extending about 260 feet offshore from the high-water line would provide at least 30 feet of water along its outer face. A 300-foot pier would extend almost to the 60-foot depth.

The data obtained by Richards' survey was used by the Marine Chart Division to produce a large-scale (1:20,000) chartlet of the area which was published in Notices to Mariners, May 12, 1966, with the material to be entered on new editions of the existing chart until it was completely recompiled.

A copy of the survey was furnished to the Alaska Barite Co. Equipped with this information, the company arranged with the U. S. Coast Guard to install a light and a buoy at strategic locations in the channel.

The company arranged to ship the ore in vessels of 22,000-long-ton capacity, 626 feet in length, and with a draft of 33 feet. Three shipments were to be made annually commencing in August 1966, and eight to ten additional shipments were to be made by barge.

As a result of the survey, the Alaska Barite Co. opened a producing mine in the Duncan Canal area near Petersberg and, since October 1966, has made 10 shipments from the mine of approximately 220,000 long tons. Facilities valued at about $750,000 have been installed at the mine, which is operated by a crew of 10 to 20 men, the number depending on the season of the year. Further development of the process to include crushing and grinding of the barite has generated additional employment at Kenai.

Thus, a new industry resulted directly from the provision by the Coast and Geodetic Survey of basic environmental data. "The survey work completed in 1965 by the Coast and Geodetic Survey," Fleming says, "has allowed us to open up a producing mine. . . ."

The complete economic impact of the mining operation will not be known for some time. The deposit being mined still contains at least a five-year supply of the mineral, and there is a strong possibility that more barite deposits may be discovered in the same general area.

Burchard, in reporting on his discovery in 1914, added that while "no other deposit of barite was observed . . . the similar appearance of other cliffs on islands in the group further north, as observed through a field glass, suggests the possibility of other deposits." □

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

Offices of OFCM and WWS Are Consolidated; Plans and Programs Effort Is Realigned

A new headquarters office has been established and another realigned in an ESSA reorganization designed to make more efficient the work of the agency.

An Office of Assistant Administrator for Environmental Systems has been created to consolidate the functions previously in the Office of the Federal Coordinator for Meteorological Services and Supporting Research and World Weather Systems, as well as to provide a focus for systems analysis of ESSA-wide and Federal government-wide systems.

The Office of the Assistant Administrator for Plans and Programs has been restyled along program and disciplinary lines as opposed to its previous functional organization.

The Office of Assistant Administrator for Environmental Systems was established to bring into one office the related coordinating and planning of Federal activities in certain scientific areas that have resided in several offices. The new unit will merge the Office of World Weather Systems and the Office of Federal Coordinator for Meteorological Services and Supporting Research. Provision of guidance to the ESSA portion of the Marine Environmental Prediction Planning Staff has been assigned to the new office.

It also provides ESSA with a systems analysis and design capability to discharge ESSA's responsibilities for Federal Government-wide programs which have been assigned to it as lead agency as well as to provide offices for certain ESSA-wide systems.

The office will also become the focal point for the planning and management of field experiments involving other agencies, nations, and non-government scientific groups.

Dr. Richard E. Hallgren, Director of the Office of World Weather Systems, has been named Acting Assistant Administrator for Environmental Systems. C. E. Roache, former Deputy Federal Coordinator for Meteorological Services and Supporting Research, will be Acting Deputy Assistant Administrator. Three Divisions have been established within this office:

A Federal Plans and Coordination Division will provide leadership and coordination in the development of plans for the efficient utilization of Federal meteorological services and supporting research and for participation in the cooperative World Weather Program. Dr. Clayton E. Jensen, former Chief of Supporting Research of the Federal Coordinator's Office will be the acting chief of the new division.

The Systems Division, headed by John W. Connolly (acting), former Chief, Programs Division of the Office of Plans and Programs, will conduct systems studies relating to ESSA's total environmental involvement. It will examine alternative methods for achieving future national environmental science goals and conduct studies related to the design and analysis of interagency and international programs.

A Field Research Projects Division will conduct the engineering and operational planning, coordination and implementation of experiments or tests requiring the joint participation of agencies, countries, or scientific groups including the arrangement of logistic support. William S. Barney, Manager of the BOMEX Project Office, will be Acting Chief of the Field Research Projects Division.

The Office of Assistant Administrator for Plans and Programs, under the direction of Donald F. Moore, provides ESSA with a focal point for the development, implementation, and maintenance of an effective planning and programming system throughout ESSA and for the development of plans for meeting approved ESSA objectives. In close collaboration with line and staff organizations, the office develops a five-year program and compatible financial plans from which ESSA budgets can be formulated. It conducts a continuing evaluation of ESSA programs and accomplishments, and provides advice and guidance to the Administrator on the program aspects of resource allocations.

The office has been operating under a functional organization over the past 18 months. Under the realignment, one Group and four Divisions will be restructured according to major programs and disciplines assigned to ESSA.

Donald Martineau is Deputy Assistant Administrator for Plans and Programs.

An Office of Special Studies under the direction of Morton Rubin (acting) will provide guidance and direction for ESSA's major program areas with regard to long-range goals and plans. It will also conduct cost-benefit analysis and other basic studies required in planning and operating ESSA programs.

The following four program-oriented Divisions will support the Assistant Administrator for Plans and Programs:

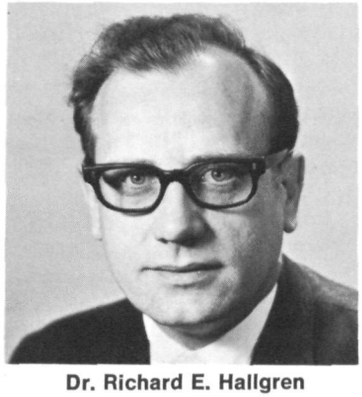
Marine Science Services Division, Cdr. Edwin McCaffrey, Acting Chief.

Earth Science Services Division, Cdr. Charles Townsend, Acting Chief.

Atmospheric Science Services Division, Donald C. House, Acting Chief.

Telecommunications and Space Services Division, Dr. William O. Davis, Acting Chief.

Donald F. Moore


Dr. Richard E. Hallgren

Dr. Hess Named To Head ERL

The appointment of Dr. Wilmot N. Hess as Director of the Environmental Science Services Administration's Research Laboratories in Boulder, Colorado, has been announced.

Dr. Hess, 42, has been Director of Science and Applications at the National Aeronautics and Space Administration's Manned Spacecraft Center in Houston, Texas. He was named one of the Ten Outstanding Young Men of Government in 1967 by the United States Junior Chamber of Commerce.

In his new post with the ERL, Dr. Hess will direct a wide range of fundamental investigations to increase knowledge of the geophysical environment and to develop advanced environmental services.

At NASA's Manned Spacecraft Center, he has been responsible for direction of the Lunar Receiving Laboratory. He has planned and conducted research in earth and lunar sciences, provided environmental data required to support mission and spacecraft design; has conceived, developed and integrated experimental meteorological programs and instrumentation for space; and has provided space environment data and support during manned space flights.

Dr. Hess went to Houston in 1967 from NASA's Goddard Spaceflight Center in Greenbelt, Md., where he had served since 1961. As head of Goddard's theoretical division, he directed research in almost every discipline of space science, including particles and fields, aeronomy, ionospheric physics and geodesy. His groups were active in quantum mechanics, studies of atomic collisions, celestial mechanics, the origin and development of the radiation belt, theoretical astrophysics, and lunar science.

From 1959 to 1961, he was associated with the Livermore Radiation Laboratory in Livermore, California, where he directed nuclear and space physics research.

Dr. Hess was born in Oberlin, Ohio, and was graduated from Clinton, N.Y. High School in 1943. He served in the Navy at Columbia University from 1944 to 1946, and was graduated from Columbia in 1946. He did graduate work at Purdue University and Oberlin College, and received his master's degree in physics from Oberlin in 1949. He received his Ph.D. in physics from the University of California in 1954.

all in the family PERSONNEL NOTES

Dr. Hyman Orlin has been named Special Assistant to the Director of the Coast Survey for Earth Science Activities. Dr. Orlin, a geodesist, has been associated with the Coast Survey for almost 23 years. As Special Assistant, he will be the principal advisor to the Director in geophysical matters. In addition to program planning budget, research and evaluation of techniques and results, scientific analysis and study, and coordination, the principal geophysical activities with which he will be concerned are gravimetric.

Capt. Robert C. Darling, ESSA Commissioned Officer and Director of the Coast Survey's Executive and Technical Services Staff, has been appointed Associate Director of the Coast Survey for Hydrography and Oceanography. Capt. Darling will be responsible for the Survey's oceanographic programs and for furnishing project guidance to the marine centers in Norfolk, Va., and Seattle, Wash.

James R. Neilon, former Chief of NMC's Information Processing Branch is now the technical assistant to the Chief of the Communications Division. Mr. Neilon joined the Weather Bureau in 1960 and since then has been involved in numerical weather predictions. In 1968, he received the Department of Commerce Silver Medal for his role in automating weather communications.

Capt. Roger F. Lanier, ESSA Commissioned Officer, has become the commanding officer of the USC&GS Ship RAINIER. Capt. Lanier, whose last assignment was as special assistant to the Associate Administrator of ESSA, previously commanded the USC&GSS PEIRCE and served also on five other Coast Survey vessels.

Capt. Alfred C. Holmes has been appointed technical assistant to the Associate Director of the Coast Survey's Aeronautical Charting and Cartography Division, and also as Chief of the Division's Research Group. Prior to this assignment, he served as Operations Chief of the Survey's Pacific Marine Center in Seattle.

Maurice E. Ringenbach has been selected Director of the Coast Survey's Engineering Development Laboratory. The Laboratory is responsible for the design of equipment systems for use by the Survey in its land and ocean-based operations. Mr. Ringenbach came to the Coast Survey from the Weather Bureau's Equipment Development Laboratory, where he served as Director.

Cdr. Donald R. Tibbit now commands the USC&GS hydrographic ship McARTHUR. Prior to his new appointment, he was Director of the National Tsunami Warning Center in Honolulu. Cdr. Tibbit joined the Coast Survey following graduation from the University of Oklahoma.

Cdr. Floyd J. Tucker, former executive officer of the USC&GS Ship DISCOVERER, has become the new Operations Officer at the Coast Survey's Atlantic Marine Center. Cdr. Tucker succeeds Capt. Pentti A. Stark, who has assumed command of the Miami Ships Base.

Francis W. Poole, forecaster at the Anchorage, Alaska, Weather Bureau Office for the past two years, has been named to head the Juneau, Alaska, office. Prior to his duty in Alaska, he served in the Chicago Forecast Center, and at Rockford, Ill., and Minneapolis, Minn.

James Smarz has been selected official in charge at WBO Iliamna, Alaska. Mr. Smarz joined the Alaska Region in 1968 and has served at the Anchorage Forecast Center as well as remote field stations.

Cdr. Philip J. Taetz, former Chief of the Commissioned Personnel Branch, has assumed the post of Operations Officer aboard the USC&GS Ship SURVEYOR.

Cdr. George M. Poor has succeeded Lt. Cdr. Charles H. Nixon as officer in charge of the ESSA Commissioned Officer Training Section in Norfolk, Va. Cdr. Poor was formerly Chief of the Pacific Marine Center's Processing Division at Seattle.

Miami's Atlantic Oceanographic Labs Reorganized

The ESSA Research Laboratories' Atlantic Oceanographic Laboratories have been reorganized as the Atlantic Oceanographic and Meteorological Laboratories.

They will consist of five existing Miami-area laboratories: Physical Oceanography, National Hurricane Research, Marine Geology and Geophysics, Experimental Meteorology, and Sea-Air Interaction.

The consolidation creates an interdisciplinary focus to concentrate critical research on oceanography and tropical meteorology in a single location and under a single organization. The new organization will be shaped around environmental research problems which will draw upon the collective strength of several colocated groups in Miami, such as the ESSA fleet, the Research Flight Facility, the National Hurricane Center, the Coast and Geodetic Survey's Engineering Development Laboratory, as well as other cooperating Federal agencies involved in hurricane activities.

Dr. Harris B. Stewart, Jr., Director of the Atlantic Oceanographic Laboratories, will become the Acting Director of the new AO&ML. The Physical Oceanography Laboratory, the Marine Geology and Geophysics Laboratory, and the Sea-Air Interaction Laboratory will be transferred intact into AO&ML. The Physical Oceanography Laboratory is headed by Bernard D. Zetler. Dr. George H. Keller is Director of the Marine Geology and Geophysics Laboratory, and Feodor Ostapoff is Acting Director of the Sea-Air Interaction Laboratory. Dr. Joanne Simpson is Chief of the Experimental Meteorology Branch and Robert C. Gentry is Director of the National Hurricane Research Laboratory.

A new Miami Laboratory building has been proposed in the 1970 budget and, if approved, will be the headquarters for the AO&ML.

Newton M. Lieurance (left), ESSA Director of Aviation Affairs, presents the first copy of the new publication, "A Pilot's Guide To Avition Weather Services," to Major-General Joseph D. Caldara, USAF (Ret.) President of the Flight Safety Foundation. More than half a million copies of the ESSA safety brochure have been issued.

Radar Weather in the Home Offered To Residents of Galveston, Texas

In the island city of Galveston, Texas, people are weather-conscious.

The heaviest loss of life—approximately 6000—ever suffered from a U.S. hurricane occurred there in 1900 and since that time, several tropical storms have dealt staggering blows to the island.

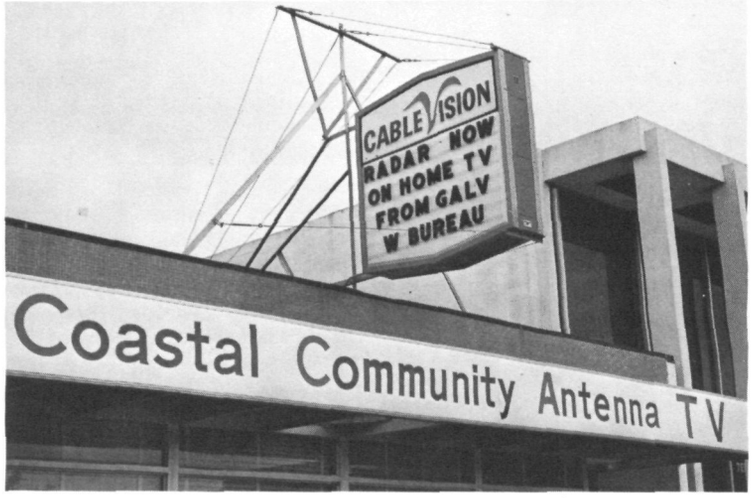
So it is logical that Galveston is the nation's first city to provide its television viewers with continuous radar weather.

Galvestonians now can observe the ESSA Weather Bureau radarscope continuously by turning to Channel 10. Additionally, they can hear continuous weather broadcasts interpreting the radar picture.

Early this year the Galveston Weather Bureau office signed a contract with Coastal Community Antenna Television, Inc., to make possible the new service. The Cablevision company has been awarded a franchise by the city. Its primary purpose is to bring to Galveston stronger TV signals from distant stations.

The Galveston Weather Bureau was the first station to install remote slow-scan radar and one of the first chosen for VHF-FM continuous broadcasts.

Slow-scan remoting appears to have numerous advantages over earlier methods. A data insertion device allows radar specialists, under the direction of meteorologist-in-charge Davis Benton, to bring the picture to life by pointing out the types of weather systems, their intensity, characteristics, movement and other significant features. It also serves as a map overlay for the 250-nautical-mile radar surveillance area.



Marquee, above Cablevision Studios; advertising weather.

Since space does not permit complete wording of city names and weather features, official Weather Bureau contractions are used. A brochure prepared by the Weather Bureau explains the features of the service.

Marine interests have shown a lively interest in the new service, as have public officials, business firms and private citizens with an interest in the weather. Benton calls it "a new dimension in mass weather dissemination," and Galveston residents agree.

Coast Survey Centralizing Chart Distribution

The Coast and Geodetic Survey is centralizing the distribution of the approximately thirty million aeronautical and nautical charts it issues annually.

The charts which have been distributed by C&GS offices in New York, Kansas City, and San Francisco, will be distributed from C&GS headquarters in Rockville, Md., where they are compiled. The Anchorage, Alaska, office of the C&GS will continue as a distribution office for aeronautical charts in Alaska.

Chart distribution was terminated on June 30 by the offices in New York and San Francisco, and the Kansas City office will end its chart distribution in October.

To speed deliveries of nautical charts to its agents, the Survey, a unit of the Environmental Science Services Administration, has revised its distribution program. All nautical charts will be shipped to agents by airmail, except for those in Maryland, Delaware, Virginia, and the District of Columbia. In addition, agents now are receiving every four weeks an Advance Order Notice listing the charts being published during the following four-week period. Advance orders are filled immediately upon publication of the new editions of charts.

Aeronautical charts are also being shipped airmail to agents and the new Advance Order system for aeronautical chart agents will be initiated in September.

Over-the-counter sales of aeronautical and nautical charts and related publications are made from C&GS offices at Room 200, Building 14, 4200 Connecticut Avenue, N.W., Washington, D.C. Mail orders should be addressed to Distribution Division (C44), Coast and Geodetic Survey, Rockville, Md. 20852.

Charts can also be obtained throughout the United States from the 1,000 authorized aeronautical chart agents located at airports and major cities, and from the 700 authorized nautical chart agents located at seaports, marinas, and harbors.

ESSA Scientists Study Pacific Basin Underwater Features

ESSA scientists have completed an investigation of three major underwater features in an effort to determine the history of the North Central Pacific basin.

The three features are a newly discovered trough, for which the name "Emperor Trough" will be proposed; the Chinook Trough; and the Rat Island Fracture Zone(s).

Troughs are giant declivities in the ocean floor, while fracture zones are long bands where the sea bottom appears to have been broken, similar to the geologic faults found on land, such as the San Andreas Fault in California.

The project was undertaken aboard USC&GSS SURVEYOR. The purpose was to determine the interrelationship of the three underwater features and also their relationship with the linear magnetic anomalies found in the area.

The scientific party consisted of Barrett H. Erickson, chief scientist, Frederic P. Naugler and William H. Lucas, all of the Pacific Oceanographic Research Laboratory, and Thomas E. Chase of Scripps Institution of Oceanography at La Jolla, California. Captain Eugene W. Richards, of Kirkland, Wash., is commanding officer of the SURVEYOR.

Current Tracking System Tested Successfully

ESSA has announced the successful testing of a new ocean current tracking system which utilizes a satellite and a free-drifting buoy. This system can also provide satellite transmittal of oceanographic and atmospheric data collected by the drifting buoy.

The test was conducted in the Gulf Stream by ESSA and the National Aeronautics and Space Administration.

It represents the first successful attempt at tracking a free-drifting buoy in the deep ocean with satellite telemetry. M. E. Ringenbach, Acting Director of the Coast and Geodetic Survey's Engineering Development Laboratory in Rockville, Maryland, said that "the potential implication to the public and to the community of environmental scientists, as a result of the success of this experiment, cannot be overemphasized. Not only can ocean currents be traced accurately in this manner, but sensors on the drifting buoy can acquire oceanographic and atmospheric data, which can be transmitted with the navigational information. Through this technique, oceanographic and atmospheric data can be acquired from remote regions of the world."

In the test, a buoy equipped with Omega Position Location Equipment (OPLE) was allowed to drift freely in the Gulf Stream off the east coast of Florida. An Applications Technology Satellite (ATS-3) interrogated the buoy upon command. The buoy's navigational data were relayed through the satellite to the Goddard Space Flight Center at Greenbelt, Md., for processing.

The buoy was released about 15 miles off Miami, permitted to drift 24 hours, and recovered approximately 18 miles off West Palm Beach after it had traveled 66 nautical miles. During its course, the buoy was tracked concurrently by an ESSA Coast and Geodetic Survey launch, by the GULF STREAM (an oceanographic vessel operated by Nova University of Ft. Lauderdale, Florida), and via satellite by NASA in Greenbelt, Md. The project was carried out under the direction of Richard R. Ross, Chief of the Miami Branch of the Coast Survey's Engineering Development Laboratory, Office of Systems Development.

A drogue chute was attached to the buoy at a depth of 90 feet. As a result, the buoy's movement was affected primarily by the ocean current and not by the wind and waves.

ESSA, Navy and Air Force Conduct First Multiple Hurricane Seeding

On August 18, and again on August 20, the first multiple seeding experiments in a hurricane were performed by aircraft from ESSA, the Navy, and the Air Force on Hurricane Debbie. The hurricane eyewall experiments were part of Project Stormfury, a joint ESSA-Navy program of scientific experiments designed to explore the structure and dynamics of hurricanes and tropical storms, and to determine whether it may be possible for man to modify some aspects of these violent storms.

Dr. R. Cecil Gentry, Director of Project Stormfury, and Commander L. J. Underwood, Navy Project Coordinator, termed both days' efforts a "huge operational success."

"We gathered considerable valuable data—data that could not be obtained in any other way," they said.

Gentry, who is also Director of ESSA's National Hurricane Research Laboratory in Miami, said that the analyses in the coming months will lead to a better understanding of hurricanes. Determination of what the effect of the seeding of Debbie was on the storm can only be made after a careful and detailed analysis of the data.

On both days, thirteen aircraft participated in the experiments in which clouds surrounding Debbie's center were bombarded with silver iodide five times at two-hour intervals.

The seeding was done by five A-6A Intruder jet attack aircraft from the Navy's Attack Squadron 176. Four Super Constellations (WC-121N) from the Navy Hurricane Hunter Squadron VW4 in Jacksonville, Florida; a WB-47 and a WC-130 from the Air Force Hurricane Hunters of the Air Weather Service's 53rd Weather Reconnaissance Squadron based at Ramey Air Force Base in Puerto Rico; and two DC-6's of ESSA's Research Flight Facility served as monitoring aircraft before, during, and after the seeding.

The wealth of data was flown back to the National Hurricane Research Laboratory in Miami where it will be analyzed by ESSA and Navy scientists.

It is planned to conduct more experiments before the 1969 Project ends on October 15 if another hurricane becomes eligible for seeding. The next experiments are designed to seed a hurricane rainband. Rainbands—curved bands of clouds with heavy precipitation—are normally found at some distance from the storm's eye, but may constitute an important link between cumulus convective activity and a mature hurricane.

Think Cool—Read "Climates Of the World"

Next time the heat gets you down (it never gets over 134 degrees in North America) think of something cool, like the minus 127 degrees recorded at Vostok, Antarctica. Or when it rains (nowhere in North America does the average annual rainfall exceed 262.1 inches) think of Arica, Chile, where it pours an average of three-hundredths of an inch of rain per year.

Climates of the World will fill you in on monthly and annual temperatures and precipitation for about 800 stations, worldwide.

The 32-page publication, produced by the Foreign Branch of the Environmental Data Service, contains maps showing worldwide precipitation and seasonal temperature, and narrative summaries of climatic conditions for each continent. Tables give seasonal and extreme temperatures and precipitation.

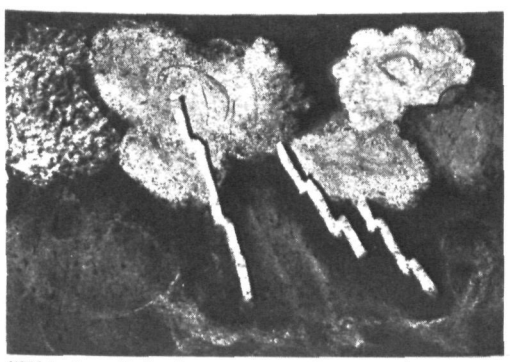
ESSA'S FOURTH BIRTHDAY OPEN HOUSE CELEBRATIONS

The Open House celebrations across the nation attending ESSA's fourth birthday were an unprecedented success.

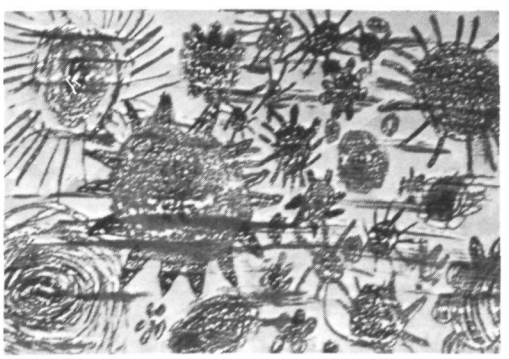
During July, thousands of persons visited ESSA installations throughout the United States and its possessions to see how weather is forecast, earthquakes are recorded, and how ships are operated.

Top laurels went to the USC&GSS WHITING, which, in a week-long observance, drew more than 4000 persons. At the World Weather Center in Suitland, more than 2000 streamed through the facility. In Boston, more than 1000 persons braved a downpour to visit the Weather Bureau airport office.

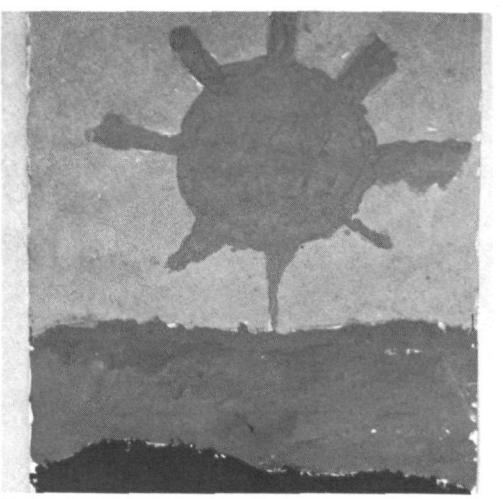
In scores of other locations, hundreds helped ESSA see in the start of its fifth year. Newspaper and television coverage expanded that audience thousandfold. And in Boulder, home of the ESSA Research Laboratories, school children got into the spirit of Open House with an art contest.



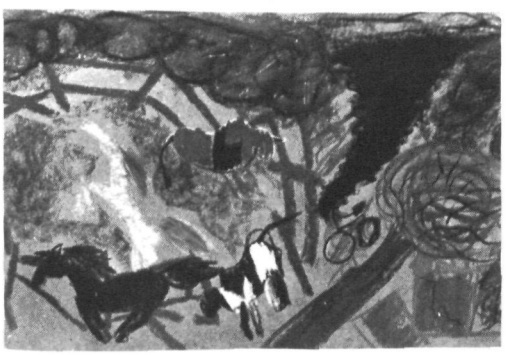
"This is a lightning storm. It happened not too long ago." Carrie Marks, 3rd Grade



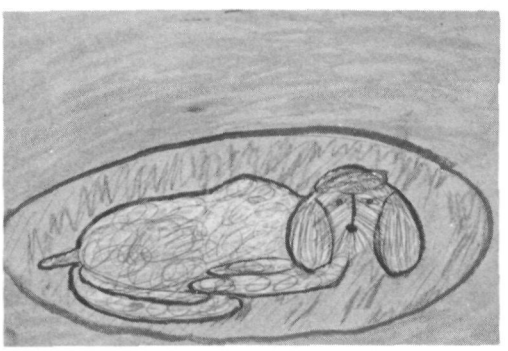
"Flowers in our Environment." Beverlee Rose, 1st Grade



"These are four layers of the atmosphere. The closer it gets to earth, the dirtier it gets." Bill Holloway, 7th grade



"The Terrifying Tornado." Verena Kasemir, 6th Grade



"A Dog's Environment (a rug)." Gracie Timms, 6th grade.

Asked to illustrate the environment as they saw it, pupils from kindergarten to junior high school submitted more than 70 paintings on subjects ranging from the earth's center to outer space. The art display at ERL's open house was arranged through the cooperation of Verle Mickish, art coordinator for the Boulder Valley Schools.

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. . . . . is Anna. Or Blanche. Or Camille, Debbie, Eve, Francelia, Gerda, Holly . . . . .

The hurricanes of 1969.

Grim games. For hurricanes are killers.

Game time can be anytime from June to November. You will know through the Weather Bureau's watches, which mean one may occur, and warnings, which mean one is on the way.

If the whistle blows, be ready.

Store plenty of drinking water and non-perishable food. Check your battery-powered equipment. Move outdoor things inside. Protect your windows with boards, shutters, or tape.

Evacuate low-lying areas early. Along the coast, storm surge may drive the sea onto the land. Elsewhere, heavy rains may cause severe flooding.

When the hurricane strikes, stay inside, even during the calm of the eye. Hurricanes can breed sudden lethal tornadoes. Stay tuned to Weather Bureau bulletins until the storm has passed. Afterward, avoid fallen utility wires and debris.

Then rename the game.

Call it survival.