Weather Satellites: II
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Weather Satellites: II

In the seven years since they were first described in these pages they have made major contributions to meteorology. Now a satellite system surveys each day the weather patterns over the entire earth

by Arthur W. Johnson

Seven and a half years ago (in July, 1961) *Scientific American* presented an article by Morris Neiburger and the late Harry Wexler titled "Weather Satellites." The article was based on preliminary results from the first two satellites in a series developed and operated by the National Aeronautics and Space Administration under the name Tiros (Television Infrared Observational Satellite). The authors predicted, among other things, the establishment of a national weather-satellite system that would eventually provide daily photographic observations of the entire earth, together with other kinds of information useful in understanding patterns of weather and in making weather forecasts.

Here I shall briefly recount what has happened since then. I shall also describe plans for improving weather satellites to make them still more useful than they have already proved to be. Finally, like Neiburger and Wexler, I shall venture a few predictions about the future of weather observation by satellite.

Evolution of the System

It did not take long after the launching of the first Tiros in April, 1960, for it to become plain that the kind of information that could be gathered by satellites hundreds of miles above the earth would be highly useful in the daily observation of the weather. Several agencies of the U.S. Government—NASA, the Department of Commerce (which includes the Weather Bureau) and the Department of Defense—worked out plans for a system of satellites that would provide worldwide weather data for all interested users. By the end of 1961 Congress had passed at President Kennedy's request an act directing the Department of Commerce "to establish and operate a meteorological satellite system for the continuous observation of worldwide meteorological conditions from space satellites and for the reporting and processing of the data obtained for use in weather forecasting." The system is called the National Operational Meteorological Satellite System.

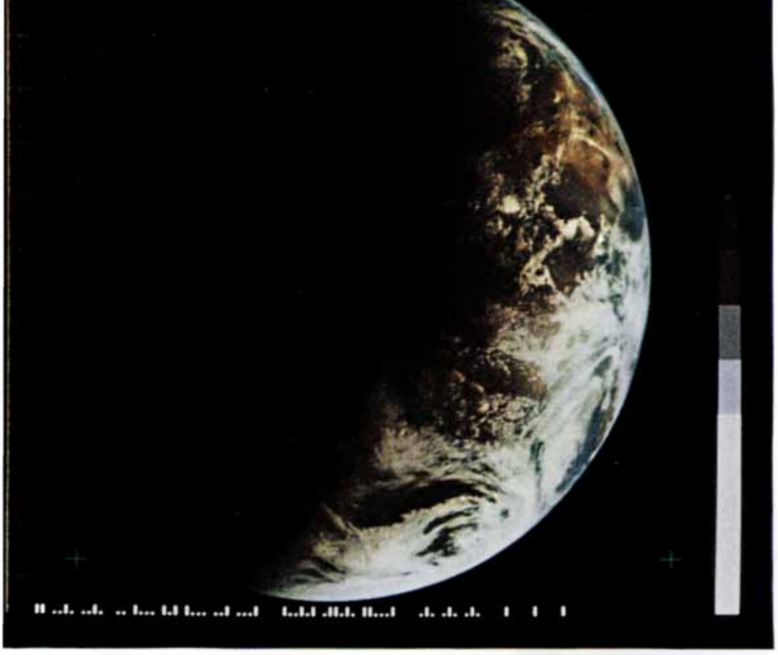
The three agencies that devised the system also drew up a list of objectives to be achieved during the first decade or so of operation. One objective was round-the-clock observation that by the end of each 24-hour period would have covered the entire surface of the earth; this objective incorporated the development of an automatic picture-transmission system that would enable photographs made by the weather satellites to be received at a number of stations on the ground. A second objective was continuous viewing of the atmosphere from satellites in synchronous orbit, that is, orbiting the earth at an altitude calculated to keep the satellite constantly above the same geographical area. The color photographs on the opposite page and on page 54 were made by such a satellite, which had an orbital position above the mouth of the Amazon River. A third objective was the making of quantitative measurements of such weather factors as temperature, pressure, humidity, wind direction and wind speed; the measurements would be used in computer-generated mathematical models of the atmosphere for highly sophisticated weather forecasting. As the reader will see, the first of the three broad objectives set for the National Operational Meteorological Satellite System has been largely attained, and much progress has been made toward the second one. A great deal must be done to realize the third.

During the early phase of the satellite system weather information was obtained from the Tiros vehicles, although they were intended as research satellites rather than as parts of an operational system. (From the beginning research and development satellites have been designed and operated by NASA, and the operational satellites resulting from the research and development programs have been the responsibility of the Environmental Science Services Administration in the Department of Commerce.) Useful as the early Tiros vehicles were, they left much to be desired from an operational standpoint. The reason was that satellite technology at the time fell far short of the requirements of the weather-satellite system.

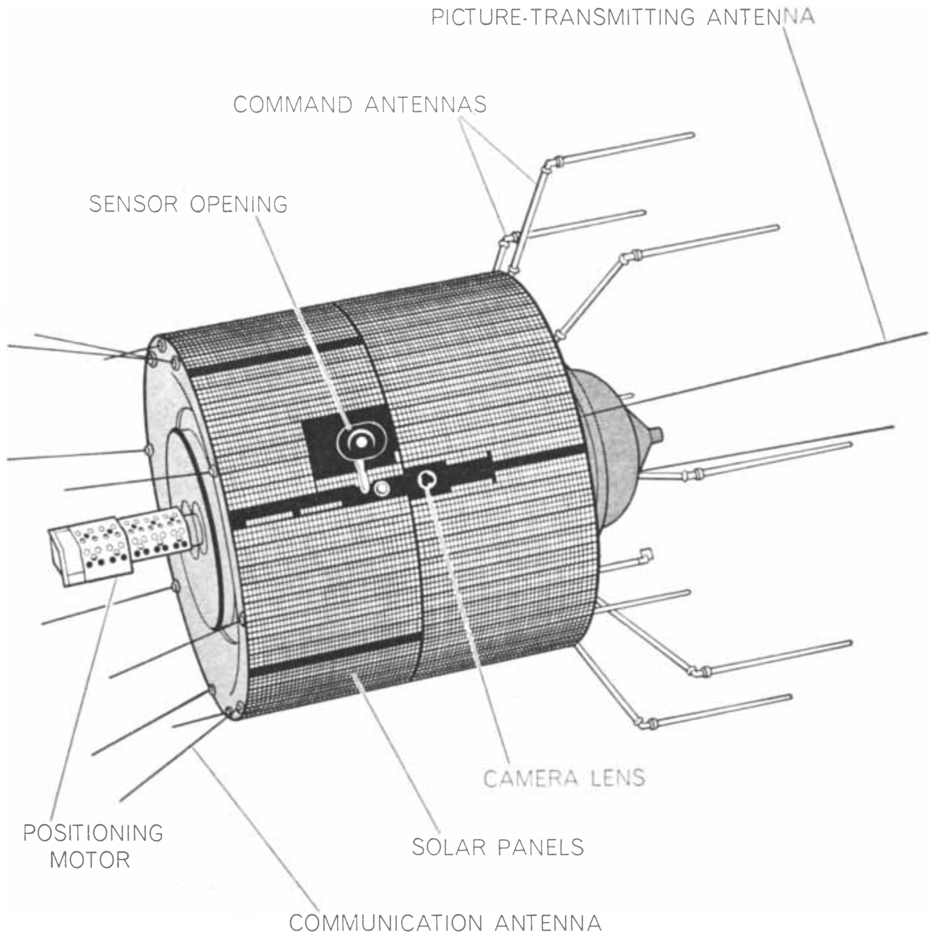
For example, the first Tiros vehicles had their sensing equipment in the base and were so oriented in space that they occupied a fixed position with respect to the plane of their orbit. As a result the satellite could observe only about 20 percent of the earth's surface on any given day. Even when the sensors could acquire useful information, they were seldom pointing straight down at the earth, so that much painstaking geographic orientation and rectification of data were necessary to make the photographs and telemetric material from the satellites useful. Further difficulties arose from the fact that the orbits of the first Tiros vehicles were similar to the orbits of the man-in-space programs: they were inclined at 48 degrees to the Equator, so that the amount of surface they could observe was limited in terms of latitude. Later the inclination was increased to 58 degrees, allowing observation as far north and south of the Equator as about 65 degrees of latitude, but the observations were still made from an inconvenient angle and included considerable distortion.

Toward the end of the Tiros series, which continued until the launching of

COLOR PHOTOGRAPH OF THE EARTH from an altitude of 22,300 miles above the mouth of the Amazon River was made on November 18, 1967, by a weather satellite. South America is near the center of the photograph; the western bulge of Africa can be seen near the right edge of the photograph, and the southern part of the U.S. is at top left. The Applications Technology Satellite, a research spacecraft developed by the National Aeronautics and Space Administration, was in a synchronous orbit, meaning that it stayed above the mouth of the Amazon. Six photographs made by the satellite at various times of the same day are on the next page.



Tiros X in the summer of 1965, the satellite was redesigned to put the sensing equipment on the side of the vehicle. Thereafter, as the satellite rolled along its orbit in an orientation to the earth like that of a wheel to a road, the data were acquired only when the sensors pointed directly at the earth. Advances in technology also made it possible to launch the satellites into orbits that were nearly polar and nearly synchronous with the apparent movement of the sun; hence observations were made over a given area at the same sun time each day. The optical system was designed so that observations overlapped from orbit to orbit, making it possible to attain the objective of daily global coverage.



APPLICATIONS TECHNOLOGY SATELLITE of the type that made the color photographs from a fixed orbital position above the mouth of the Amazon River includes an antenna array in dome at right. Positioning motor is jettisoned when satellite begins operation.

An Operational System

With the gradual evolution of the satellites, the Tiros Operational System was established as the first national weather-satellite system. To achieve the first stated objective—global coverage—a minimum of two satellites must be in operation at all times. Part of the reason is that the satellites have separate functions, a matter to which I shall return below. Moreover, each satellite is designed to provide redundancy: if a component fails, a corresponding component can be substituted. Limitations in space, weight and power have so far made it impossible to include all these features in a single satellite. A two-satellite operational system has now been in continuous service since the launching in February, 1966, of the successors to the Tiros series, the satellites that go by the name of Essa, which applies to both their function (Environmental Survey Satellites) and their operating agency (the Environmental Science Services Administration). When it becomes apparent that a satellite in the system is nearing the end of its usefulness, another one is launched; so far eight Essa vehicles have been put into operation.

When a two-satellite system is operating normally, each satellite has a somewhat specialized function. One of the satellites provides an advanced Vidicon camera system; in response to commands from the ground the system records on magnetic tape data over the entire earth for readout at appropriate times to either of two ground stations. From the ground stations the data are relayed to the National Environmental Satellite Center near Washington for processing. The other satellite is the automatic picture-transmission satellite; in most latitudes it can transmit photographs from three successive orbits to rather simply equipped ground stations. If satisfactory communication systems exist, ground stations that are widely separated but at approximately the same latitude (such as San Francisco and Washington) can be connected so that the coverage at both of them is extended to include data from as many as six or seven orbits. More than 400 ground stations for receiving weather-satellite photographs are now operated by national meteorological services, television stations and private users in more than 40 countries. The system has also become an important part of the American contribution to the World Weather Watch system being developed by the World Meteorological Organization, an agency of the United Nations.

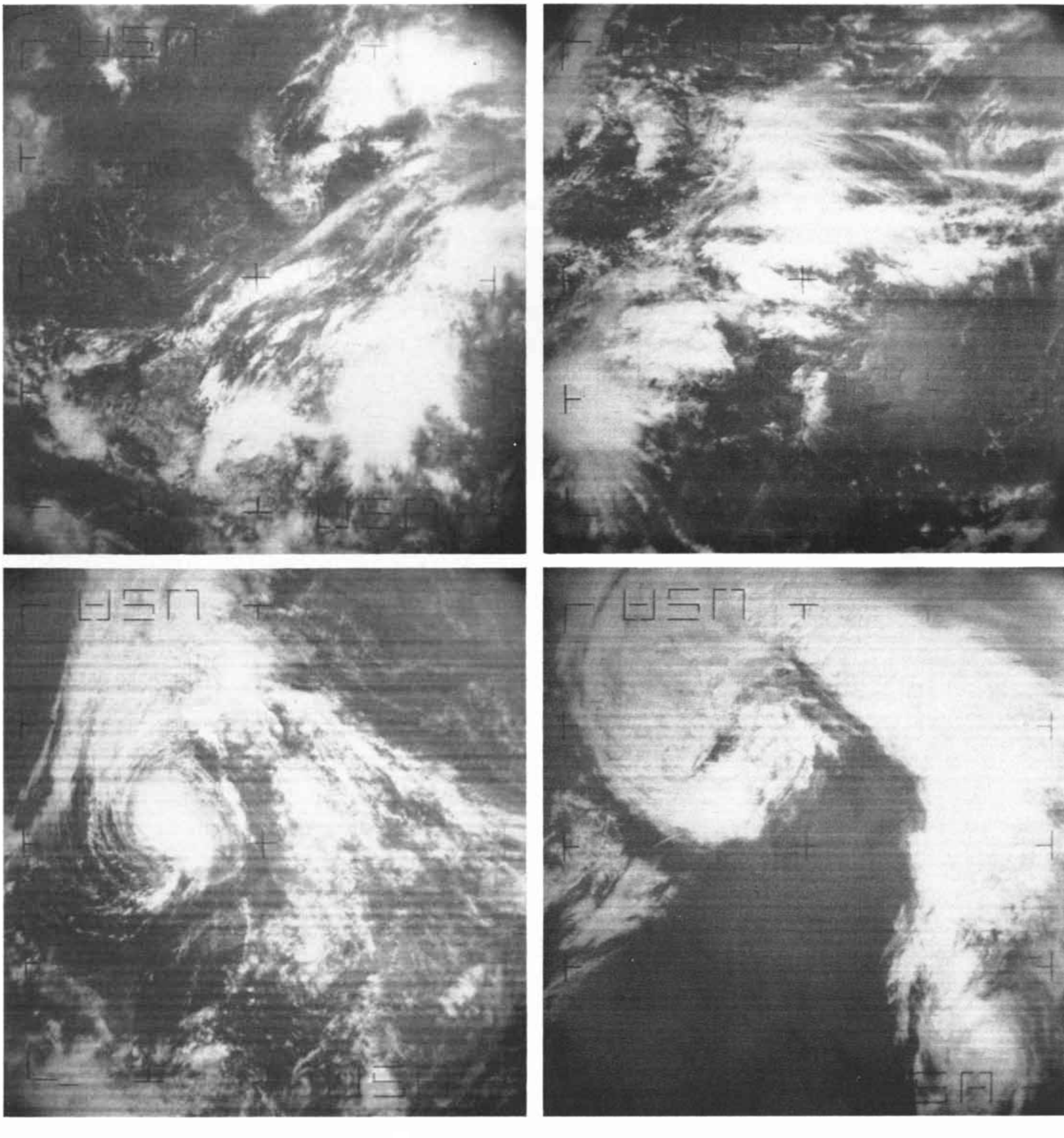
SINGLE DAY'S cloud patterns as photographed by the satellite over the Amazon appear on the opposite page. Reference marks on the photographs include a color bar, a time code (*bottom*) and a line counter (*left*) for the scanning technique by which the pictures were transmitted to the ground. The camera used three photomultiplier tubes sensitive respectively to red, green and blue light; signals they sent to the ground provided basis for the color photographs.

Needs and Capabilities

The preparation of a weather forecast requires an adequate description of the state of the atmosphere over the entire earth, or at least over the hemisphere of particular interest, at a given time. A major ingredient in any forecast, therefore, is enough observations. Unfortunately the earth and its atmosphere cannot be observed adequately by what are now called conventional means: weather stations on the ground, ships at sea and aircraft in flight. They cover no more than 20 percent of the earth, leaving great gaps over large areas of water and remote land masses.

Satellites provide total coverage of the surface, although they cannot yet match the conventional means in obtaining such information as wind speed and direction, atmospheric pressure, temperature, humidity and precipitation. A considerable effort is now under way to improve the capabilities of satellites in obtaining such information. To say this, however, is not to detract from the substantial contributions the satellites have already made to meteorology.

A case in point is the capability satellites have provided for analyzing and following tropical storms. The top photograph on page 63, made by *Essa 3* on September 6, 1967, shows Typhoon Opal, which was at the time about 1,000 miles southeast of Japan. The eye of the storm is clearly discernible. Bands of cloudiness spiral inward to the eye, where the lowest atmospheric pressure in the storm is found. Such spiral bands are known to be characteristic of tropical storms. The form and definition of the bands can be used to estimate the location of a storm's center even when the position of the eye is not apparent. On the basis of considerable experience in interpreting satellite photographs of tropical storms it is now possible to look at photographs and make reasonable estimates of the maximum wind speeds being generated by a storm. For these reasons photographs from satellites have proved valuable in detecting storms in

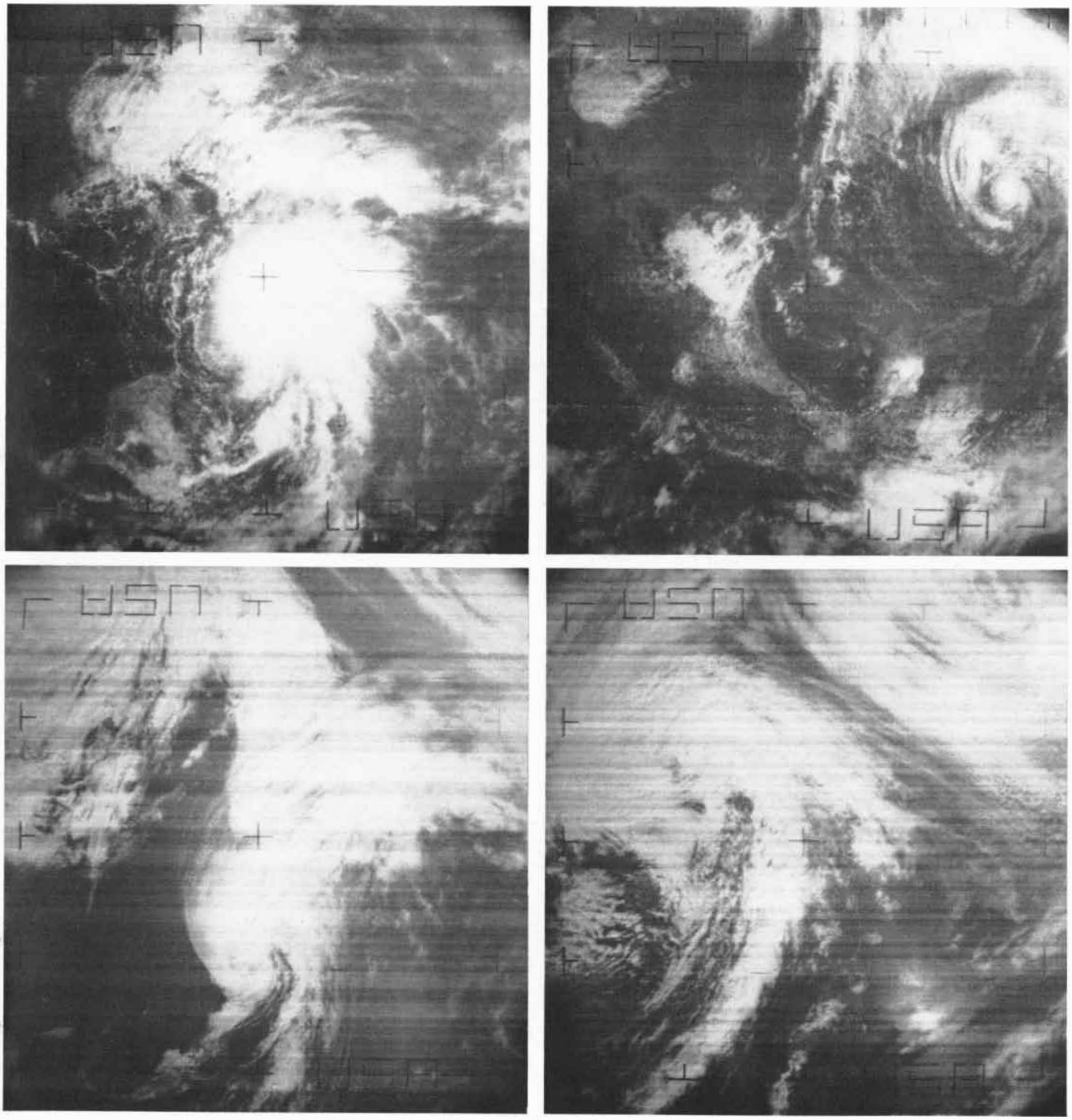


HURRICANE GLADYS, which caused severe damage in Florida and along the Gulf Coast last October, was tracked by the two satellites the Environmental Science Services Administration keeps in polar orbit for obtaining photographs of weather patterns over the

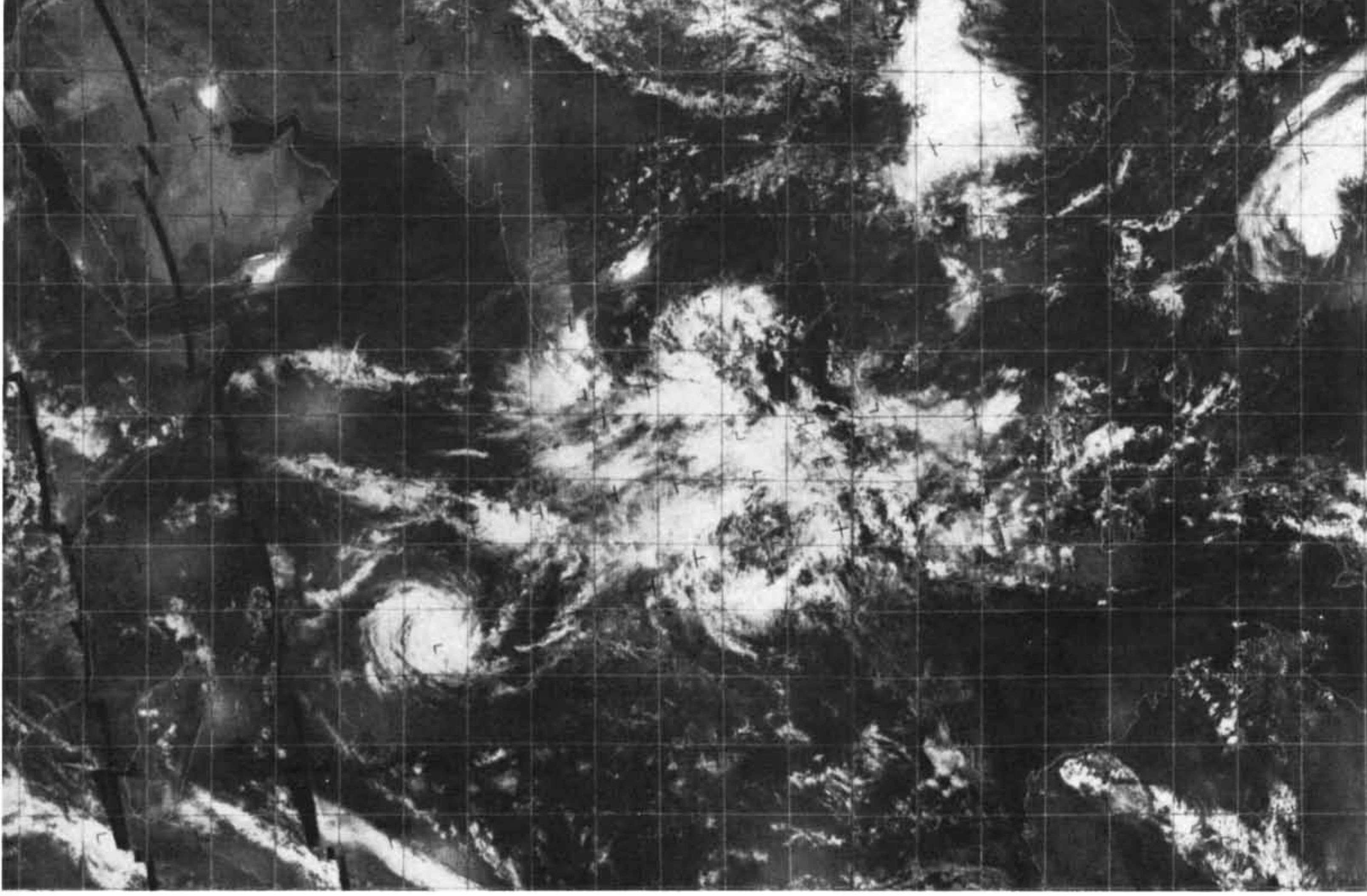
remote areas, planning aerial reconnaissance of such storms and issuing warnings to aviation and shipping firms and the public. A series of satellite photographs made it possible to keep a close watch on Hurricane Gladys, which struck Florida severely three months ago [*see illustrations on these two pages*].

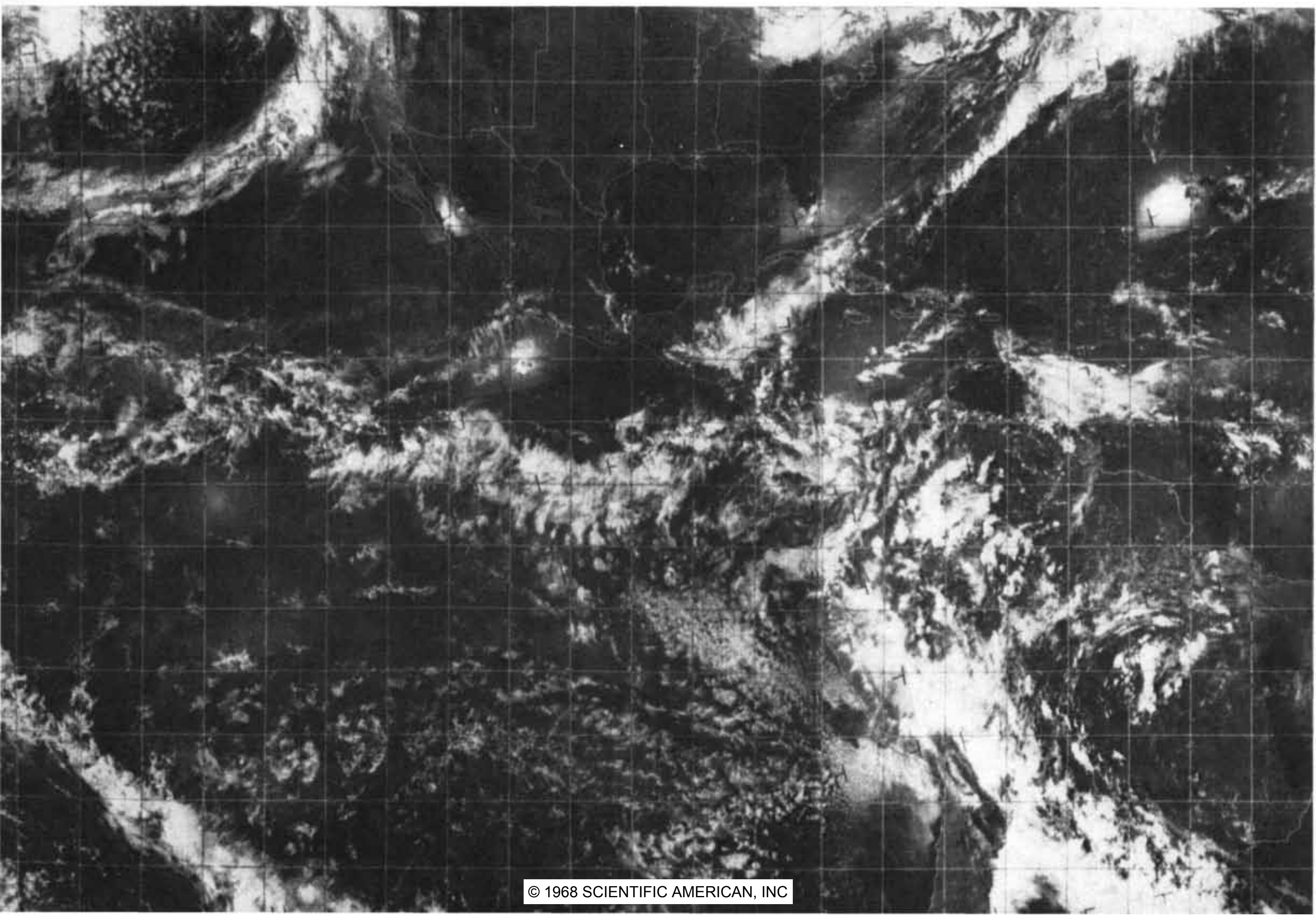
From satellite photographs it has also become possible to detect the jet streams visually: the zones of strong and highly turbulent winds that are of major concern to the aviation industry [*see bottom illustration on page 63*]. High cirrus clouds terminate at the edges of a jet stream. When sunlight falls on these clouds at a certain angle, they cast a strong shadow on the clouds below. The shadow reveals the location and course of the jet stream.

Snow cover and sea ice can be readily identified in satellite photographs [*see top illustration on page 67*]. The appearance of snow cover varies with the nature of the terrain, the extent of forests and the depth of the snow. It is now possible to prepare from satellite photographs charts of snow and ice distribution for both the Arctic and the Antarctic regions. The charts are made



entire earth during the course of a day. At top left the hurricane is shown as it appeared on October 14; it was then over the Caribbean Sea near Cuba. The remaining photographs, reading from left to right, show the daily development of the storm through October 21.



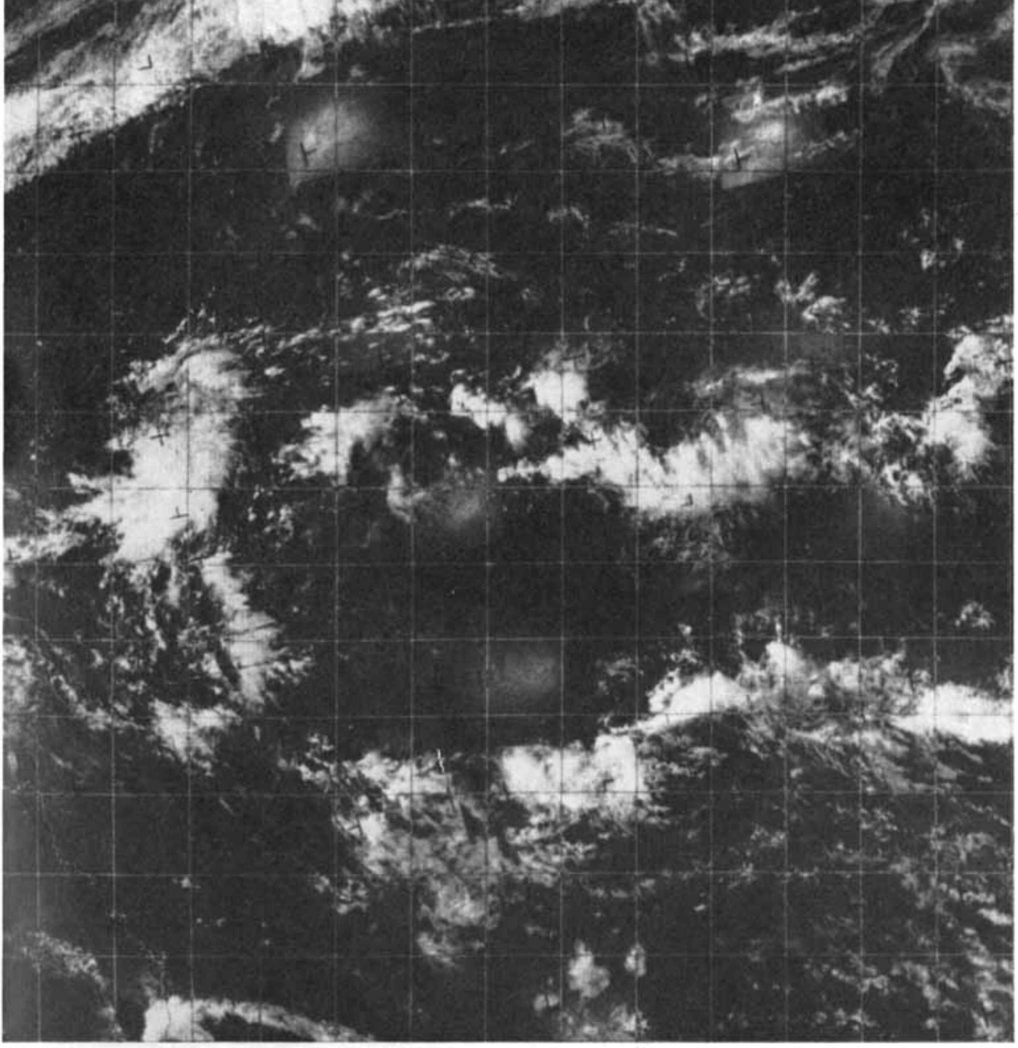


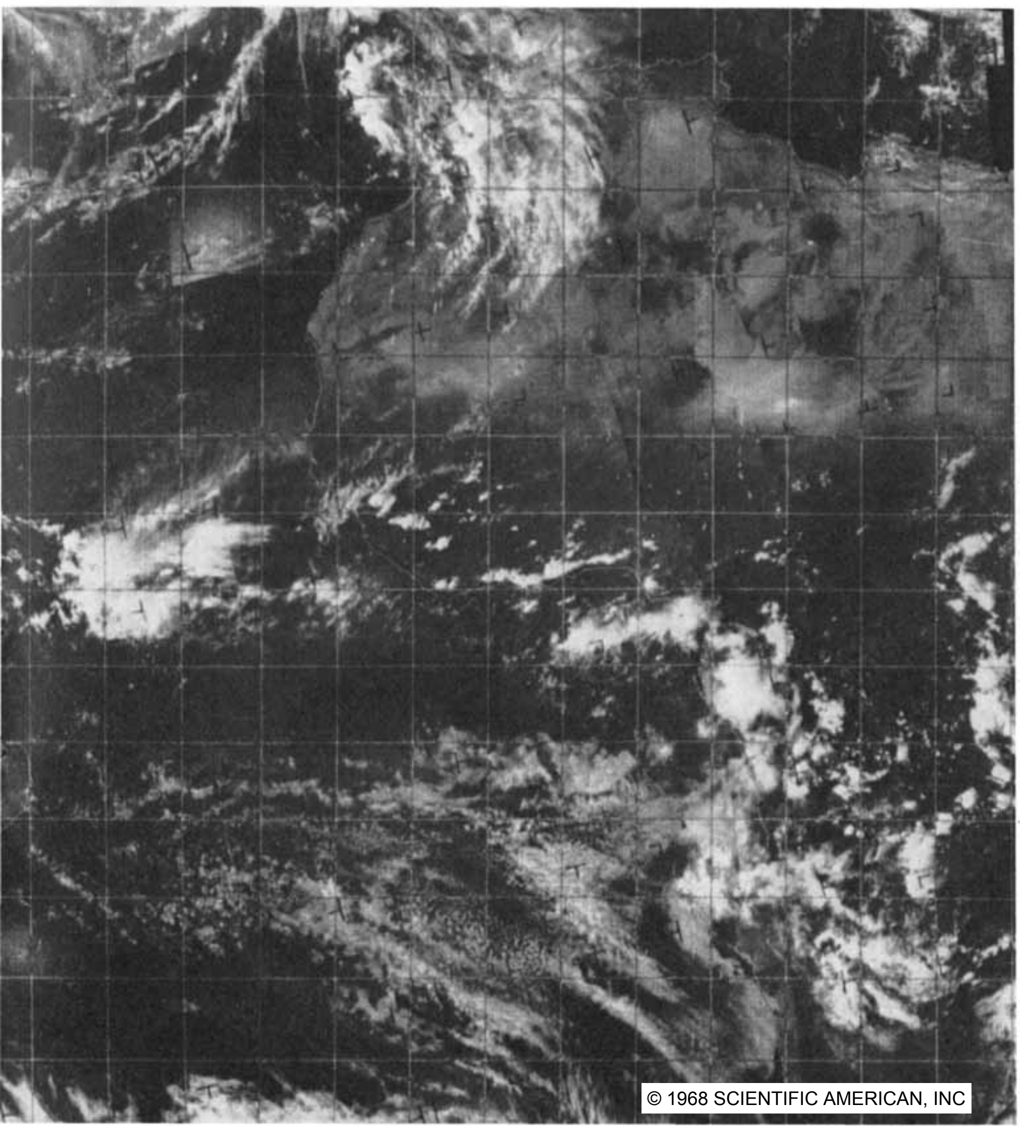
available to shipping interests in the U.S. and other countries. Icebreakers that encounter difficulties in moving can modify their course on the basis of advice provided by analysts in Washington. Another benefit of the photographs in polar regions is in planning for detailed aerial mapping. Potentially costly airplane flights have been avoided when satellite photographs revealed unfavorable weather conditions; the savings have exceeded $100,000 in a single season of Antarctic mapping.

Although the automatic picture-transmission system was originally designed for local weather forecasting, the area covered in the photographs received by a single ground station is so extensive that the information can be put to broader use. One such use is in the preparation of the weather charts required for international flights over water. Until recently such charts were based on observations made from aircraft and surface stations; a chart showed the weather at the surface and provided a "best guess" of the vertical and horizontal distribution of clouds. Now photographs from weather satellites can provide chart-makers with up-to-date information on clouds. The crews on international flights have reacted enthusiastically to the charts thus prepared.

Technological Considerations

Photographs made by a satellite are transmitted to the ground by means of a scanning procedure. On the ground the photographs from satellites equipped for automatic picture-transmission are printed line by line at the local stations within range of the transmission. Photographic data reaching the ground from a satellite equipped with an advanced Vidicon camera system are recorded on magnetic tape at sophisticated command and data acquisition stations and sent by wire to the satellite center near Washington. There the picture signals are displayed on a kinescope a line at a time



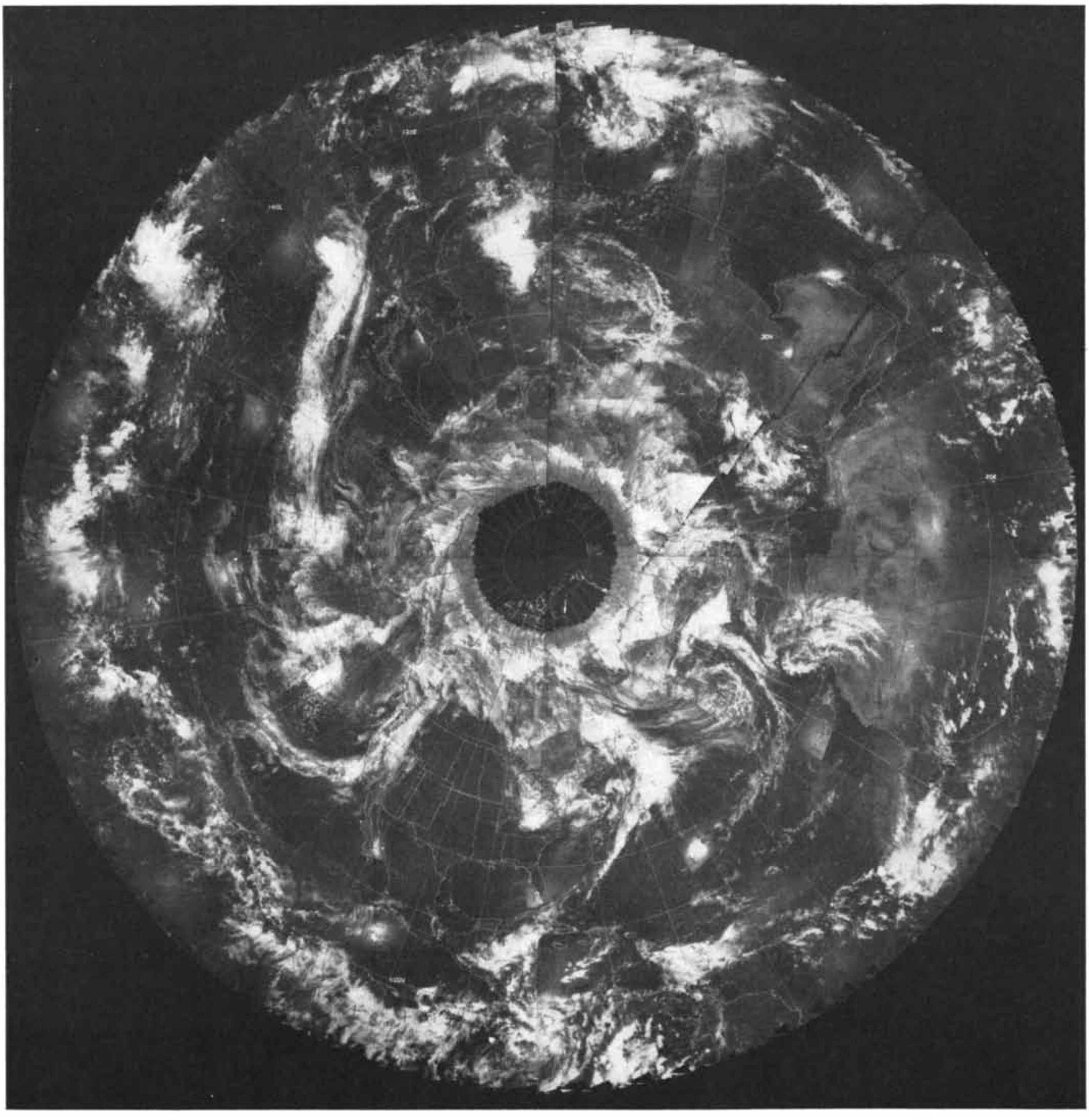


GLOBAL WEATHER PATTERNS for a single day are obtained by computer processing of photographs made by polar-orbiting satellites in the U.S. operational-satellite system. These photographs encompass the region along the Equator from 35 degrees south latitude to 35 degrees north latitude. The day was October 29, 1968. Of particular meteorological interest was the circular cyclonic disturbance over the Indian Ocean southeast of the Arabian Peninsula, which is at upper left in the upper photograph.

and recorded on 35-millimeter film. When the recording of a single photograph on a frame of 35-millimeter film has been completed, precomputed latitude and longitude lines and other geographical information pertinent to the area of coverage are superposed on the film, together with a legend giving the date and time of the photograph and other relevant information.

Every day the data for the entire earth are processed by high-speed computer into three projections that show the day's weather pattern over the globe [*see illustrations below, on opposite page and on preceding two pages*]. Two polar stereographic projections show respectively the Northern and Southern hemispheres. A Mercator projection shows the tropical region from 35 degrees north latitude to 35 degrees south latitude. The processing techniques employed to achieve this kind of presentation require the most powerful and sophisticated computer facilities currently available.

The camera system that produced the color photographs, which were made only from a satellite in the development series known as Applications Technology Satellites, incorporated three light detectors of the photomultiplier type. They were respectively sensitive to wavelengths characteristic of the colors red, green and blue. On the ground the output of the three tubes was recorded on color film. The resulting photographs are beautiful and fascinating to study, but from a meteorological standpoint it is not certain that they provide enough in-



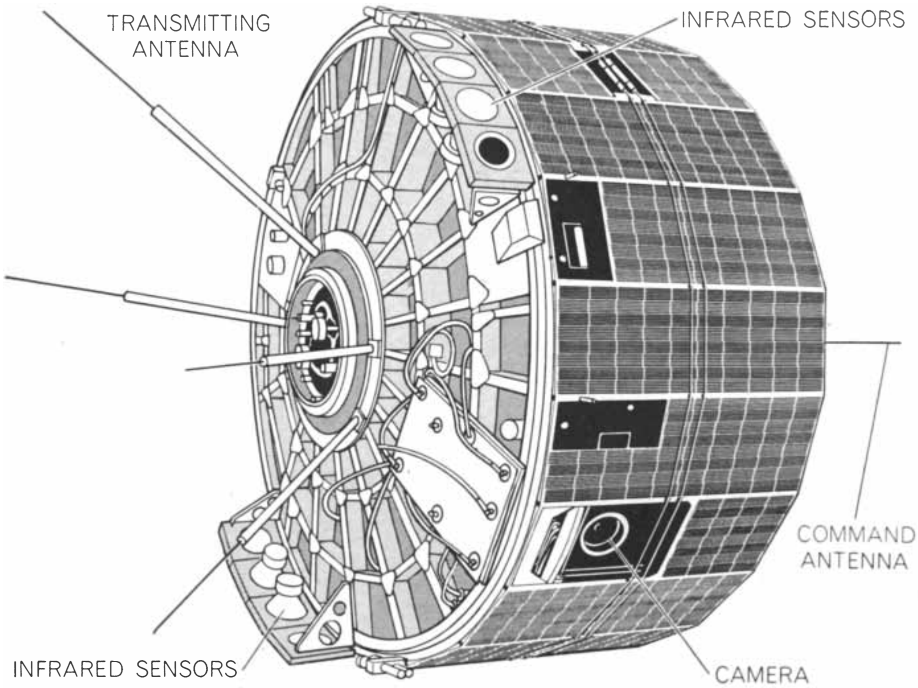
NORTHERN HEMISPHERE on October 29, 1968, appears in computer-produced mosaics of photographs made during the day by a satellite in polar orbit. Circular pattern of clouds at left center, off U.S. West Coast, is type that generates jet streams.

formation beyond what can be obtained from black-and-white photographs to warrant the extra cost of the color technique for routine use. No decision has been made to include a color capability in any future operational weather satellite.

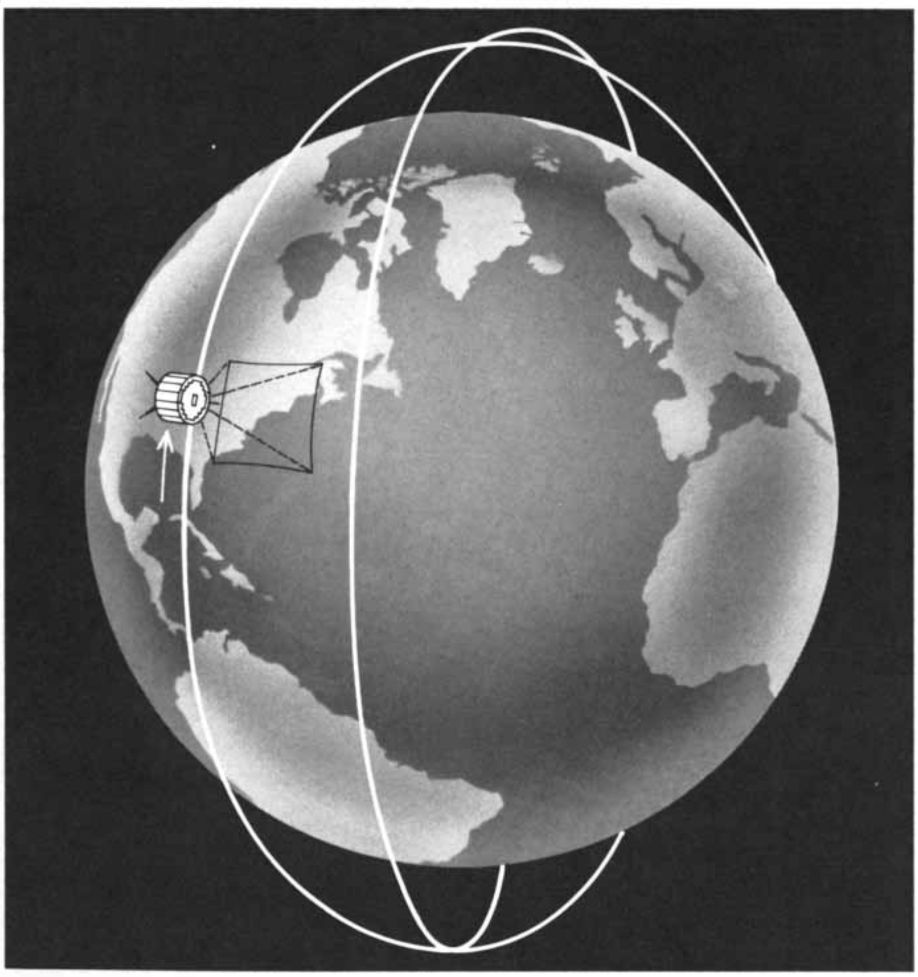
Early in the era of weather satellites it became necessary to devise a simplified, schematic means of presenting the observed data, because adequate communication networks for the distribution of photographs did not exist in many parts of the world and could be established only at prohibitive cost. The schematic presentation that was worked out is called nephanalysis (from the Greek word *nephelē*, meaning cloud). A nephanalysis looks rather like a weather map published in a newspaper, except that it contains a number of additional symbols to incorporate the kind of data that can be provided only by satellites. This type of analysis has been made available to weather stations connected to the U.S. facsimile network and can be transmitted internationally by U.S. Government broadcasts from New York and San Francisco. Techniques of data presentation currently being developed will soon replace the nephanalysis as it is now known with a system that displays more of the actual pictorial data.

In the Neiburger-Wexler article considerable emphasis was placed on the acquisition of certain types of information about radiation for use in calculations of the earth's heat budget. Since the ultimate source of energy for the

SOUTHERN HEMISPHERE on the same day showed conspicuous mantle of snow and ice overlying Antarctica (*center*) and cyclonic disturbance at lower right. The computer added the grid lines and outlines of the continents in assembling the mosaic.



WEATHER SATELLITE of the kind now in service in the National Operational Meteorological Satellite System is called Essa for Environmental Survey Satellite and for the operating agency, the Environmental Science Services Administration. The camera lens is on the side because the satellite orbits in a wheellike orientation to the earth. Photographs are made when camera points directly toward ground. The solar cells provide power.



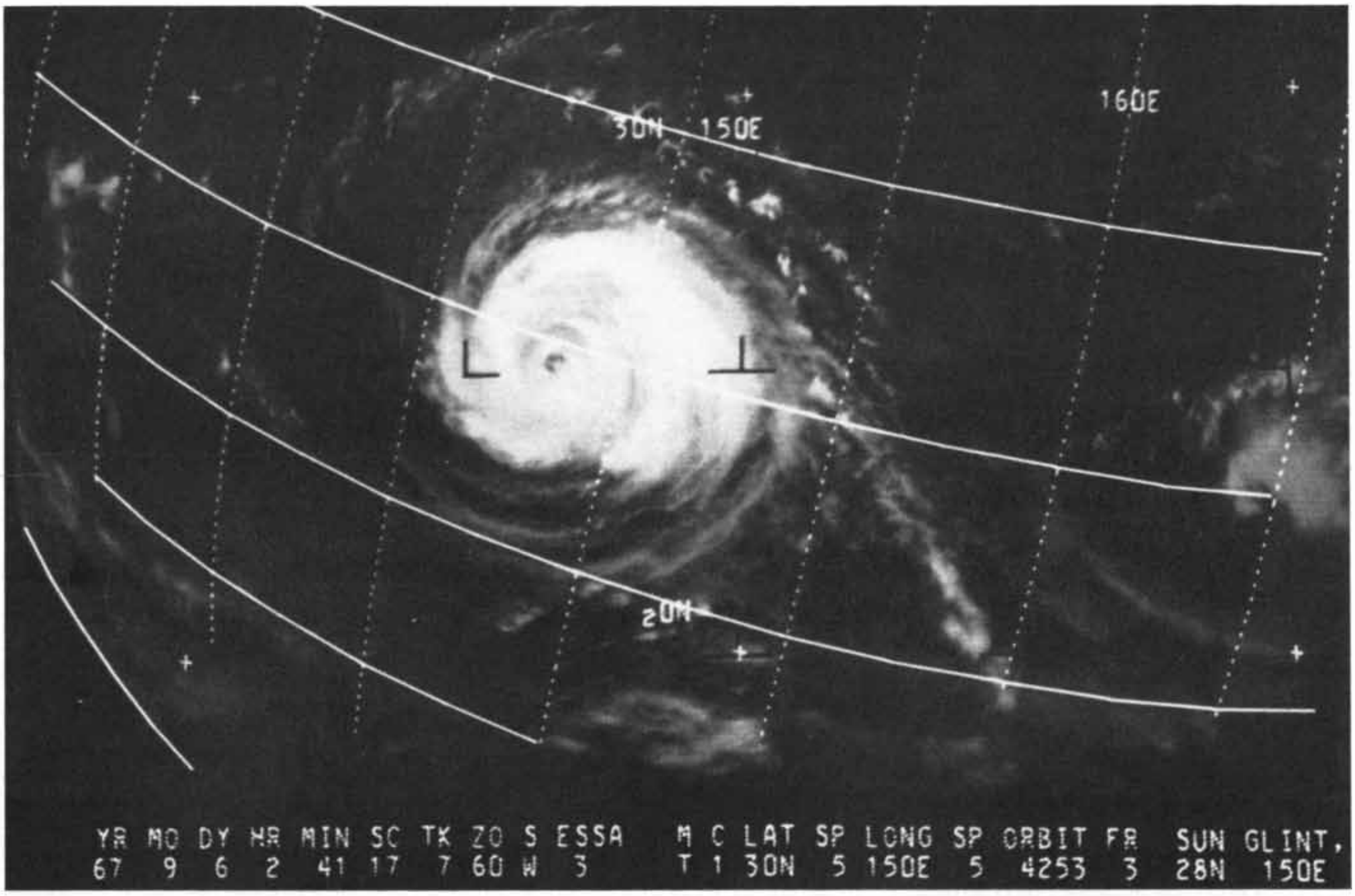
ORBITAL PATH of the Essa satellite is arranged so that the spacecraft is synchronous with the apparent movement of the sun. If the time at the Equator on a given orbit (*right*) is 3:00 P.M. when the satellite passes over the Equator, the time below the satellite when it completes a full orbit (*left*) and again crosses the Equator will once again be 3:00 P.M.

earth is the sun, it is necessary to know the amount of incoming and outgoing radiation in order to determine the effect of the radiation on the large-scale circulation processes of the atmosphere. Radiometers of several types have been carried on 10 weather satellites. Unfortunately the radiometers have varied considerably in their reaction to the space environment, so that they have not yet provided a basis for completely reliable computation of heat exchange. It has been possible, however, to relate information from the radiometers to large-scale cloud features and to employ it in calculations of albedo, or reflectivity. The calculations have indicated values of albedo quite different from those that had been derived from other computations. Not enough information has been obtained so far to resolve the discrepancy.

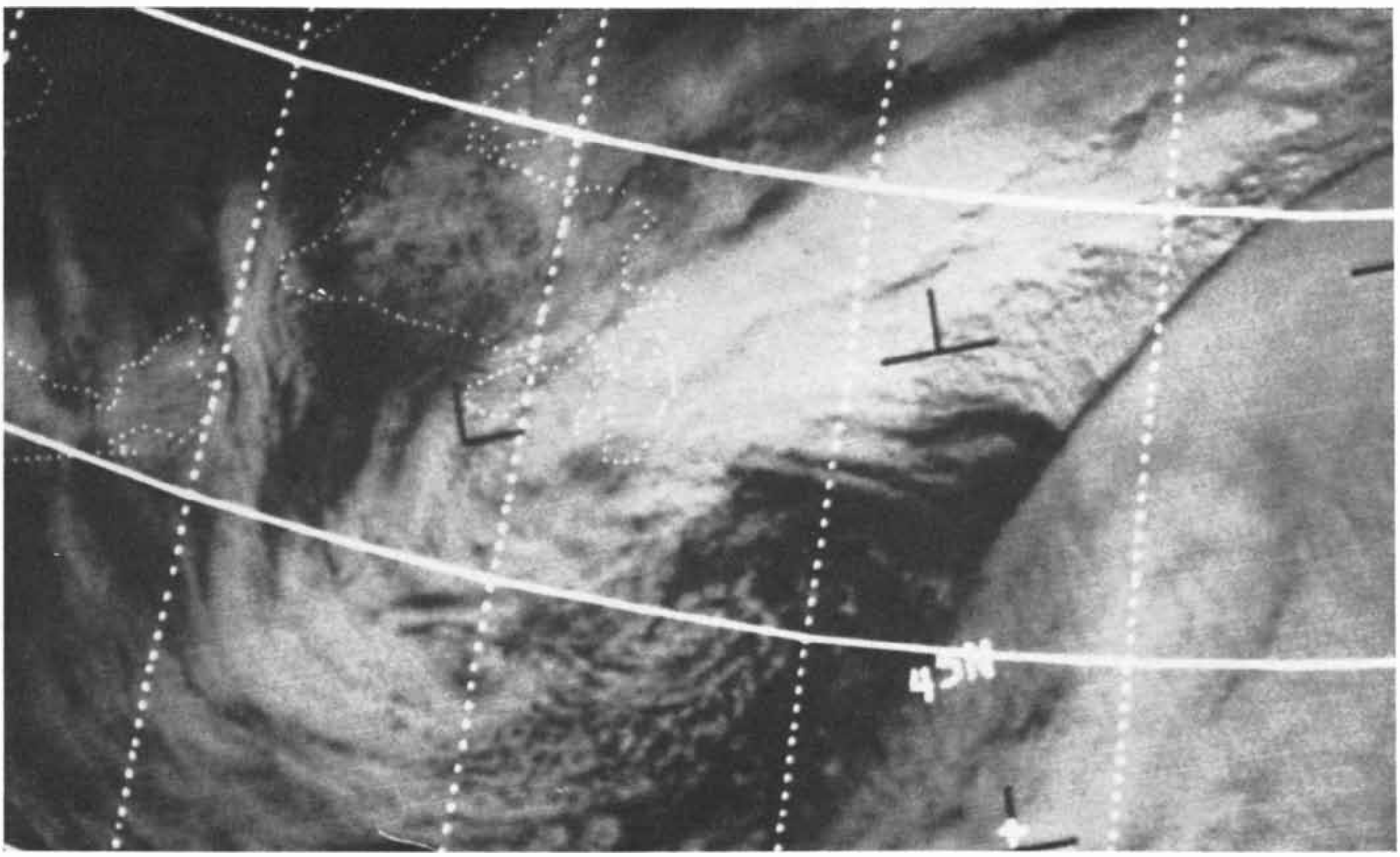
Areas of Research

The operational-satellite system as it now exists goes a long way toward meeting the first objective of the satellite system—daily global coverage—but it provides no capability for meeting the objectives of continuous viewing of the atmosphere from earth-synchronous satellites and measurement of weather factors other than cloud distribution. As a result NASA is at work on the development and testing of the next generation of weather satellites. The first satellite of the new generation will be launched this spring or summer. It will be known as *Tiros M* and will be the prototype for the Improved Tiros Operational Satellite System. *Tiros M* will be larger than the operational satellites now in service, will carry additional sensors such as one to measure the flux of protons from the sun and will have room for still more sensors that may be devised as a result of research now in progress.

A particularly valuable series of satellites in NASA's program of research and development has been the Nimbus series. Among other things, the Nimbus satellites have proved the capabilities of the camera systems now in operational use and the technique of automatic picture-transmission. Perhaps even more important in the long run will be the demonstration by Nimbus of the value of sensing in the infrared region of the electromagnetic spectrum. The demonstration showed that with infrared techniques observation at night is as feasible as observation in daylight [*see illustration on page 68*]. As a result the satellites in the Tiros M series will carry high-



TYPHOON OPAL was photographed by *Essa 3* on September 6, 1967. The storm was over the Pacific Ocean about 1,000 miles southeast of Japan. It shows a cloud pattern characteristic of tropical storms. In this case the eye of the typhoon is unusually distinct.

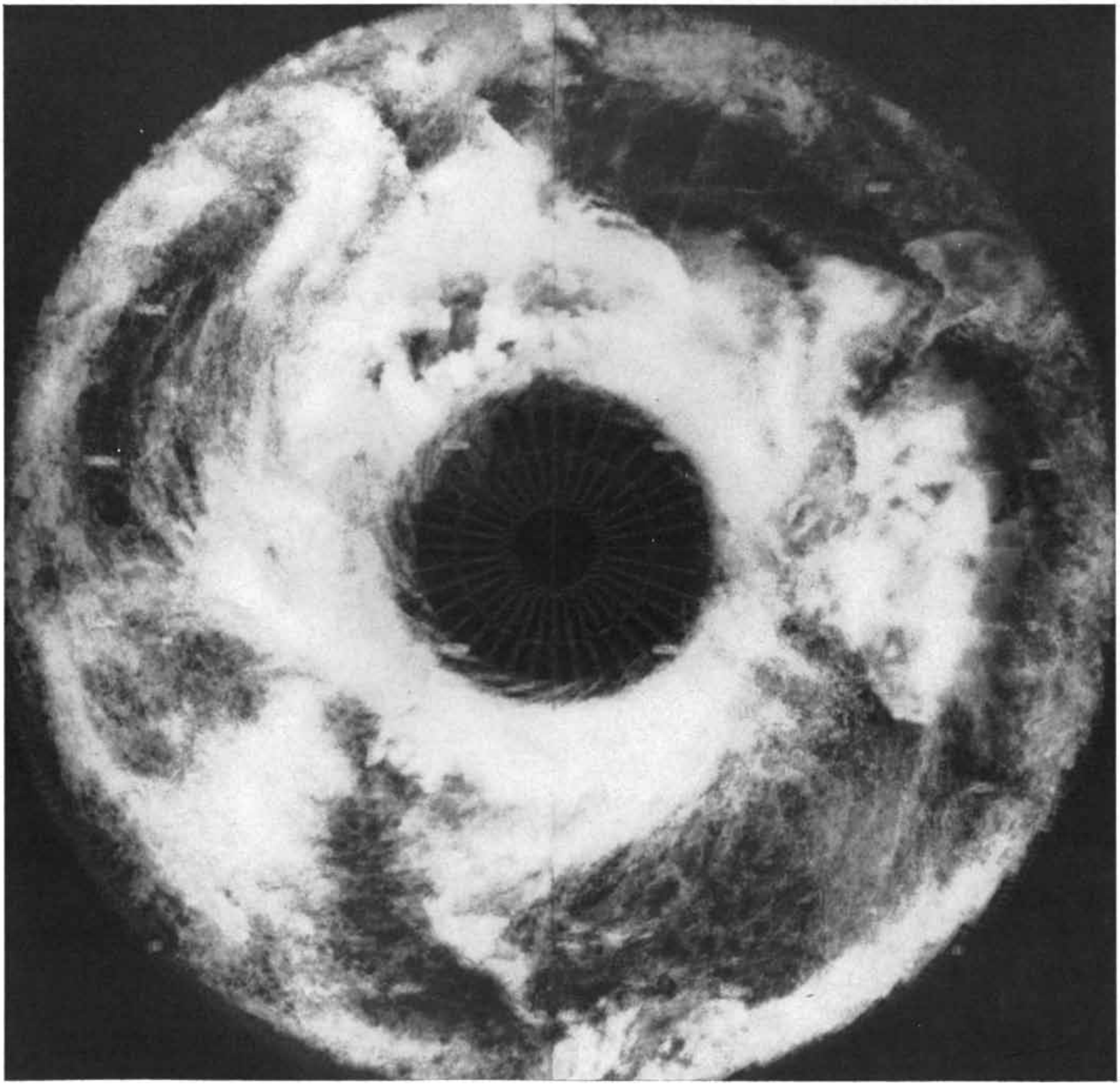


JET STREAM of strong and turbulent winds is indicated by the thin dark line curving along the right side of the photograph. The stream is made visible because high cirrus clouds terminate at its edges, and when sunlight strikes the clouds at a certain angle, a shadow falls on the clouds below, delineating the boundary of the stream. This jet stream was photographed near Newfoundland.

resolution infrared sensors, which will provide the nighttime observation required by the first objective of the weather-satellite program but not available from the present operational system.

Data obtained with high-resolution infrared sensors can be interpreted in terms of temperature, because the intensity of the energy received at the sensor, and later relayed to the ground, increases with the temperature of the object being viewed. With this kind of data the subjectivity that is now inescapable in the determination of cloud types by interpretation of satellite photographs will be decreased somewhat, since knowledge of the temperature of a radiating surface such as the top of a cloud makes it possible to infer the height of the cloud tops accurately. Such information is valuable not only for the determination of cloud types but also for analyzing the kind of weather system shown in the satellite pictures.

Studies of the uses of infrared sensing are continuing. One of the newer and more promising applications is in oceanography. Infrared sensing makes it possible to determine the location of ocean currents; more important, through analysis of data from successive days it provides information on the direction of the currents. On the basis of infrared data from satellites the Environmental Science Services Administration has prepared colored, maplike charts of ocean temperatures. By incorporating high-resolution infrared radiometers in the Tiros M series it will be possible to provide such charts several times weekly—even daily if such frequency should prove desirable and the ocean area of interest is largely free of clouds. It is also possible to determine by satellite the in-

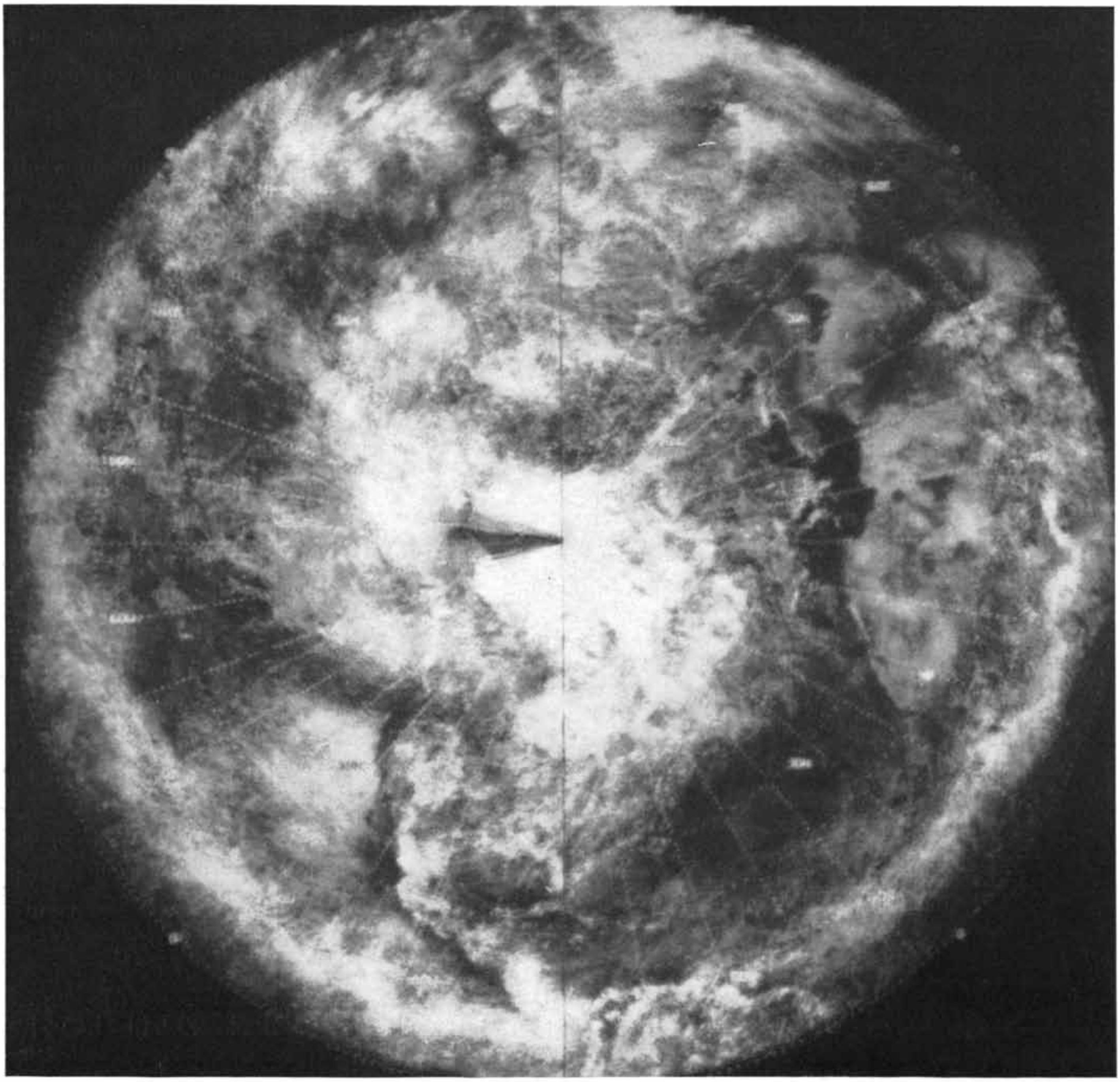


WINTER PATTERN of clouds over the Northern Hemisphere during a two-week period in February, 1967, was obtained by making multiple exposures of daily mosaics of photographs from Essa satellites. North America is at bottom center. Region around the North Pole is dark because the sun does not shine there in February and there is no reflected light to be photographically recorded.

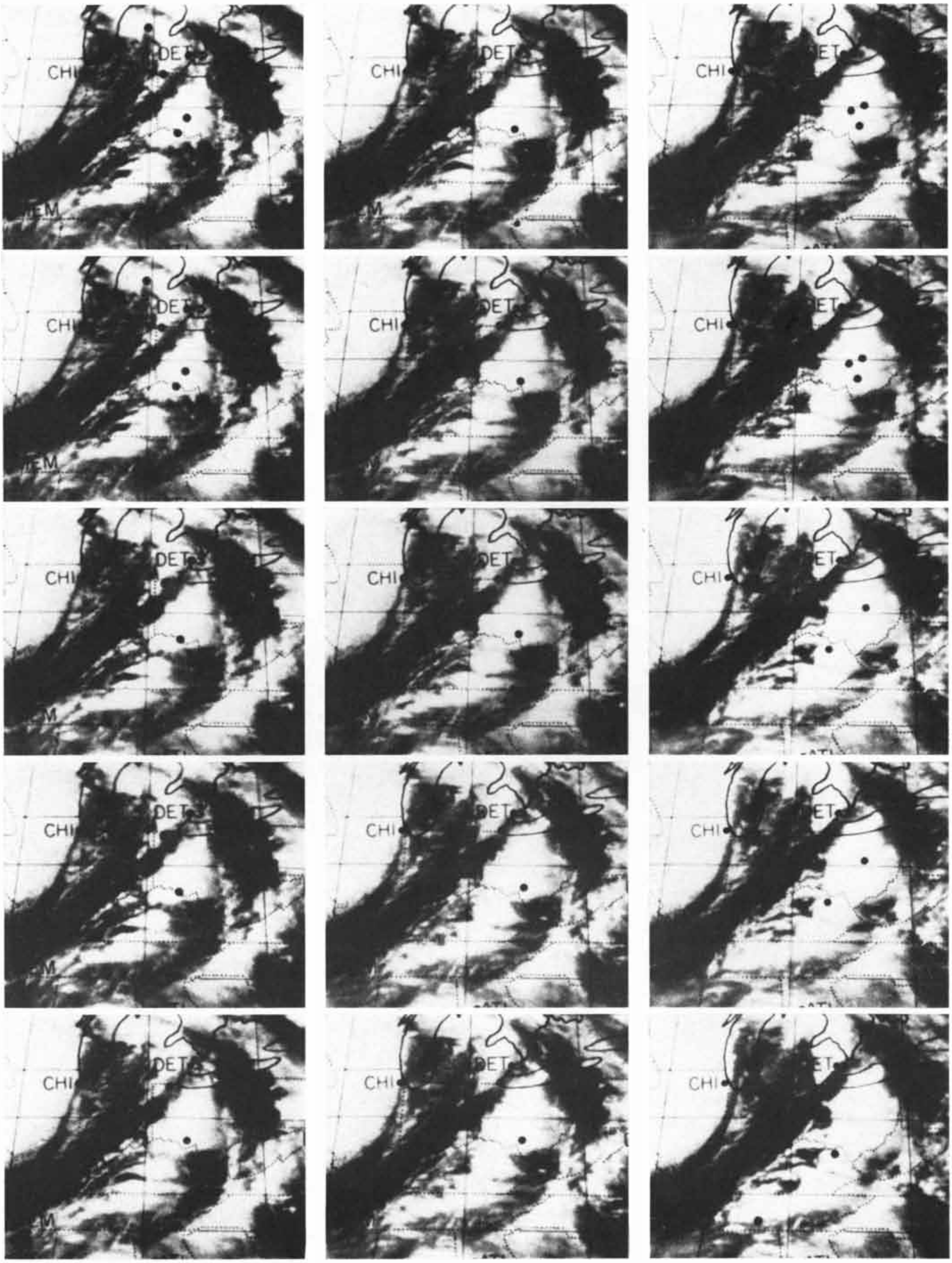
frared temperature of land surfaces. It is expected that in many instances the temperature pattern thus obtained will make it possible to distinguish clouds from snow and ice—a discrimination that is sometimes difficult in the interpretation of satellite photographs made at visible wavelengths. Knowledge of the distribution of snow would clearly be valuable for forecasts of water supply and floods.

One of the purposes of the Nimbus system is to test new sensors designed to measure the vertical distribution of temperature in the atmosphere. Present methods of weather prediction include the highly involved processing of equations of motion by computer. The equations require information based on the densest possible coverage of many weather factors, including not only spot temperature readings but also the vertical distribution of temperature. Techniques developed by the National Environmental Satellite Center and other groups provide for the measurement of temperature by spectrometer in the band of wavelengths centered on 15 microns and in the region between eight and 12 microns. Mathematical work on the measurements yields average temperatures for distinct layers of the atmosphere about 3,000 feet thick.

The spectrometer capability has been demonstrated in flights of high-altitude, constant-level balloons. The first spectrometer in a weather satellite was aboard the vehicle that would have become *Nimbus III* if it had not had to be destroyed during launch last May. A Nimbus spacecraft scheduled for launch early this year will also carry a spectrometer. We expect that the use of spectrometer data in mathematical models of the atmosphere will make possible the



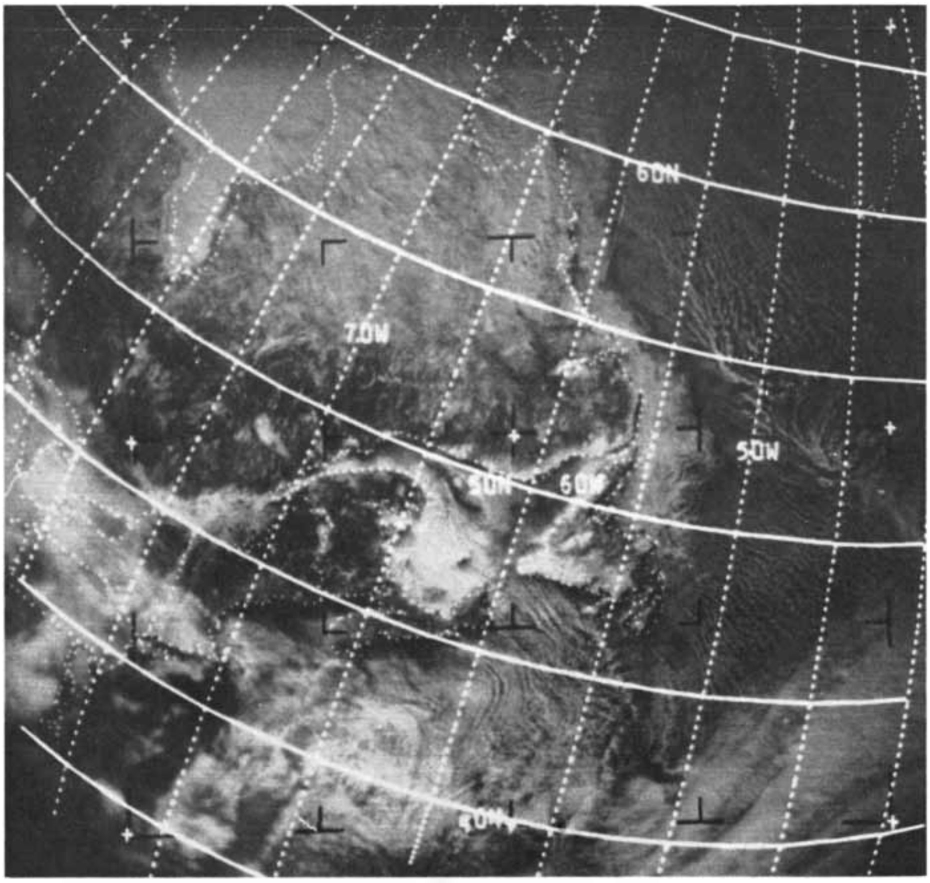
SUMMER PATTERN of clouds over the Northern Hemisphere is shown for a two-week period in July, 1967. Greenland is at right center; India, much more covered with clouds than in winter because of monsoons, is at top center. Multiple-exposure averaging technique was worked out by Jack Kornfield, A. F. Hasler and V. E. Suomi of the University of Wisconsin and K. J. Hanson of ESSA.



THUNDERSTORM AREA over the central part of the U.S. was photographed last April 23 by an Applications Technology Satellite. A number of photographs were marked with grids, abbreviated names of cities such as Chicago and dots to indicate where tornadoes appeared. The photographs were then assembled on a time-lapse motion-picture film so that the movement of the storms could be observed. These photographs are from the film. Aim of techniques is to see if conditions producing tornadoes can be identified.

improvement of weather forecasting to the extent that reasonably accurate predictions of large-scale weather patterns can be made as much as two weeks in advance.

Weather research is of course not limited to the U.S. Programs designed to increase knowledge of the atmosphere and to lengthen the period of time over which weather forecasts will be reliable are being organized jointly on a worldwide basis by the International Council of Scientific Unions and the World Meteorological Organization. Highly concentrated observation programs for certain areas are being planned for the next few years. Another international program is the bilateral space agreement between the U.S. and the U.S.S.R., which calls for an exchange of data from weather satellites over a direct communication circuit that now exists between Washington and Moscow. The U.S.S.R. has been sending television and radiation data over the circuit to Washington, with some interruptions, since 1966. Comparable U.S. data are provided over the circuit to Moscow on a daily basis. Here is a potential connection of the meteorological services of the two major powers and an example of the peaceful use of outer space on an international basis.

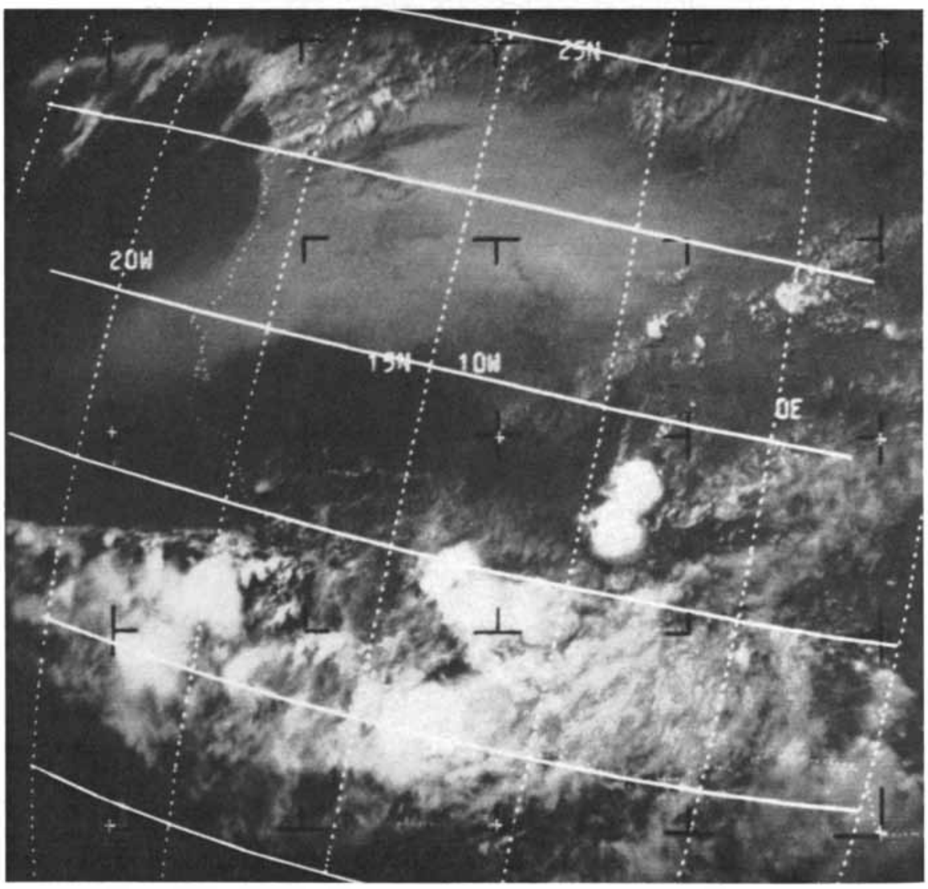


SNOW AND ICE cover of Newfoundland and Quebec is visible in a photograph made by *Essa 3* on February 19, 1967. The light area below and to the left of the notation "50N" is the ice in the Gulf of St. Lawrence and the St. Lawrence River. Hudson Bay is at upper left.

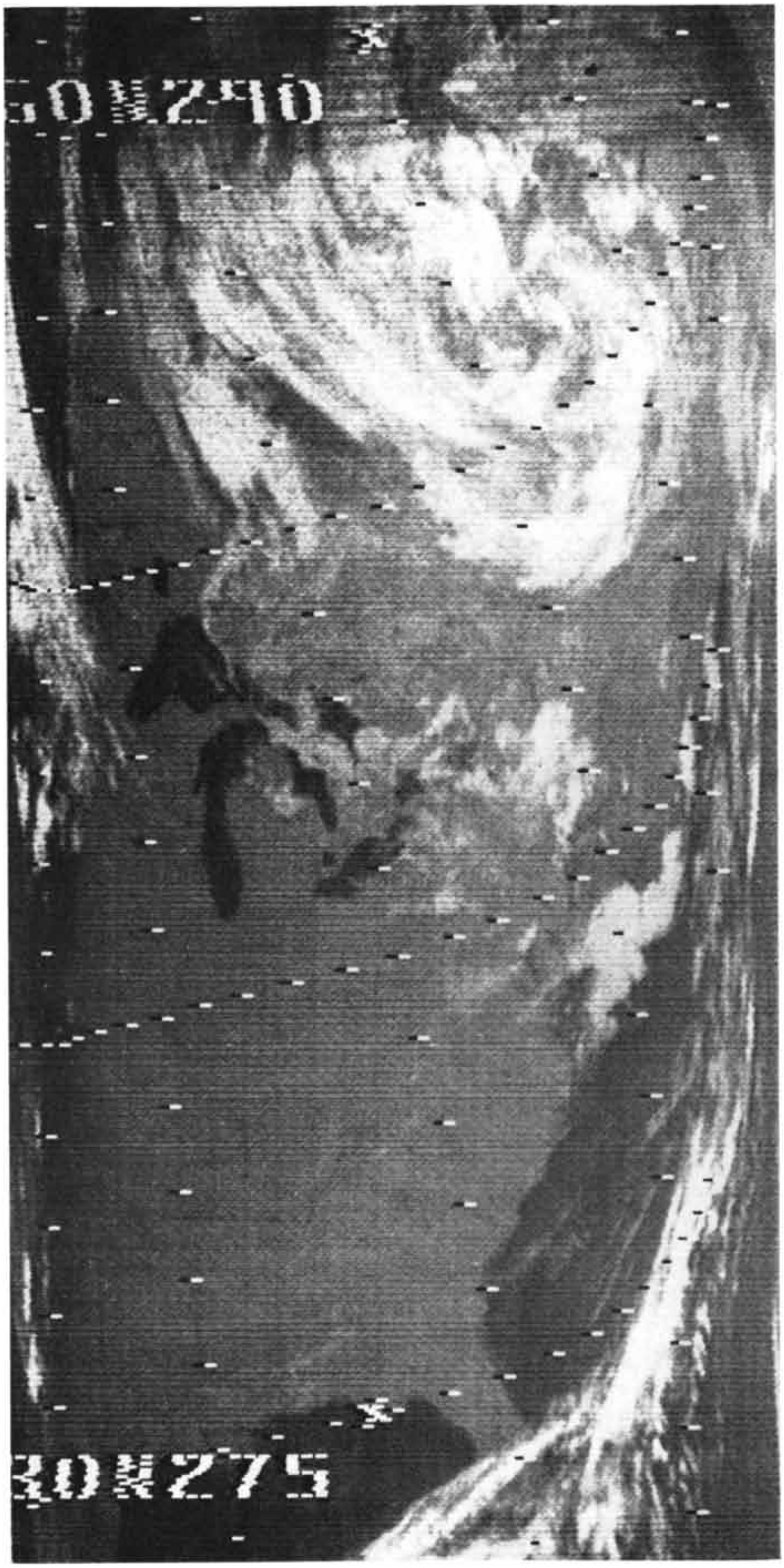
Prospective Developments

The Applications Technology Satellites, two of which are now operating, represent a particularly promising achievement in the weather-satellite enterprise. They are flown at an altitude of 22,300 miles, which means that their orbital period is 24 hours and synchronous with the earth's rotation. This type of spacecraft is a big step toward the fulfillment, at least during daylight hours, of the objective of nearly continuous viewing of the atmosphere. We hope that the resources will become available to establish an operational system of such satellites so that at least two of them can be kept in orbit at all times. With one of them stationed over the Atlantic and the other one over the Pacific, both could be operated by a single ground station in the U.S. Such a system is entirely feasible, and its design has been started.

Studies are in progress on the uses of the information that synchronous satellites can provide. We have prepared motion pictures in which data for an entire day, as received from a synchronous satellite, are shown in a brief sequence. Our hope is that it will be possible by means of such films to study the displacement of storm systems and cloud formations and thereby to determine wind speed



SANDSTORM over the Sahara was photographed by *Essa 5* on June 7, 1967. Storm can be seen over the Atlantic Ocean near "20W" and "15N" and extends some 3,000 miles eastward.



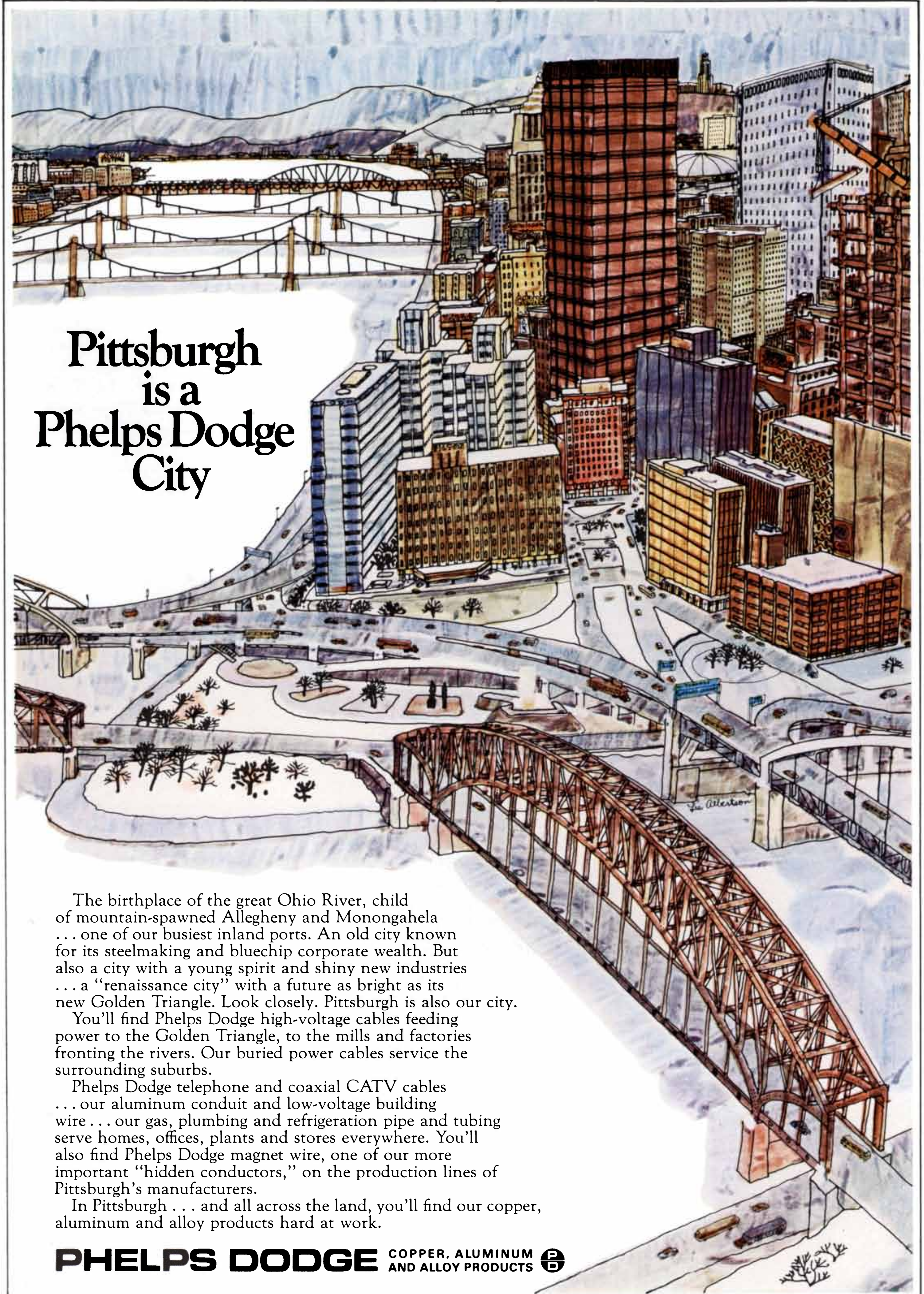
INFRARED VIEW of eastern U.S. was obtained on September 24, 1966, by the research satellite *Nimbus II*. In processing, the usual arrangement of infrared photographs, in which the warmest areas are the lightest, has been reversed, so that the warm waters of the Great Lakes appear dark and the cold ice-crystal cirrus clouds over Florida (*lower right*) are light.

and direction, storm motion and rates of cloud development and decay. The availability of more or less continuous observation of tropical storms far beyond the reach of normal reconnaissance, and of nontropical storms with their attendant warm and cold fronts, jet streams and cloud patterns, presents exciting opportunities to meteorologists. More important is the fact that this nearly continuous surveillance of the atmosphere will enable meteorologists to provide complete descriptions of the distribution and variation of weather systems—a capability that could be expected to lead to improvements in the service rendered to all users of weather information.

The information on the flux of solar protons that will come from the Tiros M series will go to the Institute for Telecommuni-Sciences in the Environmental Science Services Administration. Within the institute is the Space Disturbances Laboratory, which prepares forecasts of solar disturbances that affect communications and manned space flights and that can be expected to affect the operation of the supersonic transports the aviation industry intends to put into service. It can be hoped that the laboratory's forecasts will benefit conspicuously from the proton-flux measurements made by weather satellites.

Among the capabilities under consideration for incorporation in future satellites is a very-high-resolution observation technique. It could find and evaluate geologic resources and could keep track of the characteristics of soil and vegetation [see "Remote Sensing of Natural Resources," by Robert N. Colwell; SCIENTIFIC AMERICAN, January, 1968]. Modifications to provide for geodetic mapping, navigation services and communication with fixed and moving platforms (buoys and balloons) are clearly within reach of operational satellite systems.

In the past decade weather satellites have steadily added to the flow of information man has about his atmospheric environment, and they have materially improved the quality of that information. Such advances have stimulated meteorologists to look beyond describing the atmosphere and predicting its behavior toward the possibility of precisely modifying the weather for the benefit of man. It is clear that far more investigation is needed before weather modification is undertaken on any substantial scale. In such investigations weather satellites will certainly play a central role.


Pittsburgh is a Phelps Dodge City
The birthplace of the great Ohio River, child of mountain-spawned Allegheny and Monongahela . . . one of our busiest inland ports. An old city known for its steelmaking and bluechip corporate wealth. But also a city with a young spirit and shiny new industries . . . a "renaissance city" with a future as bright as its new Golden Triangle. Look closely. Pittsburgh is also our city.
You'll find Phelps Dodge high-voltage cables feeding power to the Golden Triangle, to the mills and factories fronting the rivers. Our buried power cables service the surrounding suburbs.
Phelps Dodge telephone and coaxial CATV cables . . . our aluminum conduit and low-voltage building wire . . . our gas, plumbing and refrigeration pipe and tubing serve homes, offices, plants and stores everywhere. You'll also find Phelps Dodge magnet wire, one of our more important "hidden conductors," on the production lines of Pittsburgh's manufacturers.
In Pittsburgh . . . and all across the land, you'll find our copper, aluminum and alloy products hard at work.
PHELPS DODGE
COPPER, ALUMINUM AND ALLOY PRODUCTS
PD

Cosindas on Cosindas on Polaroid Land Film

Marie Cosindas has had one-man shows of her Polaroid photography in many of the world's major art museums. One of her recent commissions has been a series of portraits for Helena Rubinstein.

"I started out as a painter. And a painter I remain.

Only now I use Polaroid Land color film and a camera instead of oils and brushes. Somehow it seems right to me that the artist today should use the materials that technology has given us.

Of course, just being contemporary doesn't make something good. To me Polacolor film is good. Primarily because of its extraordinary color.

But it's just as important not to have to depend on a laboratory; to be able to see the results right away; and to be able to develop and continuously build upon an idea.

The portrait on the opposite page, for example, is one of a series commissioned by Helena Rubinstein, the cosmetics manufacturer, to be used for advertising. They wanted the unusual effect I get with Polaroid film.

When I began photographing this model, she saw the results immediately and became involved with what I was working towards. She reacted with feeling. In short, we established a relationship.

That's the beauty of Polaroid Land film. The instant pictures help form an instant relationship. Which, I believe, adds that special quality that can turn photographs into art."