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WEATHER SATELLITES

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This past year has been a momentous one for the Nation's meteorological satellite program. A year ago, Tiros VI was transmitting television pictures of the cloud cover of the Earth. Tiros VII was being prepared for its launch, the Nimbus spacecraft subsystems were in their advanced stages of qualification and preparation for integration into the spacecraft itself, the program was proceeding along lines that had been established in 1960 when the interagency responsibilities for the various aspects of the program were defined, and we in the U.S. were busy preparing to meet with the U.S.S.R. to discuss the implementation of a joint meteorological satellite program.

Since then, Tiros VI has ceased its transmissions after 1 year of operation, VII and VIII have been successfully launched and are still operating, the Nimbus spacecraft and the system are in the final stages of qualification and preparation for launch, and the direction and emphasis of the program have been sharply changed, and new interagency relationships established. The U.S.-U.S.S.R. cooperative program stands exactly where it did in the spring of 1963. However, the international aspects of the program entered an entirely new phase with the use of the automatic picture transmission system on Tiros VIII, permitting the receipt of picture data from the satellite at many ground stations throughout the world.

THE TECHNICAL ACCOMPLISHMENTS

The phenomena the Tiros satellites have observed and the data collected by the TV and infrared sensors aboard the spacecraft are impressive. It would be impossible to present even a fair sampling of the 340,000 pictures that have been received and analyzed and of the 5,000 orbits of visible and infrared radiation data that have been taken, or to summarize the more than 100 scientific and technical papers that have been published. The new observations and the operation of the Tiros system have become so routine that there exists a constant threat of our being swamped by the flood of information. Indeed, the quantity of data to be received, processed, and assimilated—particularly for operational applications—is the major problem for the meteorological satellite program.

The routine nature and the global scope of the operation are best illustrated by the Tiros Daily Progress Report which is prepared by the NASA and U.S. Weather Bureau personnel in the Tiros Technical Control Center at Goddard Space Flight Center and distributed to the interested executives of NASA and the U.S. Weather Bureau and to the managers of the program. Report No. 209, dated 20 April 1964, selected at random, reads:

TIROS DAILY PROGRESS REPORT NR 209
20 APRIL 64

TIROS I NOT TRANSMITTING

TIROS II BEACON TRANSMISSION 108.00 MC AND 108.03 MC.

TIROS III BEACON TRANSMISSION ON 108.03 MC.

TIROS IV BEACON TRANSMISSION ON 136.23 MC AND 136.92 MC.

TIROS V BEACON TRANSMISSION ON 136.23 MC AND 136.92 MC.

TIROS VI NO BEACON TRANSMISSION. PERIODIC INTERROGATIONS SCHEDULED TO CHECK SPACECRAFT SUBSYSTEMS.

TIROS VII

1. PICTURES TAKEN—128 TV PICTURES WERE TAKEN OF WHICH 124 WERE METEOROLOGICALLY USABLE.

2. UNUSUAL PICTURES—NONE.

3. SIGNIFICANT STORMS OBSERVED—NONE.

4. ENGINEERING REPORT—

A. SPACECRAFT: FOUR SYSTEM TWO TV READOUTS WERE PROGRAMMED. THREE SEQUENCES ALARMED ON TIME. ONE SEQUENCE ALARMED LATE (1 MIN).
B. COMMAND AND DATA ACQUISITION OPERATIONS: FOUR FRAMES READOUT AT WALACQ WERE NOISY UNUSABLE DUE TO USE OF THE MEDIUM GAIN ANTENNA.

5. METEOROLOGICAL REPORT—

5 NEPHANALYSES WERE OBTAINED FROM 4 ORBITS INTERROGATED FOR TV DATA. 5 WERE RETRANSMITTED BY FACSIMILE. 4 CODED NEPHANALYSES WERE TRANSMITTED BY TELETYPE. 48 PICTURES WERE RECEIVED AT NWSC BY PHOTOFACSIMILE AND 5 OF THESE WERE RETRANSMITTED. ORBITS 4520 TO 4534 OCCURRED DURING THIS PERIOD. THE AREAS COVERED BETWEEN 50 DEGREES N AND 20 DEGREES S INCLUDED EASTERN SIBERIA, KAMCHATKA, NORTH PACIFIC OCEAN, RED SEA, ARABIA, ARABIAN SEA, INDIAN OCEAN, UNITED STATES, GULF OF MEXICO, CARIBBEAN SEA, CENTRAL AMERICA, AND WESTERN CANADA.

SIGNIFICANT METEOROLOGICAL FEATURES OBSERVED WERE FRONTAL BAND SOUTH OF KAMCHATKA.

FRONTAL BAND NORTH ATLANTIC OCEAN NEAR 40 DEGREES NORTH AND 52 DEGREES WEST.

POSSIBLE ITC NORTH PACIFIC OCEAN 5–10 DEGREES NORTH BETWEEN 155 AND 170 DEGREES WEST.

POSSIBLE ITC INDIAN OCEAN ALONG EQUATOR BETWEEN 51 AND 62 DEGREES EAST. POSSIBLE ITC NORTH ATLANTIC OCEAN NEAR EQUATOR BETWEEN 10 AND 30 DEGREES WEST. POSSIBLE SQUALL LINE OKLAHOMA TO SOUTHEAST KANSAS.

LANDMARKS OBSERVED WERE: KAMCHATKA, SEA OF OKHOTSK, RED SEA, FT. PECK RESERVOIR, GULF COAST AND CUBA.

TIROS VIII

1. PICTURES TAKEN—224 TV PICTURES WERE TAKEN OF WHICH 222 WERE METEOROLOGICALLY USABLE. 7 APT PICTURES WERE TRANSMITTED. THE AREAS COVERED INCLUDED: AUSTRALIA, NEW ZEALAND.

2. UNUSUAL PICTURES—NONE.

3. SIGNIFICANT STORM OBSERVED—NONE.

4. ENGINEERING REPORT—

A. SPACECRAFT: EIGHT SYSTEM ONE TV READOUTS WERE PROGRAMMED. SEVEN SEQUENCES ALARMED ON TIME. PLAYBACK PICTURES WERE NOT RECEIVED ON ONE READOUT DUE TO TV DROPOUTS DURING THE PREVIOUS INTERROGATION.

B. COMMAND AND DATA ACQUISITION OPERATIONS: NINE STEPS OF ONE TELEMETRY READOUT WERE LOST DUE TO OPERATION DIFFICULTIES AT WALACQ.

5. METEOROLOGICAL REPORT—

7 NEPHANALYSES WERE OBTAINED FROM 8 ORBITS INTERROGATED FOR TV DATA. 7 WERE RETRANSMITTED BY FACSIMILE. 5 CODED NEPHANALYSES WERE TRANSMITTED BY TELETYPE. 30 PICTURES WERE RECEIVED AT NWSC BY PHOTOFACSIMILE AND NONE OF THESE WERE RETRANSMITTED. ORBITS 1751 TO 1764 OCCURRED DURING THIS PERIOD. THE AREAS COVERED, BETWEEN 50 DEGREES S AND 15 DEGREES N INCLUDED, NORTH AND SOUTH PACIFIC OCEANS, INDONESIA, INDIAN OCEAN, SOUTH CHINA SEA, BAY OF BENGAL, NORTHERN SOUTH AMERICA, AUSTRALIA, AND CARIBBEAN SEA.

SIGNIFICANT METEOROLOGICAL FEATURES OBSERVED WERE CIRCULATION CENTER INDIAN OCEAN 37 DEGREES SOUTH 131 DEGREES EAST.

FRONTAL BAND EASTERN AUSTRALIA.

FRONTAL BAND WEST OF AUSTRALIA.

POSSIBLE FRONTAL BAND INDIAN OCEAN 35S 48E TO 47S 60E.

POSSIBLE FRONTAL BAND SOUTH PACIFIC OCEAN 33S 100W TO 43S 90W.

POSSIBLE FRONTAL BAND SOUTH PACIFIC OCEAN 27S 147W TO 33S 134W.

POSSIBLE ITC WESTERN INDONESIA 5 DEGREES NORTH TO 10 DEGREES SOUTH.

POSSIBLE ITC INDIAN OCEAN 6 TO 15 DEGREES SOUTH BETWEEN 65 AND 80 DEGREES EAST.

POSSIBLE ITC NORTH PACIFIC OCEAN 1 TO 10 DEGREES NORTH BETWEEN 110 AND 129 DEGREES WEST.

POSSIBLE ITC SOUTHEAST OF HAWAII 4 TO 11 DEGREES NORTH BETWEEN 135 AND 149 DEGREES WEST.

LANDMARKS OBSERVED WERE: AUSTRALIA, INDIA, CEYLON, ECUADOR.

Tiros Television Picture Data

The Tiros spacecraft and ground stations are illustrated by figure 1. Figures 2 to 13 include some Tiros television pictures; recognizable landmarks and other geographic features are often the most interesting features of such pictures.

In figure 2, a view of the Middle East, the Red Sea is easily identified. Crete and the Aegean Islands are the outstanding features of the picture of Greece (fig. 3). Figure 4 shows the Great Lakes, and figure 5 shows the northeastern area of the United States in sharp contrast to the ocean with Cape Cod and Long Island especially clear.

The enormous amount of data in a Tiros picture—1 million bits per picture (in the language of the computer and communication engineers)—makes necessary the reduction of the information to a format that can be readily transmitted to others for their use. Nephanalyses (cloud analyses) are produced from the

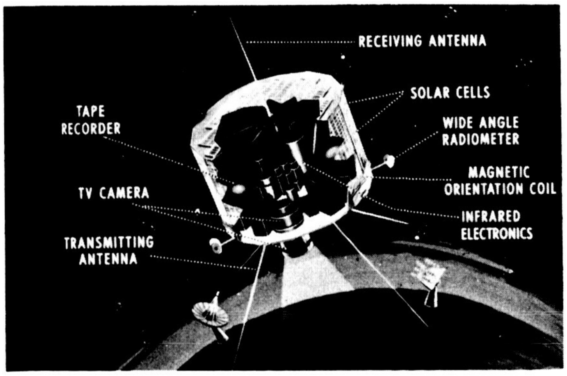

FIGURE 1.—The Tiros spacecraft.

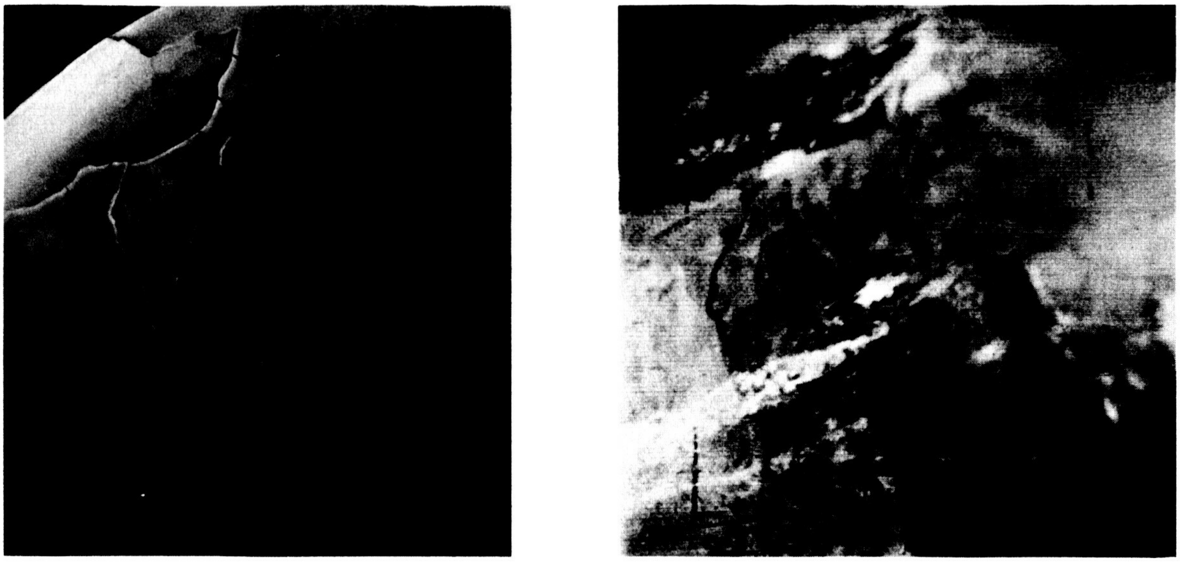

FIGURE 2.—Tiros picture of the Middle East.

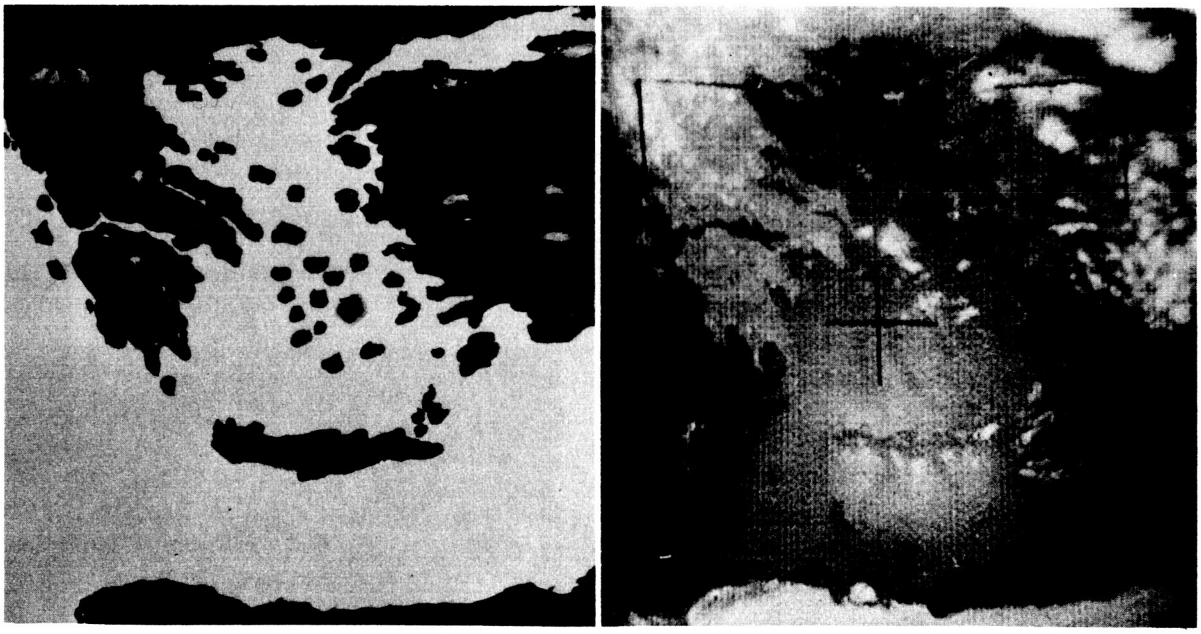

FIGURE 3.—Tiros photograph of Greece.

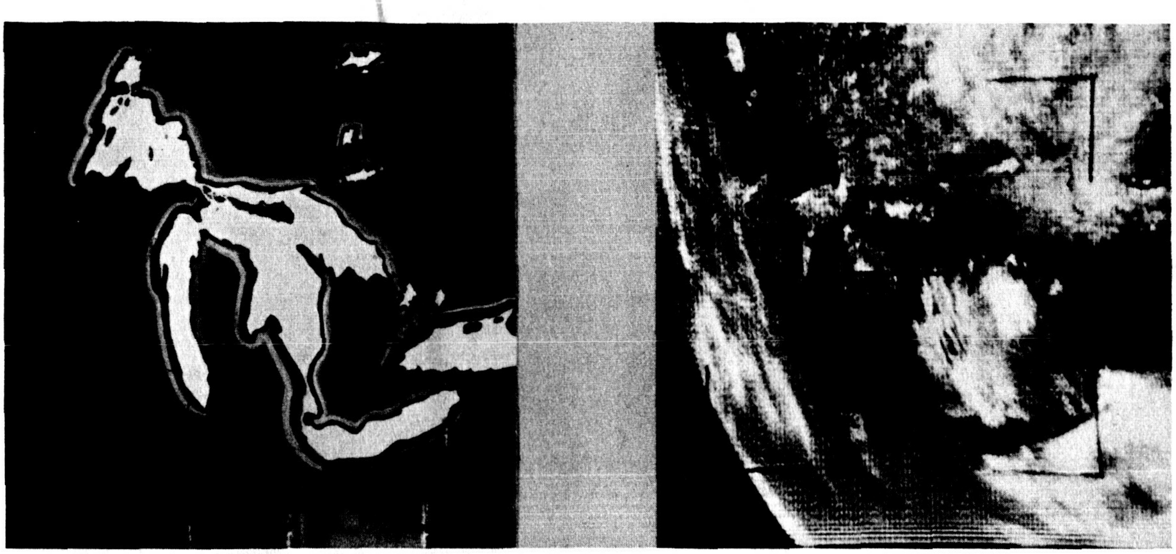

FIGURE 4.—Tiros photograph of the Great Lakes.

FIGURE 5.—A Tiros picture showing the northeastern United States.

pictures and transmitted by facsimile to the various users.

Tiros observations in data-sparse areas are made available to the meteorological community through nephanalyses of the picture data (fig. 6). A graphic shorthand is used to describe the types and distribution of clouds.

Figure 7 is a photograph of Florida with severe squall line and thunderstorm activity west of Tampa. This is another example of data from an area of few observations. The rain at Tampa was so heavy that the weather radar equipment was "blinded" and the extent of the storm activity undefined. Hurricane Anna in 1961 was one of the hurricanes observed and extensively studied by Tiros. Figure 8 shows the hurricane on July 21st off the coast of Venezuela.

Figure 9 is a cloud analysis for September 11, 1961, during an unusually busy hurricane season. Tiros observed the three hurricanes seen in this artist's rendition of the nephanalyses: Carla, Debbie, and Esther. On this same day, Tiros also observed the remains of hurricane Betsy in the North Atlantic and two full-blown typhoons in the Pacific Ocean off Japan. Esther was discovered when a ship in the Atlantic had reported high winds, and the U.S. Weather Bureau asked NASA if Tiros could take pictures of the area. Within 3 hours of the request from Miami, Tiros pictures of the hurricane were in the hands of the meteorologists.

Many other cloud phenomena have been observed by Tiros. Jet stream clouds and mountain clouds are shown in fig. 10, a photograph of the Red Sea area. In figure 11, the diamond-shaped cloud, which was about 50 miles square, was associated in time with severe thunderstorm and tornado activity as the surface analysis on the right shows.

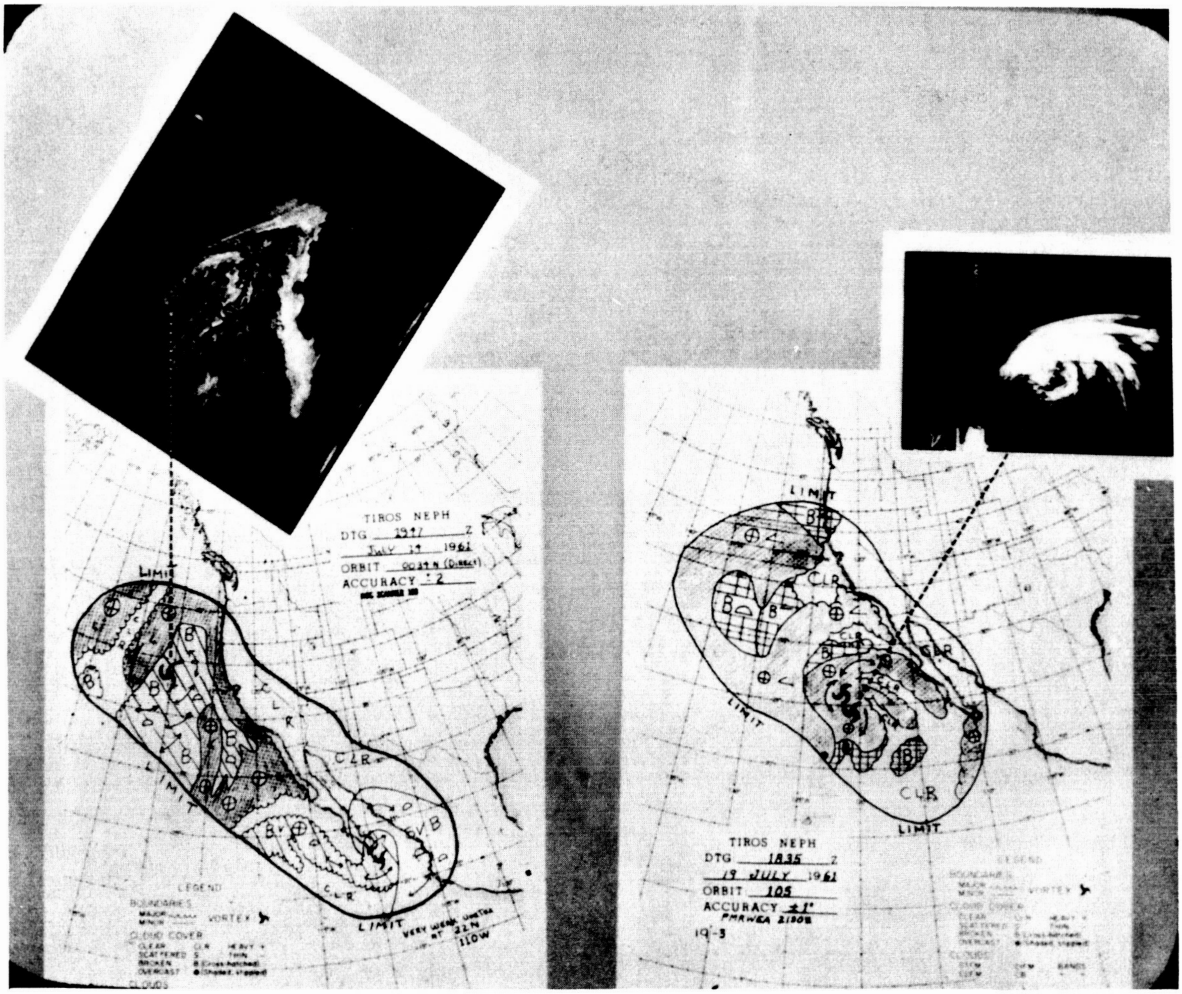

FIGURE 6.—Tiros III observations in a data-space area.

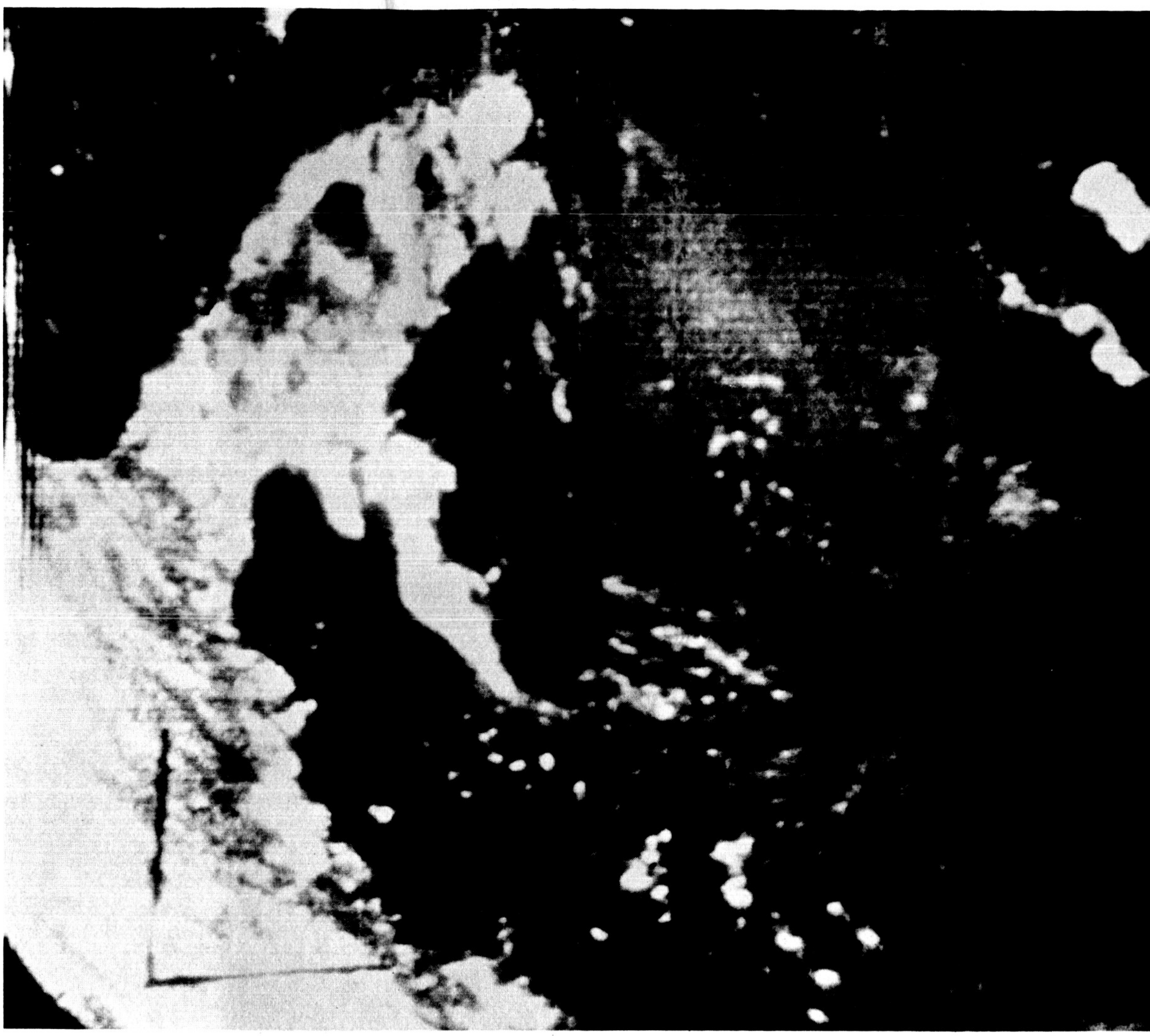

FIGURE 7.—A photograph of Florida showing severe squall line and thunderstorm activity west of Tampa.

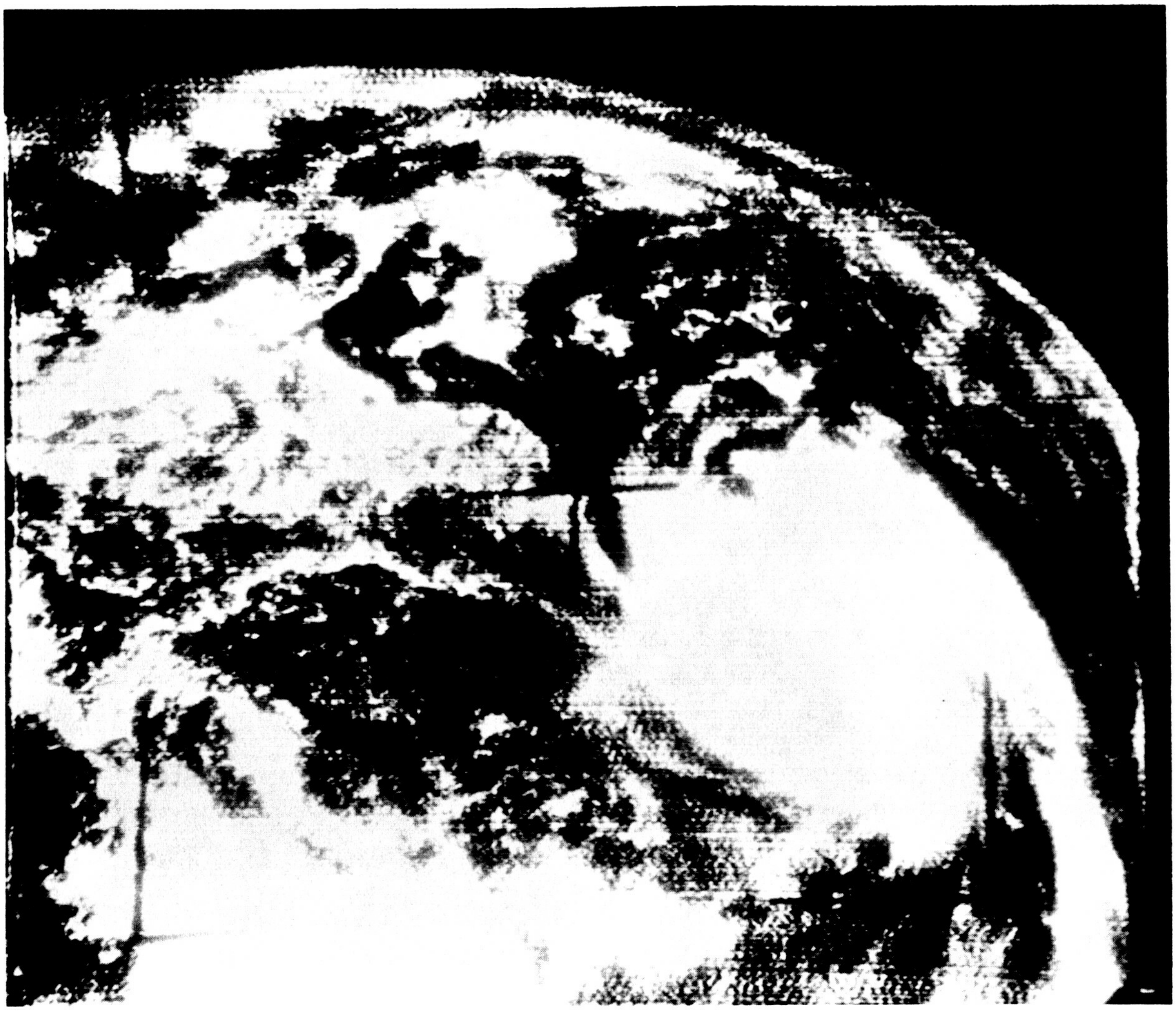

FIGURE 8.—Hurricane Anna in 1961, off the Venezuelan coast.

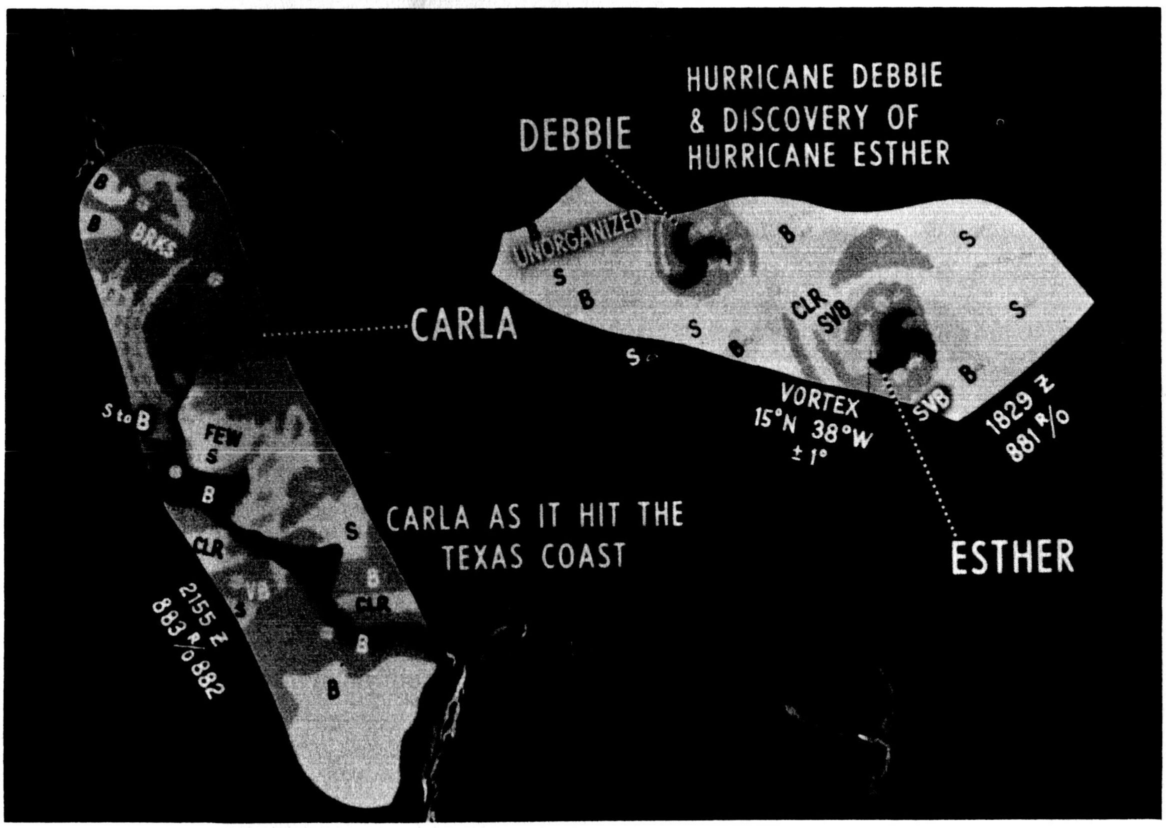

FIGURE 9.—A detailed cloud analysis made on September 11, 1961.

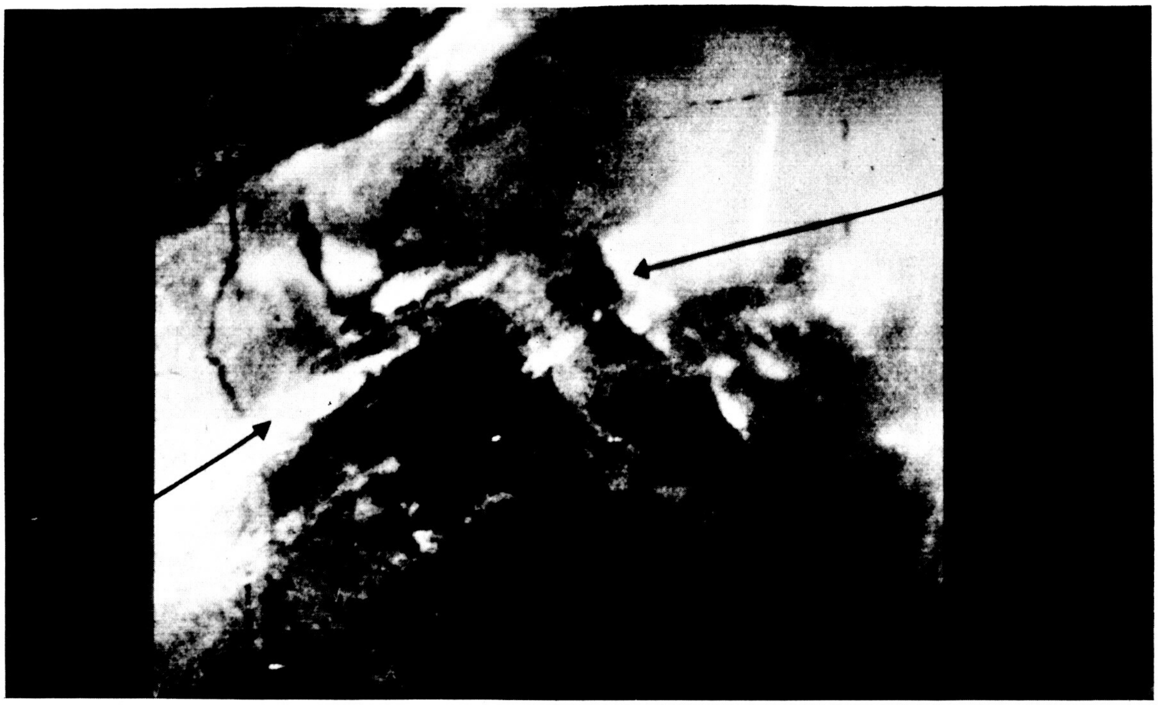

FIGURE 10.—Jet stream and mountain clouds on April 4, 1960.

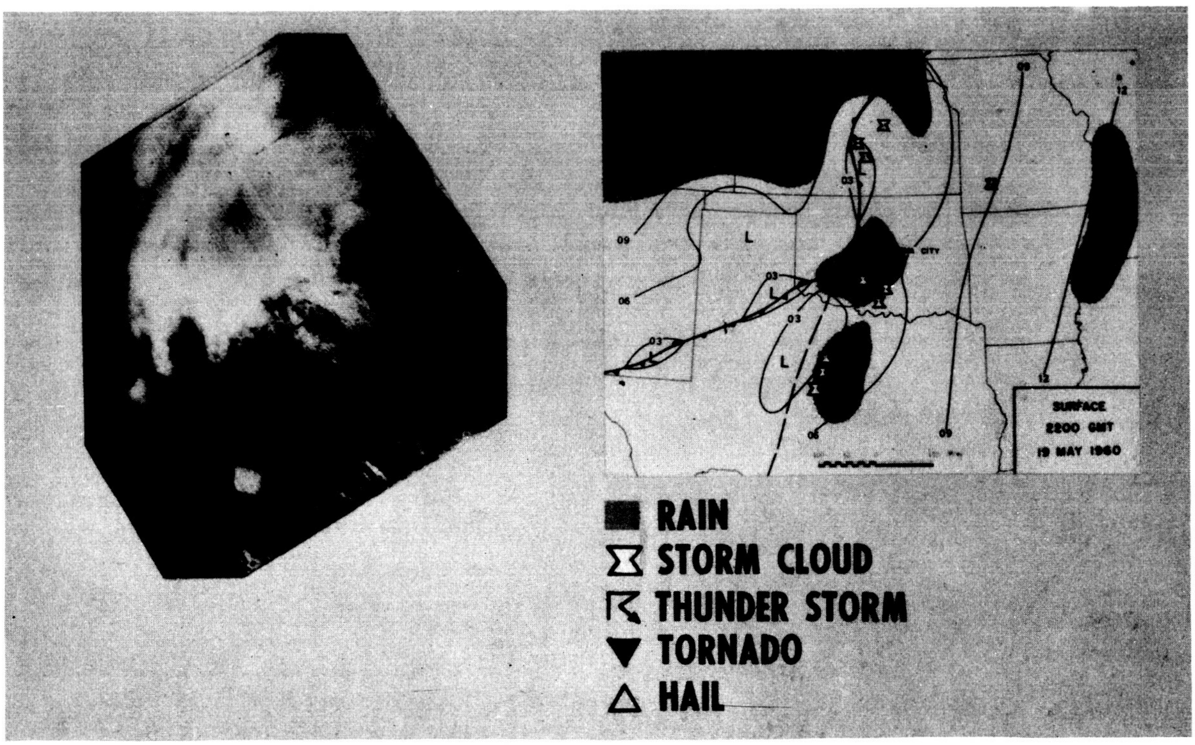

FIGURE 11.—Cloud patterns associated with a tornado.

Ice reconnaissance has been another accomplishment of the Tiros series. This was particularly true of Tiros II which carried a narrow-angle camera, in addition to the standard, to achieve 0.2-mile resolution. The high resolution mosaics of Tiros II photographs in figure 12 show Anticosti Island in the Gulf of St. Lawrence and the ice conditions on 2 days, March 23 and 29, 1961. The movement of the ice and its freeing of the island during this 6-day period are quite apparent. This reconnaissance has been of considerable interest to the Canadian Government and to the shipping companies using the gulf. Normally, extensive aircraft overflights are used for such reconnaissance.

Radiation Data from Tiros

The year 1963 saw the establishment of the Tiros five-channel radiometric measurements as tools of greatest potential for the exploration of the Earth's atmosphere for meteorological purposes. This instrument, which measures the emitted and reflected electromagnetic radiation from the Earth and the atmosphere, maps the spatial distribution of the energy by using the spin of the satellite to generate the scan line and the motion of the satellite along its orbit to advance the scan line. By using filters to limit the sensitivity of the various channels to different spectral regions in the visible and infrared, it has proved possible to measure the distribution and height of clouds during both day and night and the distribution and amount of water vapor in the tropopause, to map the distribution of temperature in the stratosphere, and to observe a number of other important physical phenomena. These radiometric measurements have the critical advantage over the cloud-picture data in that they are quantitative; that is, they provide accurate numerical values of the parameter under observation.

Figure 13 is a black-and-white reproduction of a photograph of a global map of the distribution of clouds and surface features as observed by the window channel. On the original, shades of color indicate a measure of the radiation intensity seen by the satellite radiometer. Radiation intensities are expressed in equivalent blackbody temperatures ranging from 300° K to 225° K. The radiation patterns provide a remarkably good description of the cloud cover prevailing over the globe at that time. High-radiation intensities can be seen over clear skies, particularly over the north African and Arabian deserts, where radiation is received from the very hot Earth surface. In contrast, low-radiation intensities are observed over cloudy areas where radiation is emitted by the relatively cold-cloud surfaces. Radiation minima indicating high clouds exist at high southern latitudes where a number of typical winter storms are in progress; over the North Pacific where a series of frontal systems range from Japan to the Gulf of Alaska; and over the tropics, north of the equator. A major tropical storm, Flossie, is located over the Philippines.

The 48° inclination of the orbit limits the possible data coverage to a broad zone between about 55° N. and 55° S. The particular geographic locations of the ground stations which command the readout of the data stored on magnetic tape in the spacecraft limit the number of consecutive orbits which can be interrogated to eight, and create permanent wedge-shaped gaps in the possible data coverage near 90° E. (north) and 90° W. (south). Unfortunately, in this case orbit 59 was missing, producing additional gaps over central Africa and the central Pacific.

When viewing is directly downward, the instantaneous field of view of the radiation sensor covers an area on the surface of the Earth having a diameter of about 65 km. As the nadir angle increases, the area becomes increasingly elongated in the direction viewed. The maximum nadir angle employed in the construction of this map was 58°. On July 16, 1961, the Tiros III orbit was positioned relative to the Sun such that the southbound transit of the satellite occurred in sunlight and the northbound transit occurred within the Earth's shadow; hence, the portion of the map lying east of the diagonal running from 20° S., 45° E. to 20° N., 90° E. consist largely of nighttime data, whereas the portion west of the diagonal consists of daytime observations. For comparison, a surface weather map based on conventional meteorological observations was superimposed on the radiation data.

Figure 14 is a photograph of Florida, a detail of the global map of figure 13. It shows on the west coast of the peninsula a bright cloud area—high cumulus clouds associated with intense thunderstorms. This detailed cloud structure also shows on the global radiation map.

The radiation data are now yielding maps of isolines that look much like the daily weather maps one sees in the newspapers, except that the satellite does not measure pressure. Figure 15 is a map of

FIGURE 12.—High-resolution mosaics of Tiros II photographs showing the ice conditions surrounding Anticosti Island on March 23 and 29, 1961.

FIGURE 13.—A global map of the distribution of clouds and surface features as observed by the window channel.

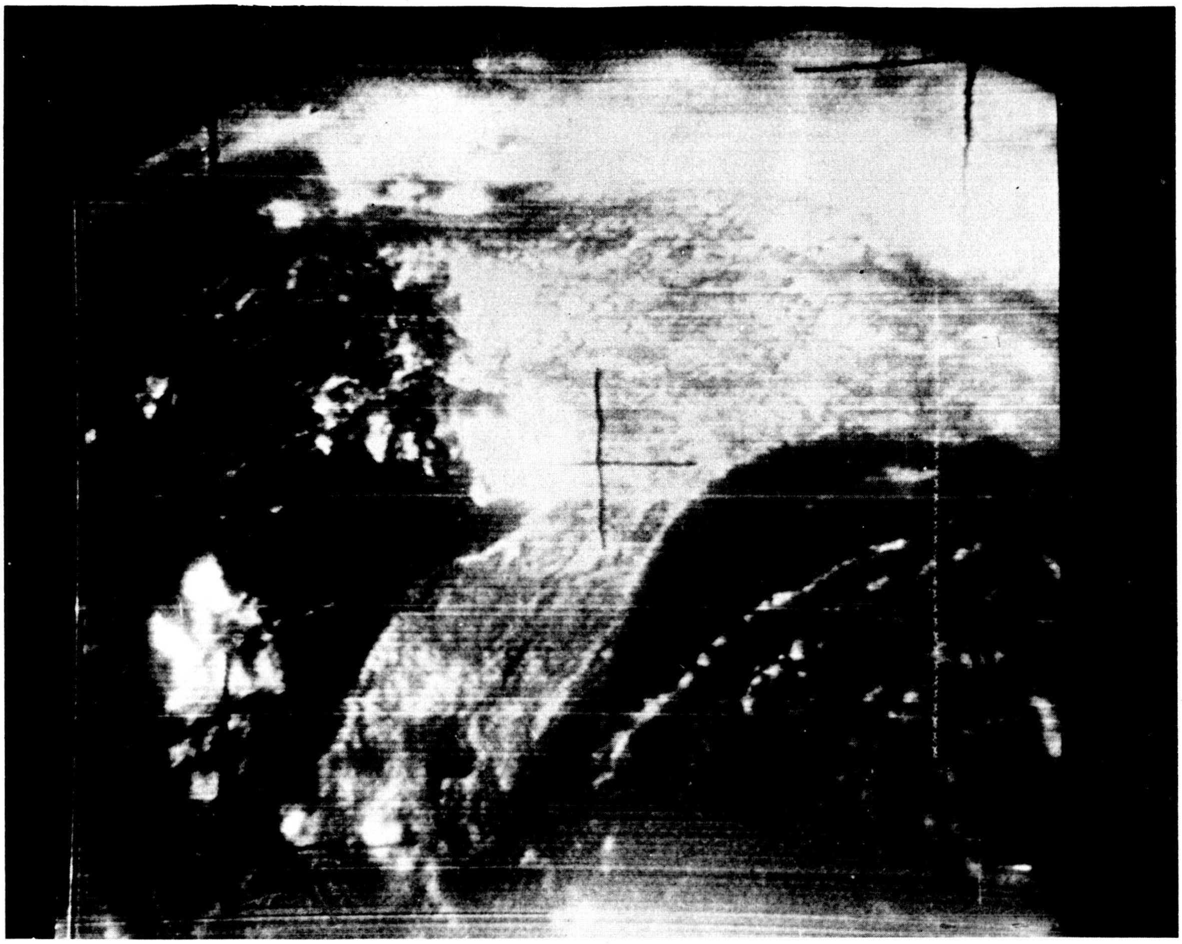

FIGURE 14.—Florida, a detail of the figure 13 global map.

Earth with the isotherms (lines of equal temperatures) in the stratosphere, as measured by the 15-micron radiometer channel plotted. Such phenomena as the Aleutian *high* and the weak summer polar vortex of the southern hemisphere are readily identified. Troposphere relative humidities over the United States were measured by the 6.3-micron *water vapor* channel of the Tiros radiometer (fig. 16). This is a new type of observation, which, frankly, we do not yet know how to use in the routine weather forecasting work.

One final Tiros accomplishment of the past year has been the exercising of the Automatic Picture Transmission (APT) system developed for Nimbus. The objective was to provide a means of transmitting cloud pictures of daylight areas of the Earth directly to the user of the data, whether he be on land, at sea, or in the air. Further, it was a requirement that the ground equipment be inexpensive so that the international community could make extensive use of the system.

In operation, the satellite-borne vidicon camera system takes a picture and over the following 200 seconds transmits it directly without external command. All APT ground stations, which consist of an inexpensive antenna and receiver and a relatively expensive facsimile machine, capable of tracking the satellite during the 200 seconds, can receive the picture. Thus, the local user receives a cloud picture of the area surrounding him (about 1,000 miles square). Figure 17 is a photograph of one type of ground station antenna being used for APT reception.

Figure 18 shows an APT ground station, completely ready for use, consisting of only two low racks. Figure 19 is an example of an APT photograph from Tiros VIII showing the west coast of the United

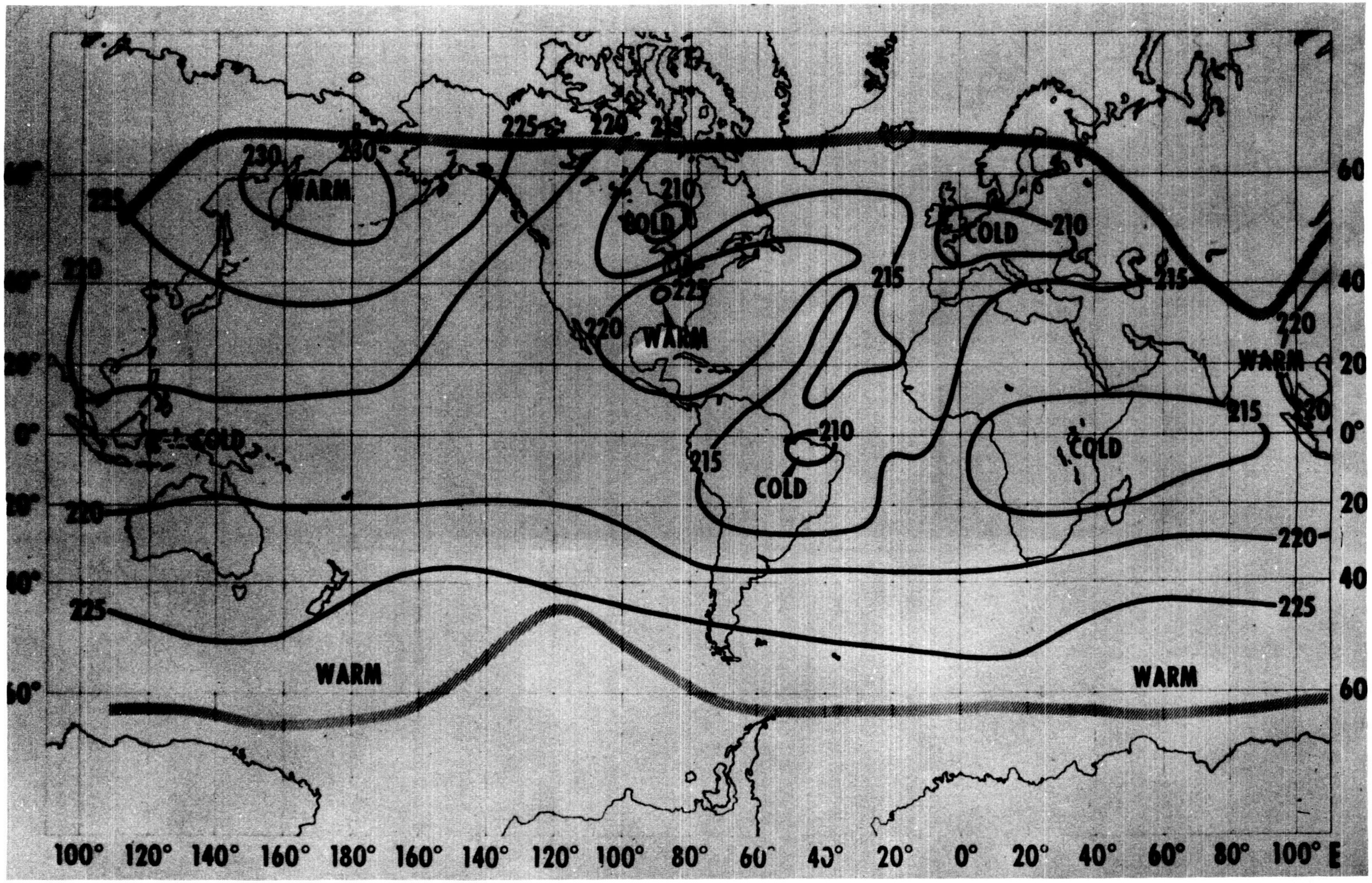

FIGURE 15.—Map of the Earth indicating isotherms in the stratosphere, 15-micron channel, Tiros VIII. Strastospheric temperature, OK. January 9–15, 1964.

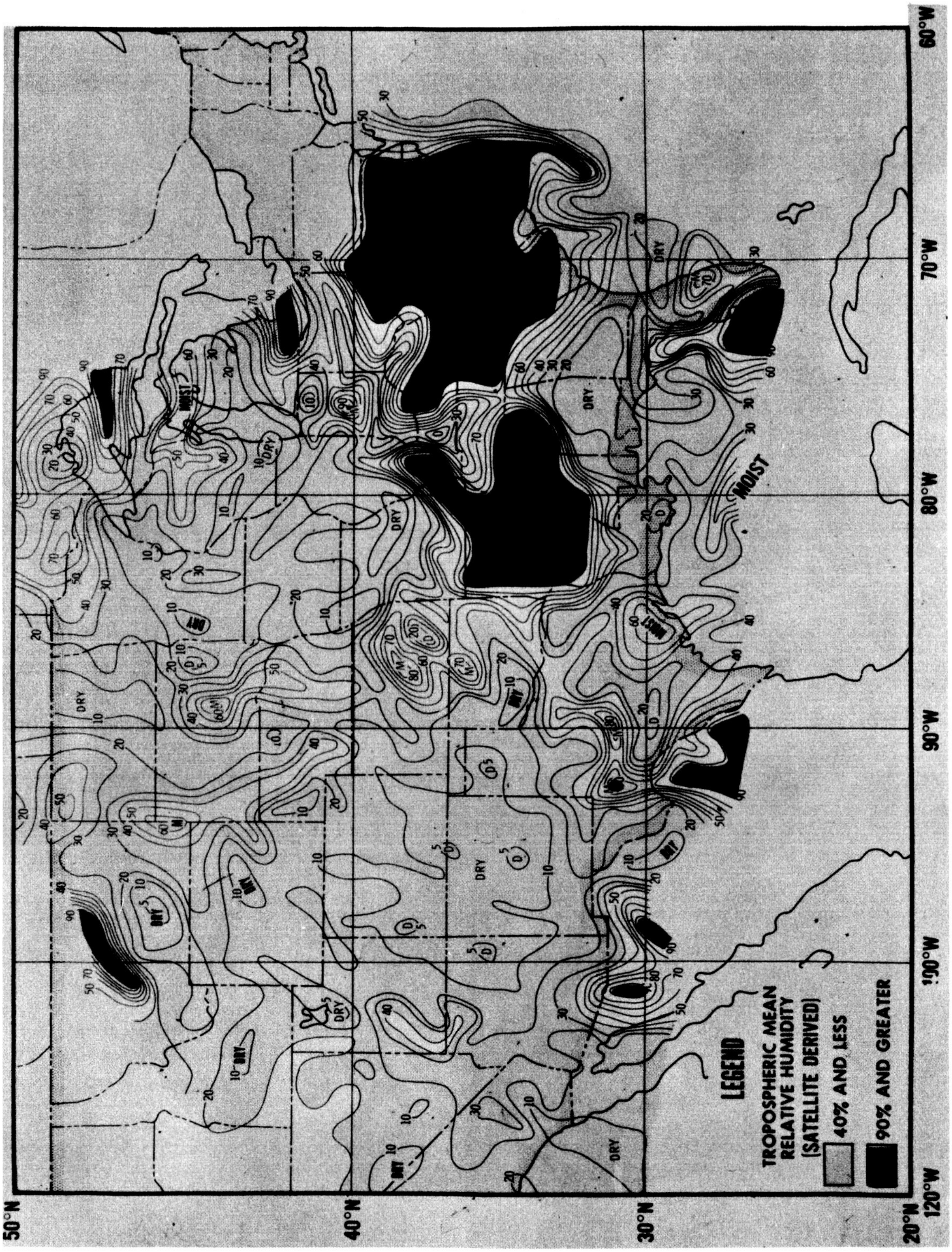

FIGURE 16.—Tropospheric relative humidities over the United States.

States. This picture was received by the APT station at Pacific Missile Range, Calif.

A specific example of the usefulness of APT in a "prognostic" sense was a photograph* obtained on orbit 1150, March 9, 1964, at 17:58:21Z. This photograph was instrumental in developing a FAWS forecast (FT–2), on the basis of discussion of the implication of the field with the FAWS forecaster which was at considerable variance with the previous FT–2. The FT–2's issued at 1700Z on the 9th and 2308Z on the 9th were compared.

Specifically, the 1700Z FT–2 of the 9th was prepared prior to the acquisition of the photograph and indicated a cold front passage at JFK International Airport with considerable thunderstorm activity and generally improving conditions after 1500Z on the 10th. This was based on a surface analysis which carried a warm front to the west of JFK and a cold front farther to the west. The implication being that

*Unfortunately no copy is available for inclusion in this paper.

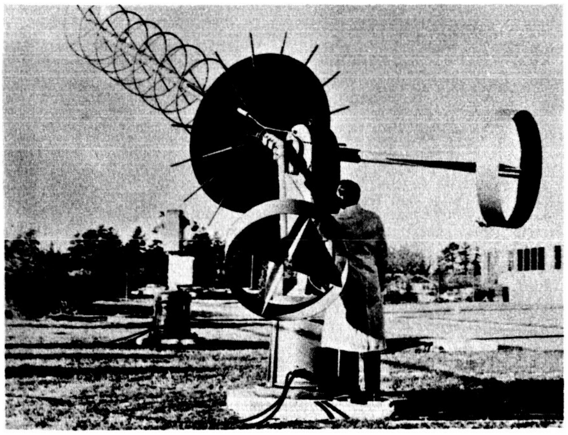

FIGURE 17.—One type of ground station antenna being used by APT reception.

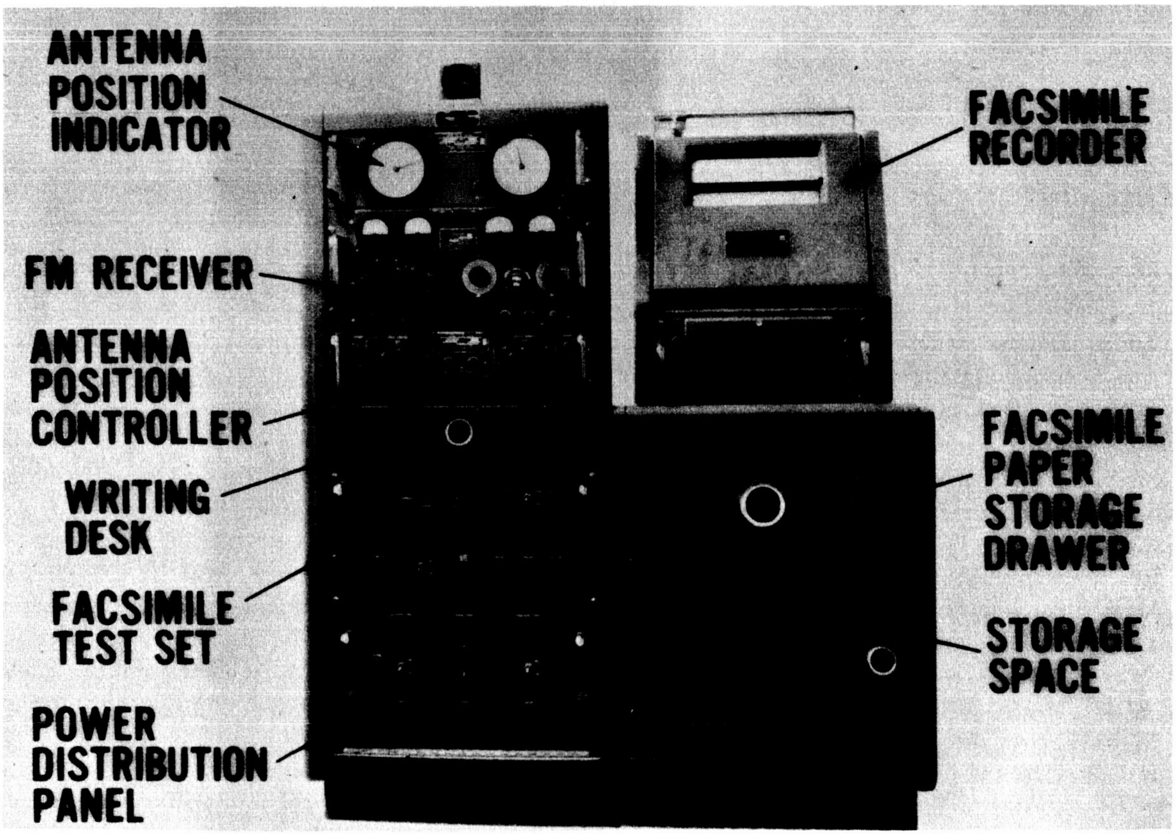

FIGURE 18.—APT ground station console.

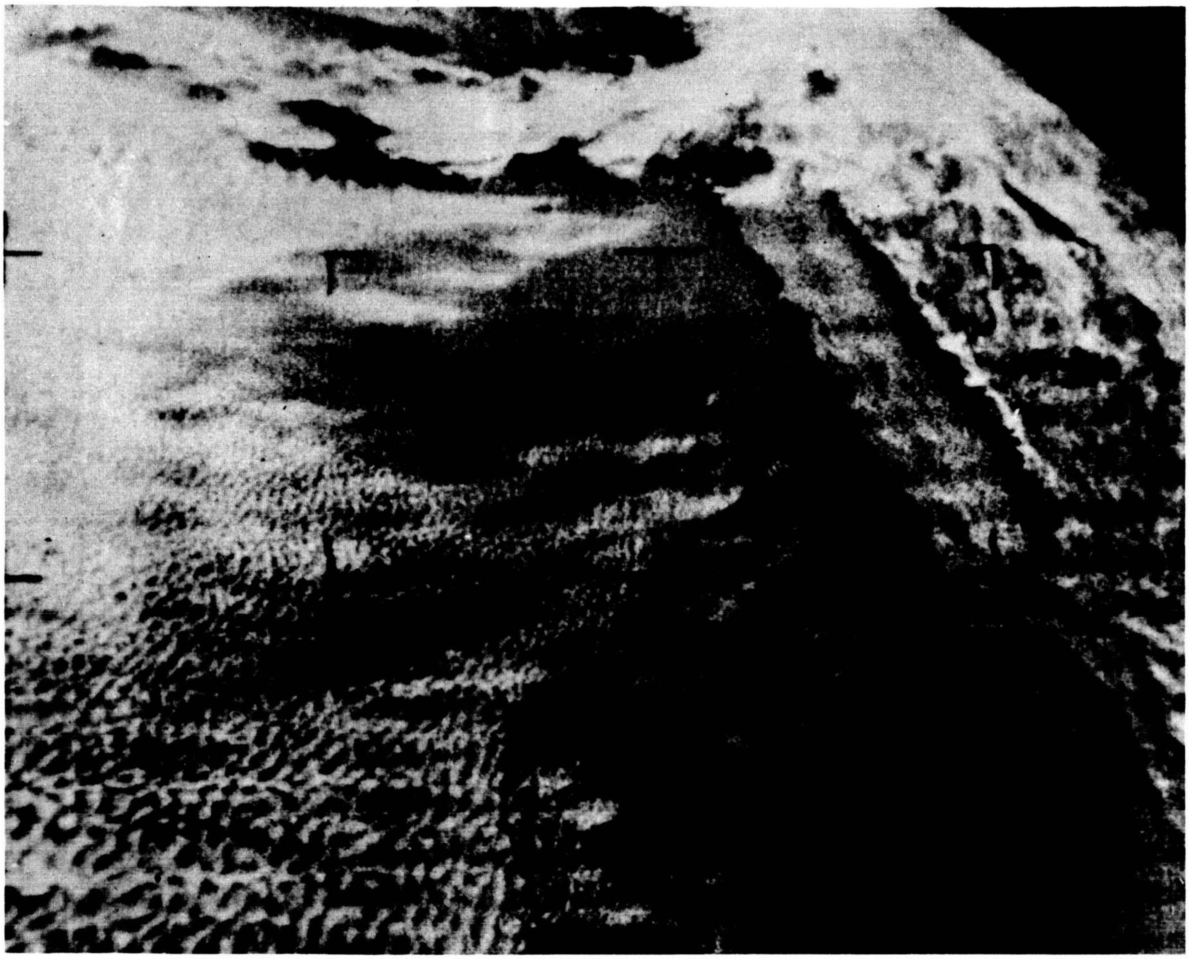

FIGURE 19.—An APT photograph from Tiros VIII, showing the west coast of the United States.

a warm front passage at JFK would be followed by a cold front passage later on. In other words, JFK would have gotten into the warm sector.

The photograph indicated that the main front was an east-west affair located well south of JFK and that what was being carried as a cold front to the west was really, in effect, an occlusion undergoing frontolysis. There was no well-defined system of cloud to indicate a front to the west, but rather a uniform cloud mass with no apparent light or dark areas. The absence of light areas implied the absence of cumulo-nimbus activity in the area to the west. Discussion with the FAWS forecaster then resulted in a reanalysis of the frontal structure and a consequent change in the FT–2. The FT–2 issued at 2308Z on the 9th deleted the FROPA and thunderstorm activity (that was in the previous FT–2) and improved the weather immediately, for a time, and deteriorated it again after 0700Z on the 10th, more or less a reversal of the previous FT–2. This revision worked out quite well. It is not meant to imply that the forecast might not have evolved in the same fashion when all the conventional data were examined for the period prior to 2300Z. However, the photograph was available, and discussion of its implication was made at about 1900Z. This started the revision in thinking, and a study of subsequent conventional data did bear out the interpretation resulting in the new FT–2. In other words, the photograph was definitely an input which, when combined with later conventional data, produced good results.

The Present Program

In the next 18 months to 2 years, we are planning to do two things:

(a) Complete the qualification of the second-generation meteorological spacecraft system, Nimbus, and launch the spacecraft.

(b) Adapt and convert the Tiros and Nimbus technology to an operational system capable of meeting the national weather service's minimum operational requirements.

NASA is undertaking both these tasks with every expectation of success.

Nimbus

The Tiros system has served the Nation well, but even before Tiros I was launched on April 1, 1960, we recognized that it was a device of limited capabilities that would ultimately be replaced. Bolstered by our early success with Tiros we took a "giant step" forward. We replaced the spinning 300-pound spacecraft, Tiros, with only 20 watts of power and carrying only 70 pounds of sensors, by the 800-pound earth-oriented Nimbus, with 200 watts of power and capable of carrying at least 250 pounds of sensors and of staying in a polar orbit. Figure 20 is an artist's drawing of the Nimbus spacecraft in flight. The developmental step between Tiros and Nimbus is well illustrated by the artist's sketch of the two systems in figure 21. The Tiros spacecraft photographs about one-seventh of the Earth every day with a resolution of about 3 miles. Nimbus will take a picture of every one-half square mile of the Earth once a day.

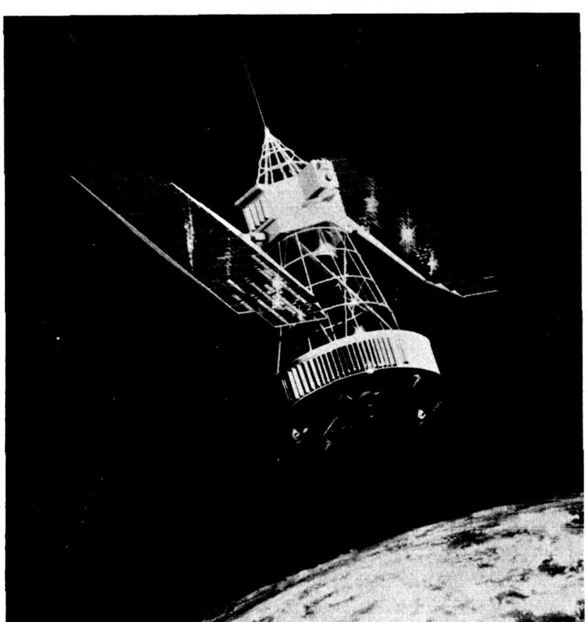

FIGURE 20.—The Nimbus spacecraft.

The Nimbus spacecraft will also carry infrared equipment for high-resolution measurements of the nighttime clouds, a feat not possible with present TV systems. An APT system using the existing ground complex of stations will be in operation. Follow-on flights will see the inclusion of advanced five-channel radiometers like the Tiros unit, for mapping clouds and cloud heights, water-vapor distribution, stratospheric temperatures and so on. Interferometers, high-resolution spectrometers, passive microwave equipment, and other atmospheric sensors will be tried.

Nimbus is absolutely *essential* to the national weather satellite program for one fundamental reason. The meteorologist in forecasting the weather—and the ultimate use of the meteorological satellite is as an operational tool supporting the weather services—uses the wind and pressure fields as his principal data inputs. Today, the satellite cannot measure these parameters either directly or indirectly. However, the meteorological satellite can and does make physically significant measurements; and we in the atmospheric sciences must learn the language the satellite speaks. Nimbus has the power, stability, and other properties required for this learning process.

The Tiros Operational System

At the request of the national weather services and with the funding of the Department of Commerce—U.S. Weather Bureau, NASA has undertaken the task of converting the Tiros technology—developed with NASA funds—to an operational system capable of meeting the minimum operational requirements. Briefly stated, these requirements are for cloud photographs of the entire Earth at least once each day. The global coverage is to be delivered by the satellite to a central processing facility; in addition, local readout of the pictures (APT) is required.

The ordinary spin-stabilized Tiros cannot provide global coverage efficiently. One of NASA's biggest contractors in the meteorological satellite area has devised a scheme which will solve the global coverage problem, and, in addition, provide more readily handled picture data. Figure 22 illustrates how a Tiros satellite, still spin-stabilized but now turned so that the spin axis is always perpendicular to the plane of the orbit, can provide global coverage. The camera, whether

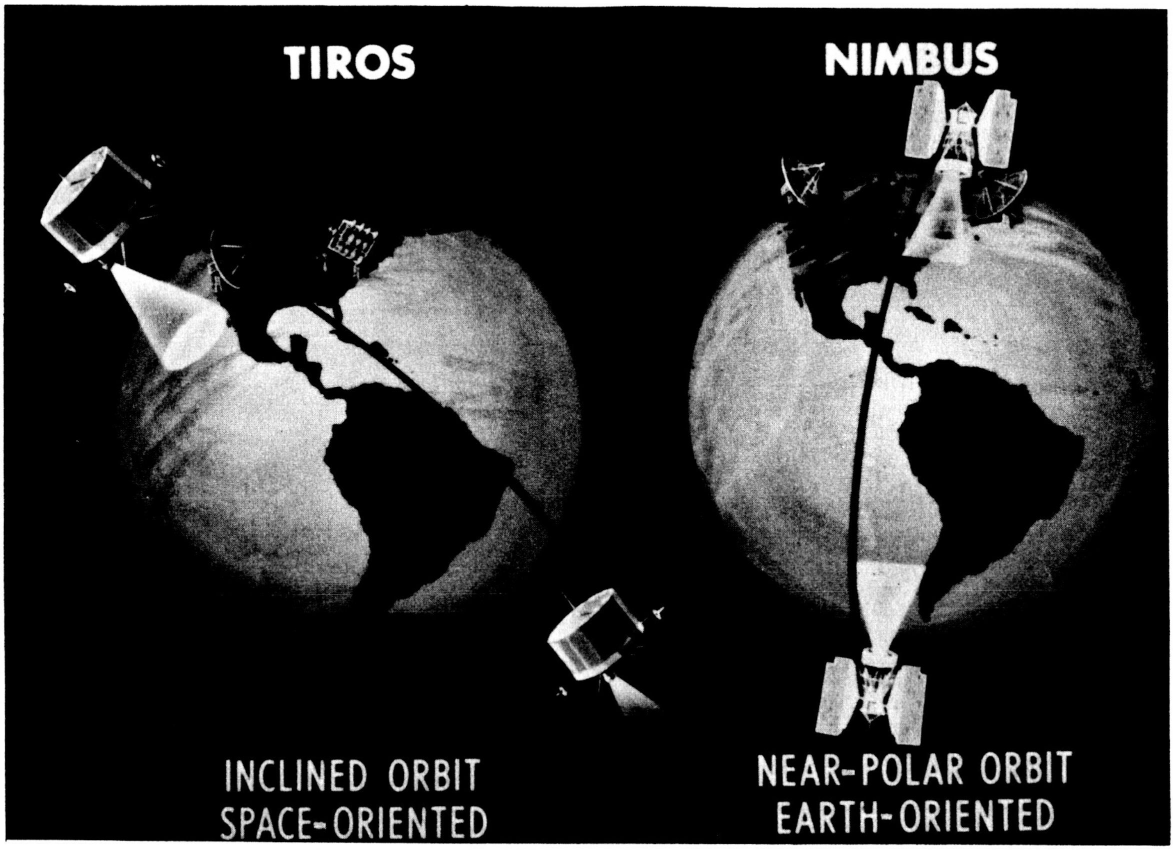

FIGURE 21.—Meteorological satellite development: Tiros and Nimbus.

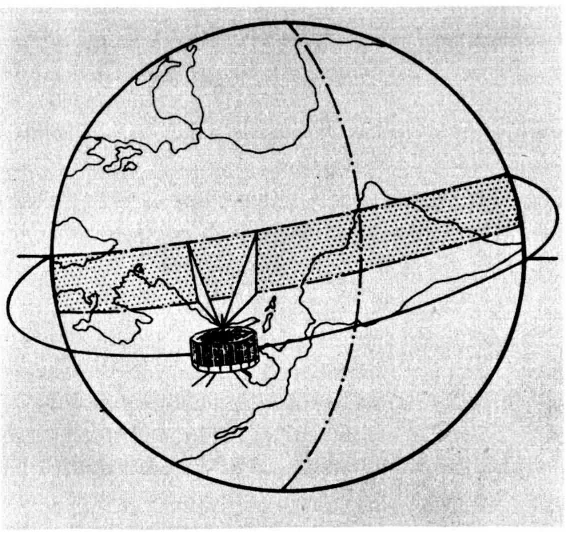

FIGURE 22.—A sketch illustrating how a Tiros satellite can provide global coverage.

a conventional vidicon or the APT system, looks outward from the side of the spacecraft. The shutter of the camera is triggered by the horizons of the Earth so that the picture is taken when the camera points straight downward.

The next Tiros launched, Tiros I, will be in this *cartwheel* configuration. This R&D unit (which has been funded by NASA) will prove the concept and the hardware and make possible the minimum operational system we are calling the Tiros operational system (TOS). It is planned now to prepare two basic cartwheel spacecraft: one will contain two APT cameras of the type developed for Nimbus for local readout and the other will contain two of the advanced vidicon cameras also developed for Nimbus. The spacecraft are identical except for the cameras. The use of two cameras in each spacecraft is indicative of the redundancy being used in the Tiros system. It is an improvement over the previous Tiros systems in the degree of "cross-strapping" of subsystems. Thus, the failure of one of the two tape recorders will not destroy the satellite usefulness, because the backup unit can be used with either vidicon or either transmitter. The same is true of other major subsystems of the spacecraft.

To be economically feasible, an operating system must have a predictable, reasonably long life. Obviously, the longer the life, the lower the annual operating costs of the system. The facts, that (1) the Tiros hardware has proved its life capabilities (Tiros VI lasted 13 months and Tiros VII will be 1 year old in June) and that (2) better use is being made of redundancy, give us confidence that an economically acceptable system can be brought into being.

THE FUTURE

We cannot produce a crystal ball at this point, but there are some important questions to be answered, some problems to be solved, and some hardware to be developed before the national and world weather services can make the most effective and economical use of this new aerospace tool. Figure 23 is an illustration of the lifetimes of typical weather systems, one of the most serious problems. This problem is characteristic of any measurement made on the weather system; only the clouds are illustrated here. A periodic measurement is being made of a power spectrum, or, more simply put, if the storm lasts only 3 hours, and Nimbus or Tiros makes a measurement every 24 hours, it is obvious that the satellite might not even see the storm. One solution, and probably the most effective, will be to place a satellite at synchronous altitudes. Then the sensor system can look down on the same area of the Earth and keep it under constant observation.

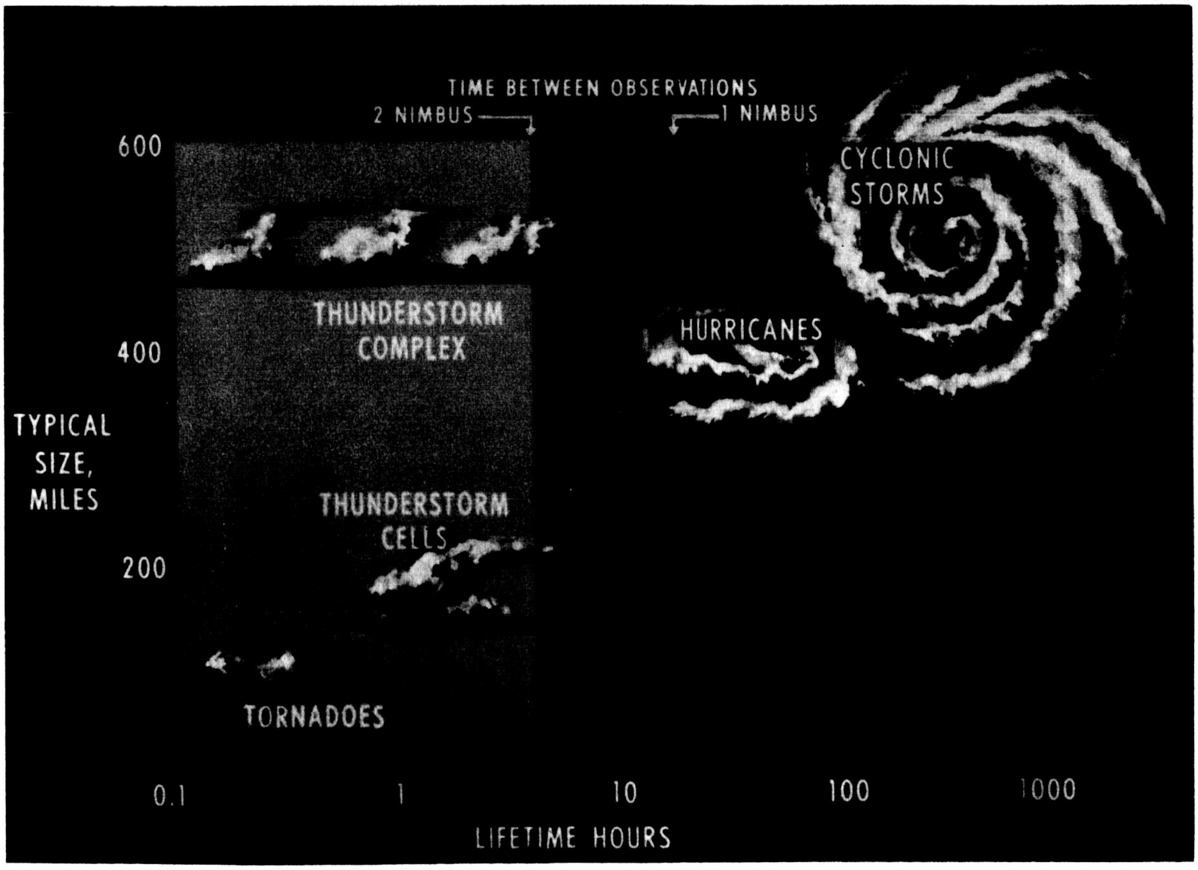

FIGURE 23.—Lifetimes of typical weather systems.

Aside from the more fundamental questions already mentioned (that of learning to "speak the language"), we are faced with the task of making nighttime cloud cover measurements, of measuring the pressure and wind fields, of developing reliable, predictable-life systems, and of finding techniques for handling 100 to 500 million bits of data in real time—to mention just a few.

CONCLUSION

In the meteorological satellite area, the nation has embarked on a program that promises to be of great benefit and service to all mankind. It will save lives and property and, in time, make the lives of each of us just a little bit fuller and more enjoyable.

It may be that the meteorological satellite program is the best example of the peaceful use of space.