Satellite Activities of NOAA 1977

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NOAA 5 SR visible image of a hurricane striking the east coast of India on November 19, 1977.
Satellite Activities of NOAA, 1977

National Oceanic and Atmospheric Administration

Introduction

In 1970, the National Oceanic and Atmospheric Administration (NOAA) was established within the United States Department of Commerce to improve our understanding of the environment and to ensure that its resources were wisely used. To make sure the Earth will continue to serve and sustain its people, NOAA pursues a variety of programs. These include operating, maintaining, and improving the Nation's operational environmental satellite systems; providing data to assess the impact of natural and people-induced factors on such things as global food supplies, national energy problems, and environmental quality; conducting fundamental research to improve our understanding of the environment; using satellite data and aerial photography for charting, coastal mapping, and geodetic research; improving weather services through the automation of forecast and observation stations, better radar systems, and continued atmospheric research; and improving the assessment and conservation of all living marine resources. Six major elements of NOAA participate directly in the aeronautics and space program. They are the National Environmental Satellite Service, the Environmental Data Service, the National Ocean Survey, the National Weather Service, the Environmental Research Laboratories, and the National Marine Fisheries Service.

Space Systems

Polar-Orbiting Satellites. During 1977, the National Environmental Satellite Service (NESS) of the National Oceanic and Atmospheric Administration (NOAA) operated two satellites, NOAA 4 and NOAA 5, of the Improved Tiros Operational Satellite (ITOS) series. NOAA 5 is the primary operational satellite and NOAA 4 is the in-orbit backup.

Development of the TIROS N series, the third generation of operational polar-orbiting satellites, is continuing. This series of satellites will replace the present ITOS series beginning in late 1978. TIROS N, the NASA prototype, will be launched in mid-1978; NOAA A, NOAA's first operational satellite of this series, is scheduled for launch in late 1978.

Installation of the TIROS N series ground equipment began at the NESS Satellite Operations Control Center in Suitland, Maryland, in September 1977. The major components of the ground system are the Data Acquisition and Control Subsystem (DACS) and the Data Processing and Services Subsystem (DPSS). The DACS equipment will be located at Wallops, Virginia; Gilmore Creek, Alaska; San Francisco, California; Suitland, Maryland; and Lannion, France. This system will acquire environmental and engineering data and facilitate complete operational control of the entire ground system and satellite. The data
processing equipment will be located at the NESS computer facility and be integrated with the acquisition system and a wideband communication network. The acquired data then will be preprocessed and conditioned for storage and products developed and distributed to the users. The data also will be retained for archive by the Environmental Data Service.

Geostationary Satellites. Geostationary Operational Environmental Satellite GOES 2 was launched June 16, 1977. On August 15, GOES 2 was positioned over the equator at 75° West longitude to replace GOES 1 as the eastern operational satellite. GOES 1 was placed on standby in an orbit centered at 105° West longitude. Synchronous Meteorological Satellite SMS 2 remained at 135° West longitude as the western operational satellite.

In February 1977, NESS increased to 72 the daily number of Weather Facsimile broadcasts from the two geostationary satellites. Each broadcast lasts 7 minutes and transmits both processed images from the polar-orbiting satellites and unprocessed sectors from the two geostationary satellites. Plain-language operational messages related to the schedules and planning activities are broadcast twice each day from the eastern satellite and once each day from the western satellite. These data are received and used by a growing number of Department of Defense and foreign meteorological agencies. In October 1977, a limited number of National Meteorological Center conventional weather charts were broadcast daily from the eastern satellite at times other than the normal weather facsimile broadcasts. These broadcasts and routine imaging operations were made simultaneously.

GOES 1 visible image at 2230 GMT, July 19, 1977, showing the thunderstorms that caused severe flooding at Johnstown, Pa. on July 19 and 20, 1977.
Satellite Data Uses

Determining Winds and Temperatures. During 1977, research continued on the automatic computation of winds from cloud motions observed by geostationary satellites. One study compared simultaneous wind vectors from identical clouds tracked by both GOES 1 and SMS 2. Results showed that the objective geographic registration of the infrared images was accurate within 8 kilometers. Median wind vector differences were 1.2 and 1.5 meters per second for computer-derived winds and for manually computed winds respectively.

In another study, an objective analysis procedure for editing low-level picture-pair winds derived from geostationary satellite images has been tested with satisfactory results. The object is to eliminate inaccurate data. This technique will reduce the amount of manual editing by 12 percent. Also, the temperature slicing technique used to calculate low-level cloud motions has been modified by increasing the array size used in the calculations. This reduces the amount of inaccurate data and presents a more coherent wind.

A technique is being developed to define the low-level wind field around a hurricane. The components are cloud motion wind vectors from high resolution visible images, the location of the hurricane center, and a hurricane intensity index. When applied to data from Hurricane Belle (August 1976), it produced results corresponding to an actual wind field.

Research was continued to determine why the subtropical jet stream acts as a southern boundary to severe weather. An examination of five case studies was made to see if cold air in the high troposphere north of the jet is a contributing factor to deep instability. Detailed 200-millibar temperature analyses showed a wedge of cold air between the subtropical and polar jet streams. Severe storms occurred where the 200-millibar cold tongue was superimposed over the surface warm tongue and in areas of weak calculated divergence at upper levels.

Work was continued to improve methods for extracting meteorological information from the High Resolution Infrared Sounder data from the Nimbus 6 experimental meteorological satellite. Processing of data was completed for the Global Atmospheric Research Program (GARP) Nimbus 6 Data Systems Test periods 5 and 6. These data will be used to provide specifications for the First GARP Global Experiment in 1978.

Research was conducted using Scanning Microwave Spectrometer data from Nimbus 6. Results showed that the data would be adequate as a lower resolution back-up system to TIROS N for deriving temperature soundings. These data also were used to estimate 700-millibar wind speeds in large typhoons and precipitable water amounts over tropical areas. The results showed fair agreement with conventional radiosonde measurements.

Monitoring Global Radiation. Time averaged global heat budget data from NOAA Scanning Radiometers continued to be archived and compiled in 1977 and were used in many studies. In one case, radiative heating data for the 1975 and 1976 Southeast Asia summer monsoons were studied. The 1975 monsoon had greater intensity than the one in 1976, and there were differences in radiative heating in Southern and Central Asia during the two spring and
summer seasons. Also, snow cover over Soviet Central Asia was greater in the spring of 1976 when the monsoon was weaker. Substantial changes in radiative heating, likely related to monsoon development, were observed over much of the central and eastern tropical Pacific. Earth Radiation Budget data from Nimbus 6 continued to be used for monitoring global incoming solar and outgoing terrestrial radiation and as a measure of the solar constant. These data will be valuable tools in conducting climate-related studies.

Knowledge of the Earth's radiation budget is an integral part of the Nation's total climate program. In 1977, NESS established a group of researchers to work with NASA on the development of an Earth Radiation Budget Satellite System (ERBSS). The object of the ERBSS is to acquire radiation budget data for understanding and predicting climatic change. The instrument designed to meet these objectives will measure reflected and emitted radiation over a broad range of spectral intervals. The ERBSS will derive radiation data from instruments to be carried on future NOAA TIROS N satellites and a NASA Applications Explorer Mission satellite.

Environmental Warning Services. Throughout 1977, the GOES Data Collection System (DCS) continued to grow in size and variety of uses. There are now 22 national and international users participating in this program which incorporates nearly 600 Data Collection Platforms (DCP). Some of the new applications included deployment of 25 magnetometer platforms for the International Magnetospheric Study Program, relaying hurricane data from a C-130 reconnaissance aircraft, and implementation of the first Aircraft-to-Satellite Data Acquisition and Relay platform on a commercial jet. Importance of the GOES DCS was realized in areas of the country where the National Weather Service (NWS) had DCPs located to detect flooding. NWS and NESS developed procedures to collect data hourly whenever a flood threat arises. These procedures were used several times in Pennsylvania, Colorado, Oregon, and Texas. Demonstrations of the GOES DCS also were presented to government officials in Santiago, Chile, and to participants in the World Meteorological Organization's regional association meeting in Mexico City, Mexico.

A major milestone in the development of the GOES DCS was reached when a second generation ground processing system became operational on June 15, 1977. The new ground system consists of computers located at the World Weather Building and the Wallops Command and Data Acquisition station, communication equipment between the computers, expanded channel capacity, real-time dissemination of collected data, and redundant equipment for emergencies.

The GOES-Tap system, inaugurated in 1975 to provide sector-by-sector weather images from GOES satellites, was expanded during 1977 to serve 20 Federal and 16 nonfederal users. The NWS also provided Tap service to users located near their Weather Service Forecast Offices (WSFO). During 1977, WSFO Tap service was increased to 72 subscribers. Lanica Airlines of Nicaragua became the first commercial airline to use the GOES-Tap. During 1977, Lanica, along with eight other Miami-based Latin American Airlines, used GOES-Tap images for aircraft routing over the Gulf of Mexico and the Caribbean. Sectorized images were provided every half hour by the Miami Satellite Field Services Station.

During the 1976–1977 winter, NWS forecasters received GOES enhanced infrared images that were used to display surface temperatures critical to frost
predictions. The forecasting technique was tested operationally in support of the Florida citrus industry. In the 1977-1978 winter season GOES infrared data will be displayed in digital rather than image form. Digital temperature data are expected to be more timely, accurate, and economical.

Using GOES infrared temperature data, NESS is developing a digital cloud-top height display to detect the position, movement, and growth of thunderstorms. This technique will be further refined using the NWS Automation of Field Operations and Services system. This will allow forecasters to monitor more objectively local thunderstorm development from satellite data. Also under development is a set of digital satellite products that show hurricane intensity, rainfall amounts, and solar insolation.

A quantitative method for analyzing tropical storm intensity uses GOES enhanced infrared images. The procedure involves contouring the coldest cloud tops to show certain temperature patterns that are related to the storm's wind speed, central pressure, and center location. This technique enables forecasters to estimate hurricane intensities at night when visible images are unavailable.

GOES enhanced infrared images are used to detect high concentrations of low-level moisture. When skies are clear in the early evening, moist air in the boundary layer will cause the land beneath it to appear darker than land under dryer air. This is because land under moist air cools at a slower rate. It is in these areas where fog is most likely to form later in the night. Thus areas with a high probability of fog formation can be predicted several hours in advance.

GOES 2 visible image of Hurricane Anita in the Gulf of Mexico on September 1, 1977. Maximum winds were 155 m.p.h.
During 1977, specially enhanced visible images were used to locate fog areas and forecast the time of fog dissipation. Early morning images were analyzed for brightness. Brightness is related to fog dissipation time.

Work continued on the detection of haze and air pollution from satellite images. Early morning and late afternoon visible pictures, taken when the sun angle is low, show these hazy, polluted areas particularly well. The haze often restricts visibility and can be a hazard to low-level aircraft operations. Thus satellite images aid in making short-range forecasts of restrictions to visibility.

Search and Rescue Support. In 1977 NESS continued to provide satellite data to support the U.S. Air Force and U.S. Coast Guard Search and Rescue operations. The California Wing of the Civil Air Patrol has been using satellite images for Search and Rescue missions since 1974. Satellite pictures show weather conditions at the time the pilots were in distress. Up to 40 percent reduction in mission flying hours has been achieved by using satellite data.

The Coast Guard used satellite data in its Search and Rescue missions to determine sea surface temperatures and ocean current boundaries. Sea surface temperatures are important to mission planning, especially in the winter when temperature differences between the Gulf Stream and adjacent shelf waters can be more than 17°C. This can mean a difference in life expectancy as affected by exposure, of several hours to several days and a radically different drift rate and direction.

Determining Ocean Conditions. SEASAT A is a NASA oceanographic satellite scheduled for launch in 1978. It is designed to provide all-weather global monitoring of oceanographic conditions using an array of microwave instruments and one visible-infrared instrument. NOAA will participate in a research and demonstration program using SEASAT A Data as they apply to NOAA requirements. Thirty-five experiments are planned in the open ocean and coastal zone on winds and waves, currents and circulation dynamics, surface temperatures, geodesy, and sea ice. Demonstration activities will involve meteorology, oceanography, geodesy, and living marine resources. In addition plans are underway to sponsor a few experiments by non-government organizations.

Ocean color research continues in support of the Coastal Zone Color Scanner to be carried on Nimbus G, scheduled for launch in 1978. The capability to acquire in situ optical measurements simultaneously with remotely sensed radiance data was demonstrated by experiments conducted in late 1975. A more extensive ship and aircraft field program was carried out in the Gulf of Mexico in October 1977, by scientists from NOAA, NASA, the Scripps Institution of Oceanography, and Texas A&M University. The objectives were to provide a prelaunch in-situ data base for development of chlorophyll and total suspended sediment models, to standardize measurement procedures for these parameters, and to test instruments for acquisition of spectral irradiance data.

The Scripps Institution of Oceanography, supported by NESS, completed development on the bio-optical state of the ocean which can be characterized by determining certain optical parameters as a function of wavelength. Then bio-optical state can be related to chlorophyll concentrations, which further can be linked to other important biological features of the ocean. Satellite
optical measurements, like those expected from the color scanner, can provide
otherwise virtually unobtainable information on the detection, growth, and
decay of plankton. Such information can provide a better understanding of
marine ecosystems.

Mean monthly sea surface temperature fields, derived from satellite infrared
measurements, were compiled for the past several years. These data were used
to construct annual-change and anomaly charts for possible use in long-range
weather forecasting and climate dynamics studies. One interesting feature was
a large cold-water anomaly that developed in the North Pacific in the autumn of
1976 and reached peak intensity in February 1977. A similar anomaly appeared
to be developing in the same general area in late summer 1977.

NESS is using GOES visible and infrared digital data to produce composite sea
surface-temperature gradient maps. By using GOES images at various times of
the day, a cloud-free composite of the sea surface-thermal structure is
displayed. During 1977, this daily composite was used to determine the
position of the Gulf Stream and the Gulf of Mexico Loop Current. The Satellite
Field Services Stations have provided this information to commercial and sports
fishermen, recreational boaters, and the merchant marine.

In March 1977, work began on preparing maps showing ice conditions in the
Labrador Sea and Davis Strait. These maps, derived from NOAA 5 and GOES 1
satellite images, were disseminated three times a week to the Coast Guard as
an aid to navigation. Also, the Coast Guard was briefed on cloud conditions
over its International Ice Patrol area, based on satellite images. This
information saves aircraft time and reduces operating costs. NESS also
continued to prepare and distribute ice maps of Alaskan Coastal waters for
shipping interests for the fifth consecutive year.

High-resolution images from Landsat 1 and 2 were used by NOAA's Pacific
Marine Environmental Laboratory to compile an atlas of underwater internal
waves off the North American east coast, the first large-scale view of this
phenomenon. The data were used to prepare two oceanographic investigations of
internal waves.

Scientists from NOAA's Outer Continental Shelf Environmental Assessment Program
used sea surface temperature data from NOAA satellites in conjunction with
hydrographic data to map surface currents in the Gulf of Alaska. This program
supports the University of Alaska in acquiring and cataloging remote sensing
data from satellites and aircraft and distributing these data to scientists
involved in Alaskan studies.

NOAA's Wave Propagation Laboratory developed a method of using satellite radar
altimeter data to determine sea state. This method has been applied to a
limited amount of GEOS 3 altimeter data, producing estimates of significant
wave height to 0.6 meters accuracy over 70 kilometer-square areas.

Determining Lake Conditions. Analysis of satellite infrared data over the
Great Lakes during November 1976 showed the lake surface temperatures to be an
average of 5°C cooler than on the same date in 1975. These low temperatures
preceded one of the heaviest ice years on record. On February 7, 1977, NOAA 5
satellite data showed Lake Michigan was completely frozen over for the first
time in twenty years.
NOAA's Great Lakes Environmental Research Laboratory and NESS used satellite multispectral images to map reflectance patterns from calcium carbonate precipitation in the Great Lakes. This milky-water phenomenon, called a whiting, was examined over a 4-year period. Results showed that whitings occur regularly during the summer and fall in Lakes Ontario, Erie, and Michigan.

Determining Hydrological Conditions. NESS continued to produce satellite maps of snowcover in about two dozen United States and Canadian river basins. Nearly 500 snowcover maps were compiled between November 1976 and June 1977. Users were the National Weather Service, U.S. Geological Survey, Corps of Engineers, Soil Conservation Service, and Bureau of Reclamation. These maps were used to help assess the extent of the 1977 drought in the western United States. Snowpacks in the high elevations of Wyoming, Colorado, Idaho, California, and Oregon, were found to be the lowest or near the lowest on record. Using NOAA 5 VHRR images, mid-April areal snowcover for California's Sierra Nevada Mountain Range was determined to be only one third of what it had been on the same date in 1975. Satellite derived snow and ice cover maps were transmitted daily to NWS hydrologists in the middle Atlantic and northeastern states. This information was used to prepare river and flood forecasts. Regional hydrologists found the information to be especially useful because this section of the country experienced one of the most severe winters in history.

A technique for estimating hourly rainfall from convective clouds using enhanced infrared and high resolution visible satellite images was field tested in 1977. Field tests were conducted by hydrologists at the Weather Service Offices at Phoenix, Arizona, and Lubbock, Texas; the Kansas City, Missouri, Satellite Field Services Station; and the Division of Hydrology in Caracas, Venezuela. Preliminary results show successful identification of areas of no significant rainfall and reasonable estimates of total rainfall in heavy precipitation areas. This technique will aid in monitoring areas of convective rainfall for agricultural uses and flash flood warnings. It is especially useful for areas where no reporting stations are present, or where surface reports are delayed by poor communications.

Also, GOES visible and infrared images were used to develop a digital enhancement technique for estimating rainfall rates and potential rainfall for tropical storms. The National Hurricane and Experimental Laboratory used this technique to prepare rainfall estimates for the National Hurricane Center's warning services. The NWS River Forecast Center at San Antonio, Texas, used this information to monitor heavy rainfall continuously as Hurricane Anita crossed the Texas-Mexico coast in September 1977.

The NWS collected rainfall data from 61 unmanned sites in its Automatic Hydrologic Observing System. These data were transmitted to River Forecast Centers via the GOES Data Collection System and were used in the river and flood forecasting program.

NESS completed a series of satellite-derived snowcover maps and graphs of North America and Eurasia for the period November 1966 to September 1977. The maps showed the monthly variation of snowcover, and the graphs showed the monthly, seasonal, and annual variation of snowcover on each continent.
NOAA 3 VHRR visible image of snow pack in the Sierra Nevada mountains April 28, 1975.

NOAA 5 VHRR visible image shows the absence of snow in the Sierra Nevada mountains on April 19, 1977.
NOAA 5 VHRR infrared image on May 1, 1977 showing water-mass structure along east coast of U.S.
A 12-month running mean of monthly values showed no significant fluctuations or trends for North America, but two large increases in snowcover were observed for Eurasia. One of these occurred in the 1971-1972 winter and the other in the 1976-1977 winter.

A study was made of near-infrared reflectance from snow using Skylab multispectral scanner data. Results showed that reflectance over uniform snowpack is significantly lower in the near-infrared than in the visible red part of the spectrum, and that the near-infrared can be used to distinguish objectively between snow and clouds. More data are needed to clearly distinguish between snow reflectance measurements made in the laboratory and those obtained from spacecraft and aircraft.

Monitoring Agricultural Conditions. In cooperation with the Great Plains Agricultural Council and the U.S. Department of Agriculture, NESS joined in an effort to develop a technique for estimating solar insolation over the Great Plains using GOES digital data. The parameters measured were surface brightness, cloud brightness, cloud cover, precipitable water, and surface pressure. The first three parameters were determined from satellite data and the last two from surface measurements. These data are presently being correlated with surface truth pyranometer data provided by the Great Plains Council. Eventually, the insolation data may be incorporated into yield models for sorghum and wheat crops.

Fisheries Monitoring. During 1977, NESS continued to produce charts showing ocean thermal fronts, observed from high-resolution satellite data, along the California coast. The Ocean Services Unit at Seattle began issuing similar information for the offshore waters of Oregon and Washington. It is known that nutrients and plankton important to the food chain for fish are concentrated along these fronts as a result of seasonal upwelling. For the past three years, these charts have been used by West Coast tuna and salmon fishermen to locate productive fishing areas. In spite of increasing fuel costs and more stringent fishing regulations, the commercial fishermen have improved their efficiency and reduced overfishing of small areas. In 1977, this service was expanded to the northwest Atlantic and Gulf of Mexico. The swordfish industry is being provided weekly Gulf Stream analyses, and some fishing companies are purchasing satellite images for direct use in their fishing operations.

The National Marine Fisheries Service, in cooperation with other Federal and private agencies, initiated research to use satellites for tracking porpoise migration in the eastern tropical Pacific. A preliminary study was conducted by fitting trained porpoises with small transmitters capable of operating a year and relaying position data via the Nimbus 6 Remote Access Management System. Data can be received for up to 200 platforms within the satellite's view and from 1000 platforms per orbit.

The Fisheries Service also participated in SEASAT A prelaunch studies conducted off the coast of California during the spring of 1977 to determine if a scatterometer system would provide accurate measurements of wind stress for use in estimating water movement. Test results will be available early in 1978. The objective is to evaluate the potential of space-borne scatterometer measurements for improved yield predictions for certain estuarine-dependent fish. The survival of these species is dependent on the egg and
larval stages being transported by surface water currents to estuarine nursery grounds.

The National Fisheries Engineering Laboratory, in cooperation with NASA and the Coast Guard, investigated the use of space-borne Synthetic Aperture Radar systems for fishery management and fishing vessel surveillance. Preliminary results were published this year describing tests of vessel surveillance conducted over concentrations of foreign vessels in the Bering Sea. Detection of a broad range of fishing vessels seems certain, but questions remain concerning additional information such as vessel speed, direction, activity, and size.

Other Uses of Satellites and Space

International Cooperation. More than 120 countries receive low-resolution Automatic Picture Transmission (APT) images, and a dozen countries also receive high-resolution images from NOAA polar-orbiting satellites. Another 20 high-resolution stations are planned, including one at McMurdo Sound, Antarctica. Ten countries in the Caribbean and in Central and South America also receive Weather Facsimile (WEFAX) images from geostationary satellites, and new stations soon will be operating in Western Europe, Africa, and some Pacific Ocean sites.

The National Weather Service, under the Voluntary Assistance Program for the World Meteorological Organization, established combination APT/WEFAX stations with improved satellite video capability in Costa Rica, Honduras, and Guatemala in November and December 1977. These stations can receive data from polar orbiting and geostationary satellites and will be the prototypes for eventual replacement of older APT equipment. The capability of the satellite to relay environmental data to ground stations within the satellite's transmission range has improved the observation and prediction efforts of many nations.

These data recently have been used by the U.N. Food and Agricultural Organization to suppress locust emergence and migration in northern Africa. They have been used to support exploratory oil drilling activities in the North Sea and Canadian Archipelago; to estimate snowfall in Norway for hydro-electric power generation; and to improve flight forecasting, flood control efforts, marine transportation, and research in weather modification in many countries. Much international good will has derived from cooperation and coordination among nations using this form of space technology.

The United States and the Soviet Union continued to exchange satellite cloud pictures during 1977. During the year the Soviets launched a new series of satellite called Meteor 2. The visible and infrared radiometers on this satellite appear to have environmental monitoring capability close to our ITOS series. Photographs received from the satellite have a resolution of about 2 kilometers. In addition the United States received data from Meteors 24 through 28 and sent data from NOAA 4 and 5 to Russia.

During 1977, the Department of State, Agency for International Development (AID), was provided with cloudcover data over the sub-Sahara part of Africa and the
Caribbean area for use in determining the probability of precipitation. As part of the tropical storm surveillance program, high winds and potential flooding in tropical areas of the world also were monitored.

**Weather Modification.** NOAA's National Hurricane and Experimental Meteorology Laboratory used satellite data for its research into the development and modification of convective cloud systems. Studies were initiated to apply rainfall estimates from satellite images to the analysis of cumulus modification experiments over an extended area. Satellite data promise to be important for diagnosing larger-scale effects of weather modification.

The Laboratory also used satellite data in hurricane research. Data collected with satellites, aircraft, and radar from Hurricane Anita (September 1977) are being analyzed to determine if systematic oscillations of cloud growth occur, if satellites can track cloud elements at speeds corresponding to observed wind speeds, and if characteristic cloud developments occur that can be related to present storm strength and potential for future development.

**Determination of the Earth's Shape and Gravity Field.** NOAA's National Ocean Survey and the Joint Institute for Laboratory Astrophysics made computer simulations of observations on the Lageos satellite by laser stations and determined geodetic station positions on the Earth with mean errors less than 5 centimeters. This method was limited in obtaining the desired accuracy because of limited knowledge of the Earth's gravitational field. Improved Doppler data and more refined data processing have reduced positional errors to less than 50 centimeters for 40 stations and 10 to 25 centimeters for differenced positions. Comparison with the external standards of Very Long Baseline Interferometry position determinations and the High Precision Transcontinental Traverse yielded comparable accuracies. A high-quality aerial camera is being developed and tested to provide higher density geodetic control more quickly and economically.

The altimeter data base set up for the GEOS 3 satellite now contains more than 1500 passes. These data have been enhanced through improved analysis techniques and have produced more accurate solutions for the Earth's gravitational field. The Ocean Survey continued to work with NASA in setting up methods and programs for using altimeter data from SEASAT A for geodetic purposes.

Analysis of GEOS 3 and Navy navigational satellite data for determination of ocean tidal amplitudes has confirmed that standard published ocean tide models are in error by a factor of one-third. As a result, a value for the acceleration of the Moon has been determined. This supports recent analysis of long-term astronomical observations.

On January 10, 1977, the Survey, the Defense Mapping Agency, and the Groupe de Recherches de Geodesie, France, started making Doppler observations at the Ukiah California Latitude Observatory, to support the French experiment to determine polar motion by Doppler tracking of artificial satellites. The Survey started a new project, Polar Motion Analysis by Radio Interferometric Surveying (POLARIS), to monitor polar motion and Earth rotation with improved spatial and temporal resolution using radio interferometry techniques. The POLARIS data will have wide application in deep-space navigation, celestial mechanics, relativity, and Earth evolution studies.
Space Support Activities

Weather Support. During 1977, the National Weather Service provided meteorological support to the Space Shuttle, Landsat, Voyager, SEASAT, and the Rocketsonde and Atmospheric Ozone Measurement Programs. For the Space Shuttle, support was principally background and planning studies of atmospheric conditions at launch and landing sites. Landsat support required forecasts of cloud-free areas under the orbital path of the satellites. For the Voyager mission, forecasts were used to develop programs to maximize return signals from the spacecraft. SEASAT support consisted of obtaining surface truth data for evaluation of the radar altimeter on GEOS 3. Meteorological support was provided to the Wallops Flight Center for its rocketsonde and atmospheric ozone projects.

Solar Activity. The NOAA Space Environment Services Center, operated jointly by NOAA and the U.S. Air Force, is the National and World Warning Agency for disturbances on the Sun, in space, in the upper atmosphere, and in the Earth's magnetic field. Alerts and measurements of these disturbances are provided to scientists in space physics and geophysics for planning scientific studies and experiments. The largest of these, the International Magnetospheric Study (IMS), is an international cooperative scientific program (1976-1979) designed to provide a better understanding of the dynamics of the Earth's external magnetic field. The Center supported the IMS with data collection and dissemination, and predictions, that were used to schedule satellite operations, rocket launches, and ground-based experiments. Similar information was provided to both military and civilian communication satellites and military reconnaissance systems. The primary data systems used were the Space Environment Monitor and

GOES 1 full disc visible image on February 24, 1977 showing dust clouds over the southeastern U.S.
Solar Proton Monitor on the GOES and ITOS satellites, the Global Solar Flare
Patrol operated by NOAA and the Air Force, and data collected from the
International Ursigram and World Days Service.

The Environmental Data Service operates the World Data Center-A for Solar-
Terrestrial Physics. Last year World Data Center-A established a temporary
IMS Central Information Exchange Office. This office is responsible for
informing satellite, rocket, balloon, and ground-based experimenters about
accomplishments, programs in progress, and future program plans for the duration
of IMS. Opportunities for program coordination are stressed and have resulted
in satellite experiment reconfigurations, rocket launch schedule changes, and
repositioning of experiments from the surface to satellite altitudes. Prompt
notification of special data collection opportunities based on multiple satellite
configurations has been provided weekly to scientists. An address list of
participating scientists was prepared and distributed to 2000 persons to
facilitate direct contact between scientists. Monthly IMS newsletters carry
the bulk of program information, maps, and news of preliminary scientific
results.

Space and Atmospheric Research

Interplanetary Physics. The NOAA Space Environmental Laboratory made dynamic,
multidimensional computer simulations of solar flares using Skylab observations
as a guide. This work, performed in collaboration with the University of
Alabama in Huntsville, enables simulation of disturbances that travel from the
Sun to the Earth.

Several models of the chemical composition (protons, electrons, and ionized
helium) of the steady solar wind have been studied. One model considers
nonradial flow near the Sun while another considers radial flow from the Sun
to any point in space. Recent work has suggested that the period from
1645-1715, when there was visible absence of solar activity, showed a steady,
magnetically featureless, low velocity, solar wind flow around the Earth's
magnetosphere.

Ionospheric Physics. Space Environment Laboratory scientists used solar x-ray
measurements from the GOES satellites to detect solar flares. Research was
started to detect these explosions on the Sun before their x-ray and extreme
ultraviolet flux intensity increased enough to significantly affect the
ionosphere. One use of early flare-detection systems will be high time-
resolution measurements to determine the ionospheric effects of solar flares.

Magnetospheric Physics. Analysis of energetic ion data in the interplanetary
medium outside the Earth's magnetosphere shows these particles have originated
from the magnetosphere. The Earth thus joins the Sun and Jupiter as a source,
within the solar system, of the energetic particles and low-energy cosmic rays
found in the interplanetary medium. Scientists have concluded that the extra-
terrestrial ring current is not composed of solar wind protons, but of heavier
ions of helium or oxygen. The theory, proposed last year, that the ionosphere
rather than the solar wind is the major source of energetic radiation-belt
ions, has been confirmed by observations that show ions of ionospheric origin
jetting upward toward the outer magnetosphere where they are trapped and
produce the ring current. Evidence is mounting that the process which energizes ionospheric ions and injects them into the magnetosphere is the same process which jets electrons from the magnetosphere into the atmosphere to produce auroral displays. An auroral theory has been developed that the ionosphere's demand for electrical current from the magnetosphere leads to the creation of electric potential difference along the geomagnetic field line. The existence of such a potential difference would lead directly to the acceleration of electrons downward to produce the aurora and ions upward to produce the ring current.

Data from GOES magnetometers were used to begin development of techniques to predict geomagnetic disturbances called substorms. This effort will help the Space Environment Services Center to predict disturbed communication conditions and predict conditions which lead to electrical malfunctions onboard communication satellites.

Stratospheric Physics. The NOAA Aeronomy Laboratory has obtained comprehensive measurements of nitrogen dioxide distribution in the stratosphere using ground and airborne spectroscopic techniques. Global measurements of stratospheric concentrations of fluorocarbons F 11 and F 12 and nitrous oxide also have been obtained using balloon-grab sampling methods. The nitrous oxide measurements yielded improved vertical transport coefficients that will allow better predictions of stratospheric ozone loss from manmade causes. Laboratory reaction rate measurements have substantially lowered the predicted stratospheric ozone destruction by supersonic aircraft and substantially raised the predicted stratospheric ozone destruction by chlorofluorocarbon release.

Data Programs

Oil Storage. The Environmental Data Service's Center for Experiment Design and Data Analysis uses the GOES Data Collection System to obtain hourly observations of ocean circulation patterns from a prototype Salt Dome Environmental Monitoring System in the Gulf of Mexico. Under the Strategic Petroleum Program, salt domes or caverns are used for oil storage. The enlargement of these caverns by leaching presents a problem of brine disposal in the coastal waters. The monitoring of potential salt brine disposal areas provides the data needed to characterize and predict brine disposal patterns.

World Food Assessments. The Large Area Crop Inventory Experiment (LACIE), a cooperative effort of NOAA, NASA, and the Department of Agriculture, has demonstrated technology to monitor global weather patterns, identify current anomalous weather situations, and make quantified estimates of the weather's influence on potential crop yields. Statistical climate crop yield models developed by the Center for Climatic and Environmental Assessment support this experiment. LACIE also is provided periodic assessments of the effects of weather and climate on crop production over the major agricultural regions of the world. These assessments utilize environmental satellite data to supplement information available from the limited network of ground based weather stations. Research leading to operational precipitation estimates from satellite data was initiated with NESS in August 1977, to enhance the global assessment capability.
Aeronautical Programs

Aeronautical Charts. The National Ocean Survey, in response to a request from the Federal Aviation Administration (FAA), will certify obstacle and terrain data for 72 air terminal sites in the United States. This is in support of FAA's Minimum Safe Altitude Warning system, which alerts air traffic controllers when an aircraft descends below a safe flight altitude within a 120-kilometer radius of an air terminal facility. Fifteen major sites were analyzed in 1977.

The FAA and the Ocean Survey also have developed product requirements and specifications for an Airport Facility Directory for the coterminous United States. It will be comprised of 7 volumes to be phased in over a period of 6 months beginning in late 1977. The Directory will be made available through subscription and will be updated every 8 weeks.

As air traffic and the complexity of regulations and control procedures increase, more specialized aeronautical charts are needed more quickly. To keep pace with this demand, the Ocean Survey organized an Aeronautical Chart Automation Project. The automated approach to aeronautical chart production was demonstrated this year when Radar Video Maps, generated by this system, were rated by the FAA as superior to those produced manually. This project is expected to make more efficient use of personnel and increase responsiveness to chart preparation deadlines.

Safety Services. The NOAA Atmospheric Physics and Chemistry Laboratory continued to conduct tests of a prototype clear-air turbulence detector and alarm system using NASA's C-141A, Learjet, and Convair 990 aircraft. The infrared radiometer detects anomalies in the water vapor ahead of the aircraft and gives 2 to 5 minutes advance warning of clear-air turbulence.

The NOAA National Severe Storm Laboratory used aircraft, conventional and dual-Doppler radars, a 444-meter weather-instrumented tower, and a mesonetwork of surface stations to investigate the Doppler radar's potential to locate and depict thunderstorm turbulence by measuring wind variations. Doppler radar capabilities in optically clear air were studied for depiction of wind shear associated with thunderstorm gust fronts which endanger aircraft during airport landings and takeoffs.

Pollution Monitoring. The Ocean Survey's Ocean Dumping Program Office conducted an experiment in the Gulf of Mexico during July and August 1977, to characterize the physical and chemical oceanographic conditions at an industrial waste disposal site. NASA aircraft acquired multispectral scanner and aerial photographic data over an organic sludge so as to track the distribution of waste. A similar experiment followed in December 1977, at a Deepwater Dumpsite in the Atlantic Ocean.
<table>
<thead>
<tr>
<th>Satellite</th>
<th>Purpose</th>
<th>Launch</th>
<th>Average Altitude (KM)</th>
<th>Ceased Operation</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>TIROS 1</td>
<td>R</td>
<td>04/01/60</td>
<td>720</td>
<td>06/15/60</td>
<td>First weather satellite providing cloud cover photography.</td>
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<tr>
<td>TIROS 2</td>
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<td>08/28/64</td>
<td>S/677</td>
<td>09/23/64</td>
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<tr>
<td>TIROS 9</td>
<td>R</td>
<td>01/22/65</td>
<td>S/1630</td>
<td>02/15/67</td>
<td>First TIROS satellite in sun-synchronous orbit.</td>
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<td>TIROS 10</td>
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<td>07/01/65</td>
<td>S/792</td>
<td>07/31/66</td>
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<tr>
<td>ESSA 1</td>
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<td>02/03/66</td>
<td>S/765</td>
<td>05/08/67</td>
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<tr>
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<td>R</td>
<td>05/15/66</td>
<td>S/1136</td>
<td>11/15/66</td>
<td>Carried first AVCS cameras. AVCS carried on all odd-numbered ESSA satellites.</td>
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<tr>
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<td>10/02/66</td>
<td>S/1427</td>
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<td>12/06/66</td>
<td>S/35,765</td>
<td>10/16/72</td>
<td>150°W WEFAX operations continue.</td>
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<td>Unstable altitude data not useful.</td>
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<tr>
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<td>G/35,815</td>
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<td>Provided first vertical temperature profile data of the atmosphere on a global basis.</td>
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<td>S/1100</td>
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<td>Launch</td>
<td>Average Altitude (KM)</td>
<td>Ceased Operation</td>
<td>Remarks</td>
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<tr>
<td>ITOS 1</td>
<td>R/O</td>
<td>01/23/70</td>
<td>S/1456</td>
<td>06/17/71</td>
<td>Second generation prototype.</td>
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<td>Nimbus 4</td>
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<td>04/08/70</td>
<td>S/1108</td>
<td>10/17/77</td>
<td>Still providing data.</td>
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<tr>
<td>NOAA 1</td>
<td>0</td>
<td>12/11/70</td>
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<td>08/19/71</td>
<td>First NOAA funded second generation satellite.</td>
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<td>ITOS B</td>
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<td>-</td>
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<tr>
<td>Landsat 1</td>
<td>R</td>
<td>07/23/72</td>
<td>S/918</td>
<td>01/16/78</td>
<td>First operational satellite to carry all scanning radiometers.</td>
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<tr>
<td>NOAA 2</td>
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<td>10/15/72</td>
<td>S/1460</td>
<td>01/30/75</td>
<td>First operational satellite to carry all scanning radiometers.</td>
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<td>ITOS E</td>
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<td>07/16/73</td>
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<td>-</td>
<td>Failed to orbit.</td>
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<td>NOAA 3</td>
<td>0</td>
<td>11/06/73</td>
<td>S/1510</td>
<td>08/31/76</td>
<td>First operational satellite to permit direct broadcast of VTPR data.</td>
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<tr>
<td>SMS 1</td>
<td>R/O</td>
<td>05/17/74</td>
<td>G/35,788</td>
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<td>First NASA prototype; 105°W on standby.</td>
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<td>S/1460</td>
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<td>01/22/75</td>
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<td>02/06/75</td>
<td>G/35,780</td>
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<td>First NOAA operational geostationary satellite; 105°W on standby.</td>
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<td>06/12/75</td>
<td>S/1110</td>
<td>-</td>
<td>Second NOAA operational geostationary satellite; 75°W.</td>
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</table>

1 R - Research, 0 - Operations, R/O - Operational Prototype
2 S - Syn-synchronous, G - Geosynchronous