DEPARTMENT OF COMMERCE ★ UNITED STATES OF AMERICA ★

Satellite Activities of NOAA 1981

Compiled by:
NATIONAL EARTH SATELLITE SERVICE

Washington, D.C.
May 1982

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Earth Satellite Service

National Oceanic and Atmospheric Administration
TIROS Satellites and Satellite Meteorology

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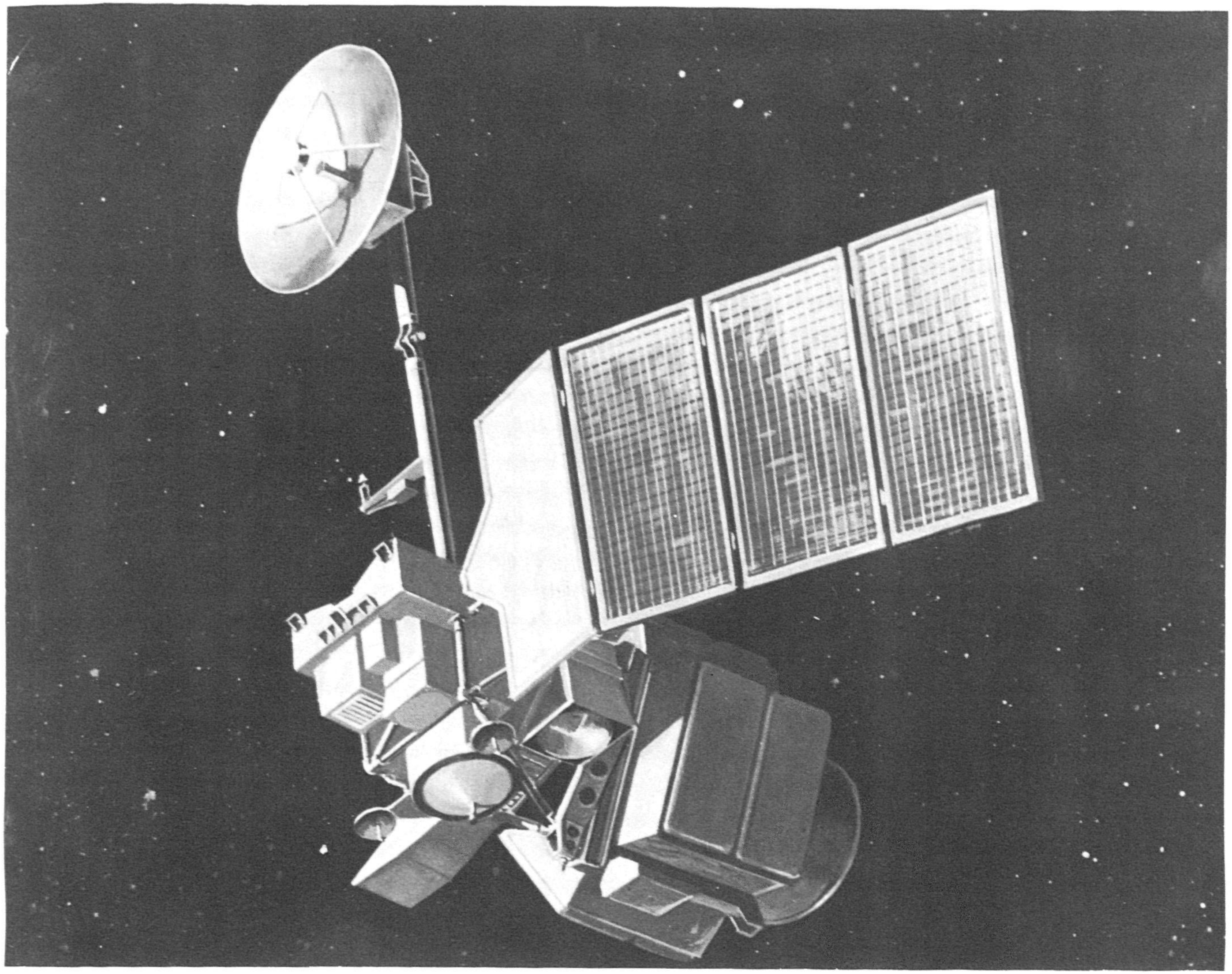
U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
John V. Byrne, Administrator

National Earth Satellite Service
John H. McElroy, Assistant Administrator



Landsat D Satellite

Satellite Activities of NOAA, 1981

National Oceanic and Atmospheric Administration

Introduction

The National Oceanic and Atmospheric Administration (NOAA) was established within the United States Department of Commerce in 1970. NOAA's long-range goal is to improve the safety and quality of life through better understanding of the earth's environment and more efficient use of its resources. NOAA manages and operates the nation's civil, operational, environmental satellite systems. It provides satellite data to assess the effect of natural and human factors on global food and fuel supplies and on environmental quality. It uses satellite and aerial data to observe and forecast weather conditions, issue warnings of severe weather and floods, and assist communities in preparing for weather-related disasters; to prepare charts and coastal maps and for geodetic research; and to assess and conserve marine life. NOAA archives and disseminates satellite data to meet the needs of public and private users and incorporates it into research programs to improve the nation's environmental services. NOAA activities that participate directly in aeronautics and space programs are: The National Earth Satellite Service, the National Weather Service, the Environmental Data and Information Service, the National Ocean Survey, the Office of Ocean Engineering, the National Marine Fisheries Service, and the Environmental Research Laboratories.

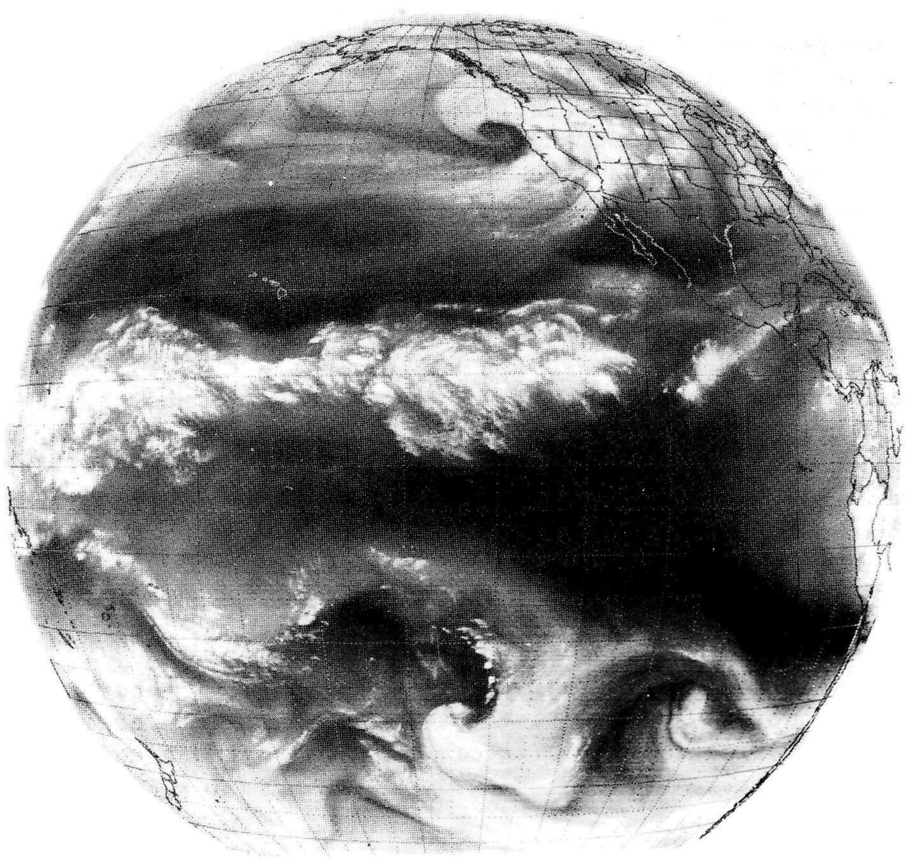
Space Systems

Polar-Orbiting Satellites. At the beginning of 1981, TIROS-N and NOAA 6 were the active polar-orbiting satellites operated by the National Earth Satellite Service (NESS). After failure of the power supply on TIROS-N on February 27, 1981, NESS operated a one-polar-satellite system until NOAA 7, launched June 23, 1981 , became operational on August 24. NOAA 6 and 7, in sun-synchronous orbits, provided environmental observations of the entire earth four times each day. NOAA 6 crosses the equator southward at 0730 local time, and NOAA 7 crosses the equator northward at 1430 local time.

These satellites carry four primary instruments: the Advanced Very-High-Resolution Radiometer, the TIROS Operational Vertical Sounder, the Argos Data-Collection and Platform-Location system, and the Space Environment Monitor.

Geostationary Satellites. At the end of 1981, GOES 4 and 5 were the operational satellites in NOAA's Geostationary Operational Environmental Satellite (GOES) system, the successor to NASA's prototype Synchronous Meteorological Satellites (SMS). GOES 4, launched September 9, 1980, replaced GOES 3 as the western operational satellite on March 5, 1981, because of deterioration of the GOES 3 Visible-Infrared Spin-Scan Radiometer (VISSR). GOES 5 was launched May 22, 1981, and replaced SMS 2 as the eastern satellite August 5, when the SMS 2 VISSR failed. Of three satellites on standby--SMS 1, GOES 1, and GOES 2, providing limited operational weather support for weather facsimile and data collection--SMS 1 was deactivated January 29, 1981, after nearly seven years' service. For the first time, a U.S. geostationary satellite was boosted up and out of orbit to alleviate cluttering at the geostationary altitude.

In orbit at 35,000 kilometers, GOES 4 and 5 are equipped with the VISSR Atmospheric Sounder (VAS). In addition to the traditional images of the earth's surface and cloud cover, the VAS records atmospheric temperatures and water vapor content at various altitudes. It has a multispectral imaging capability with 12 infrared channels and can derive temperature and moisture data over selected areas. First results of the VAS demonstration program showed promise, and planning was begun for a ground system to use the full VAS capability to improve operational forecasting. GOES satellites also carry a Space Environment Monitor, a Data-Collection System, and Weather Facsimile broadcast service.



GOES 4 moisture-channel image showing an intense storm along the west coast of U.S. on November 14, 1981.

Land Satellites. NOAA, authorized to manage an operational land satellite system based on the Landsat-D and D' satellites being constructed by NASA, expects to assume operational responsibility for the first of these satellites early in 1983, after NASA has launched and tested Landsat-D. NOAA will operate the two satellites and supporting services for data users until the private sector can take over the land-remote-sensing program. During 1981, NOAA worked with federal agencies and the user community to ensure smooth management of the system and to determine the appropriate institutional framework for private sector takeover.

The Program Board on Civil Operational Land Remote Sensing from Space, established by the Secretary of Commerce with members from 11 federal agencies and departments, coordinates federal matters related to the operational system. For interested nonfederal groups, the Secretary established the Land Remote Sensing Satellite Advisory Committee. Its 15 members will begin regular meetings in 1982, advising on system management and private sector activities.

NOAA conducted five general conferences in 1981 to inform nonfederal interests of plans and to seek advice about system management and future commercialization. It held three other meetings, specifically directed to commercialization questions. NOAA used information from these meetings and others in Africa, Asia, and South America to refine management preparations, to develop recommendations for administration proposals for legislation, and to facilitate planning for the future transfer.

Satellite Data Services

Data Distribution. Images from the European weather satellite METEOSAT 2 were first received by NOAA September 16, 1981, and became an operational product available to GOES-Tap users during October. These visible, thermal-infrared, and atmospheric water-vapor data provide excellent weather information for aviation and shipping in the eastern Atlantic, Europe, Africa, western Asia, and western Indian Ocean. Received at NASA's Goddard Space Flight Center, the data are relayed directly to NOAA for nationwide distribution.

The GOES-Tap system, which became operational in 1975 to desseminate weather satellite images by geographic sectors over standard telephone circuits, continued to expand. NESS began hardware modifications to permit more than 400 direct GOES-Tap connections through the Satellite Field Services Stations. The original 50 Weather Service Forecast Office-Taps increased by the end of 1981 to some 200 taps for a multitude of users, including the National Weather Service, military facilities, private meteorological firms, TV stations, and universities. Secondary taps off these 200 totaled more than 400.

During 1981, NESS eliminated its last "wet" photographic laboratory, at the Honolulu station. NESS now uses dry-paper, image-processing devices for satellite image display at all field locations. To reduce operating costs further and increase services, installation of an Electronic Animation System (EAS) at each field station was begun in 1981; devices were installed in Washington, Miami, and Honolulu during the year. The EAS will provide cloud animation previously provided by movie loops. The microprocessor-controlled, video disc system uses a TV camera to store satellite images sequentially on the disc. Images are played back electronically to display animated cloud motion. Versatility of the EAS permits simultaneous display of two independent "loops" on TV monitors, and meteorologists can control each loop separately for detailed analysis. The first phase of the improvement program--photo lab elimination and animation upgrading--neared completion. Engineering for the second phase, digital transmission of data, began in late 1981. Stations now transmit and receive satellite image data in an analog (facsimile) format. Computer processing and inherent hardware limitations slightly delay the transmission of facsimile images, and they cannot be used for precise quantitative analysis. Digital transmission will provide more timely and quantitative information. A microcomputer system will be developed to transmit digital infrared data in near real-time on the existing communication system, and a similar microcomputer system at field stations will permit more detailed analyses of regional weather and ocean systems.

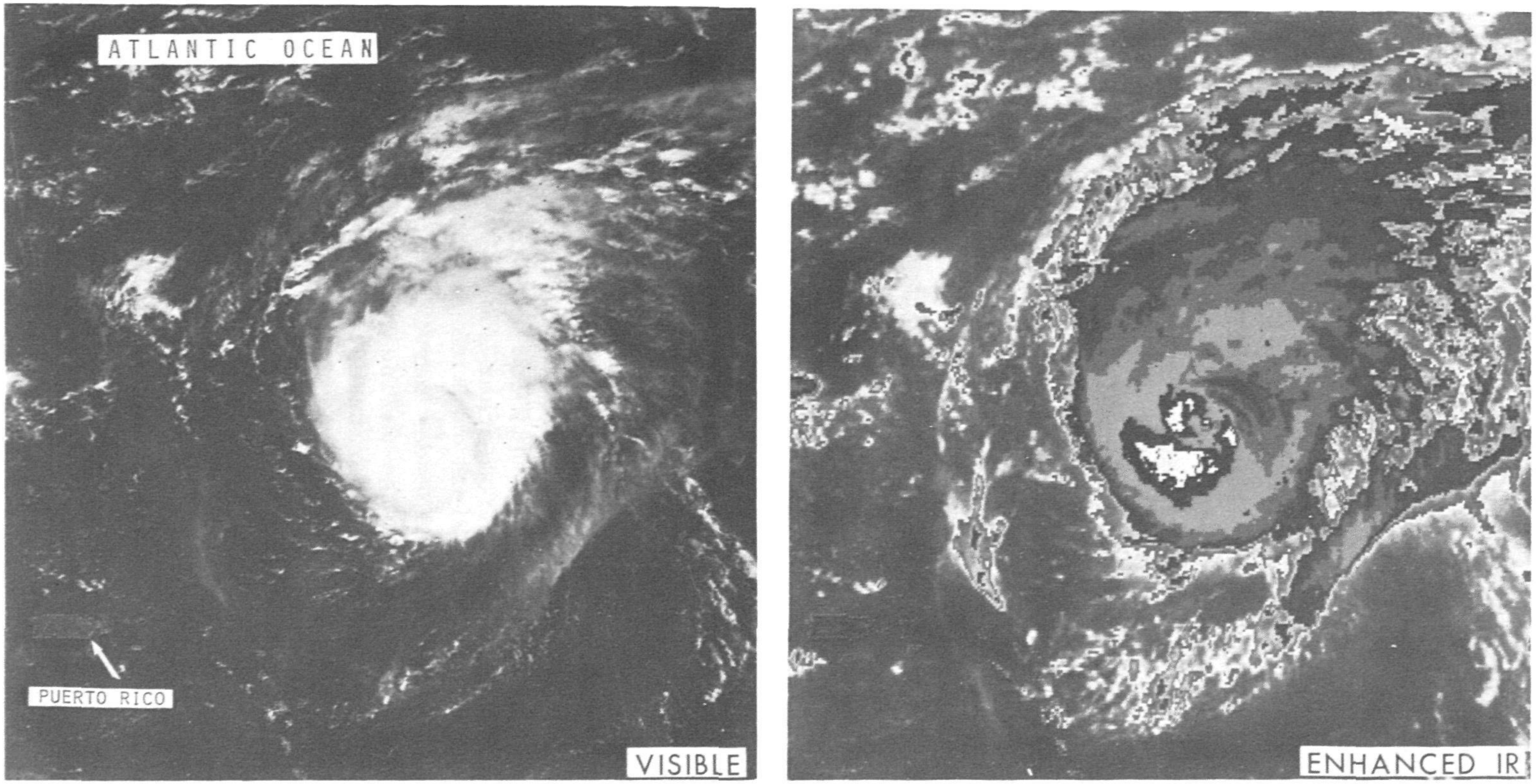
GOES Weather Facsimile (WEFAX) broadcst schedules were expanded on both the central and the west GOES satellites, so that 198 satellite sectors and 66 weather charts can be broadcast each day. Some 150 national and international WEFAX users include more than 40 U.S. Government stations. During April 1981, the first WEFAX Users Conference was held in Washington, D.C. with 130 attendees including representatives from several foreign meteorological agencies, academia, industry, and amateur radio enthusiasts.

The GOES Data Collection System (DCS) at the end of 1981 had more than 2500 data-collection platforms (a 100 percent increase in the past year) operated by 58 national and international users. There were 13 operational direct-readout stations with 2 more expected to become operational in 1982. A revised DCS Users Interface Manual reflected major changes put into effect with the automatic monitoring system that keeps watch on the quality of radio performance of the DCS platforms. Also, a major reply-channel realignment will ensure a three-kilohertz separation between channels on the same spacecraft, reducing chances of interference and allocating segments of the frequency band for specific operations, such as random reporting and interrogation. Improvements in data distribution from the NESS DCS Center at Camp Springs also included addition of a rotary direct-dial-in system.

On August 24, 1981, NOAA opened its seventh Satellite Field Services Station--at Slidell, Louisiana--and began 24-hour satellite observation of the Gulf Coast and the Gulf of Mexico weather and ocean conditions. The new station, collocated with the National Weather Service Forecast Office, will assist NWS in expanding forecasting and warning services for coastal and offshore areas from Mexico to Florida. Special attention will be paid to conditions affecting small craft and helicopter traffic supporting offshore oil platforms.

The Environmental Data and Information Service (EDIS) completed a functional design for an electronic catalog service. Implementation of the

HURRICANE IRENE



GOES 5 visible image (left) and enhanced infrared image (right) of Hurricane Irene on September 21, 1981.

basic system was planned for late 1982, to provide elements of the U.S. Climate Program a comprehensive catalog of satellite data and products. A computerized interactive service with remote access (supplemented by hard copy) will provide "one-stop" service for information about the availability, characteristics, and source of data and products from all satellite data archives. Ultimately the user will be able to place an order electronically.

In 1981 EDIS also completed studies and began procurement for a system to collect and store full-resolution GOES digital data, produce statistical summaries, and provide photographic and digital data or summary products by late 1982 or early 1983. Meanwhile, the University of Wisconsin was archiving these data for the period beginning with the first GARP Global Experiment (December 1978) until the new system is operating.

Data Support. EDIS provided central information exchange, archival, and data-dissemination services for the international Solar Maximum Year program during 1981. It also provided preliminary information exchange and participated in planning for the Middle Atmosphere Program scheduled for 1982 to 1985.

Using energetic particle data from the TIROS-N and NOAA 6 satellites, EDIS developed a computer program to identify the equatorward boundary of the auroral oval. The results will support tests of a new U.S. Air Force over-the-horizon radar system. Precipitation estimates from TIROS-N and GOES satellite images supported the Agency for International Development's disaster assistance effort, in evaluation of weather effects on crops in developing nations. During 1981, EDIS provided weather data to 50 countries in Africa, plus Central and South America and Asia.

National Weather Service support to the 1981 Space Shuttle flights was aided by GOES satellite images, particularly in monitoring weather conditions near preselected recovery sites around the world. Weather criteria for recovery or landing were stringent, and the high-resolution images provided information not available from other sources.

NWS also established special ocean service units in New Orleans and Washington to expand services to the marine community. Satellite data will be used to monitor sea surface temperatures, ocean color changes, ocean current intensity and migration, sea ice and sea fog, sea state, and other factors affecting fishing, marine transportation, offshore drilling, and other marine activities.

In 1981, NOAA began to plan experiments and tests for a variety of techniques for weather forecasting and warnings using data obtained from the VISSR atmospheric sounder (VAS) on the GOES 4 and 5 satellites. The capability of these instruments to monitor variations of atmospheric temperature and moisture was demonstrated. During September and October 1981, a hurricane research support operation used GOES-East (75° W) data. Eight 30-minute atmospheric temperature soundings over Atlantic hurricanes were made each day. Also, the GOES-West (135° W) satellite produced two water vapor images each day. These images were available to users through the GOES-Tap, and moisture images were used to locate high-altitude low-pressure areas and jet streams. These atmospheric temperature and moisture profiles are expected to improve central guidance products, severe local storm forecasting, tropical storm analysis and forecasting, and mesoscale weather event detection. Additionally, the VAS has the potential to improve sea surface temperature measurements and forecasts of clear-air turbulence, thunderstorm formation, and minimum temperatures.

In 1980, NASA and NOAA demonstrated a Centralized Storm Information System in the operational environment of the National Severe Storms Forecast Center in Kansas City. During 1981, preliminary evaluation was completed. The system is designed to increase flexibility in displaying satellite data and superimposing conventional meteorological information on the satellite images. The new technology provided field forecasters with improved mesoscale analyses and guidance. Satellite interpretation messages discussed phenomena such as rapidly developing thunderstorms, intersecting small-scale boundaries where convection often develops, and low-level wind-shear boundaries. In addition, greater emphasis was placed on weather situations that affect aircraft operations, such as areas where fog and stratus are forming, moving, and dissipating and areas of adverse winds aloft. Rapidly transmitted information permitted air controllers to assess pending air-traffic problems better and and improve terminal forecasts.

During 1981, NOAA supported several climate research programs using the Argos Data-Collection and Platform-Location system on NOAA satellites to monitor and track drifting buoys. The Argos system offers precise platform-location data (within 5 kilometers), critical for investigating ocean currents and ice-field movement, and affords reliable and economical data collection from remotely deployed surface and subsurface sensors. More than 75 buoys collected oceanographic, meteorological, and location data to support several studies: The Equatorial Pacific Ocean Climate Studies (EPOCS) are testing the hypothesis that interannual variability of the equatorial sea surface temperature is a fundamental driving force for interannual atmospheric variability. The Arctic Basin Buoy Program was designed to measure and archive data on fields of pressure, temperature, and ice velocity and their year-to-year variations; determine relationships between atmospheric variables and ice behavior; determine ice export from the basin; and improve real-time high-latitude pressure maps and forecasts of weather and ice conditions. The Observations of the Equatorial Surface Jet program examines the spatial extent of the equatorial surface jet stream in the Indian Ocean, using drifting buoys deployed at regular intervals.

Satellite Data Uses

Winds and Temperatures. NESS studies demonstrated that satellite sounding data can depict the horizontal and vertical temperature structure of the atmosphere in both tropical and extratropical regions. The temperature structure, associated with the low-level jet stream over the eastern Atlantic Ocean and western Africa, was established using only satellite data and vertical cross-sections in mid-latitude frontal zones;

results compared closely to those determined from radiosonde measurements. Also, a joint experiment was begun with the Israel Meteorological Service and Tel Aviv University to evaluate the effects of satellite soundings and cloud-vector winds on operational numerical weather forecasting models.

During three weeks of March 1981, in Denver, simultaneous radiometric and radar data from the NOAA Wave Propagation Laboratory's ground-based profiler were processed to yield vertical temperature profiles for comparison with profiles derived from the NOAA 6 satellite. Except within about 1500 meters of the earth's surface, where the satellite measurements are poor, the ground-based and satellite profile agreed to within 2°C.

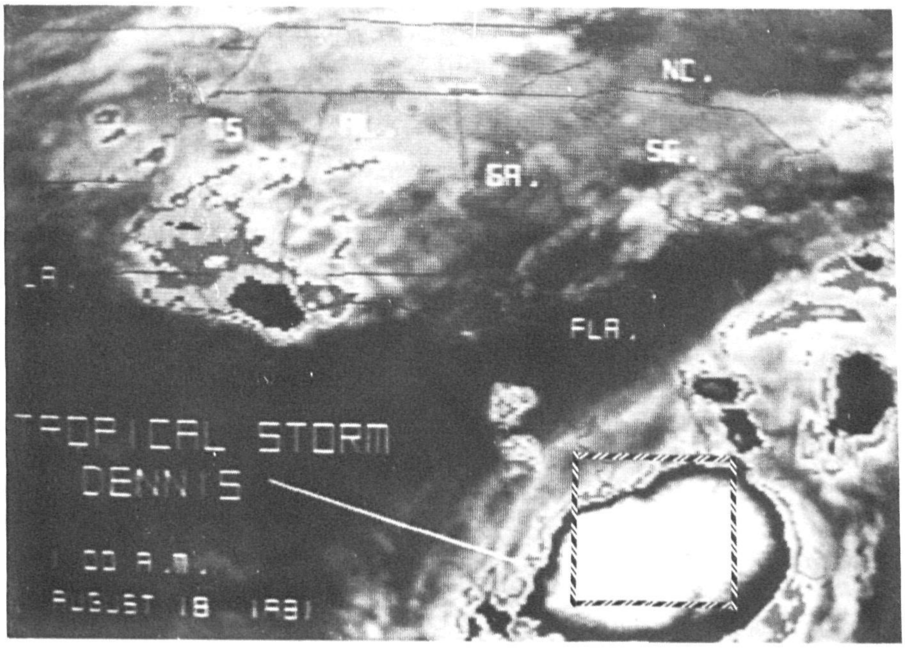
The hardware feasibility study of a Space Shuttle-launched Windsat, a satellite to measure global winds with an onboard, pulsed-doppler lidar (laser light detection and ranging), was extended to include experiments in detecting water vapor, temperature, aerosols, and atmospheric constituents. With only minor changes, the Windsat feasibility experiment accommodated a number of experiments originally proposed for other lasers. An analysis of the preliminary design of Windsat showed that it could perform with a satellite weight of less than 1000 kilograms and power less than one kilowatt.

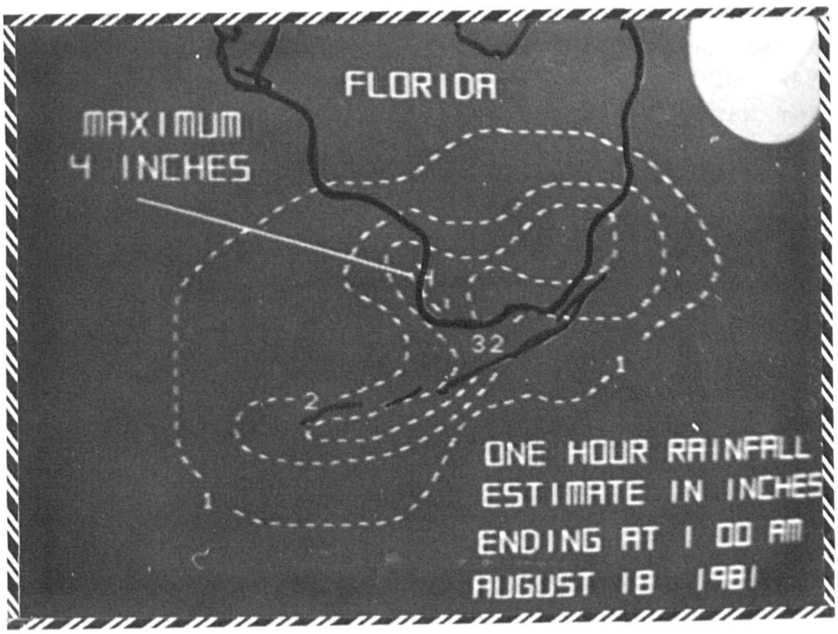
NESS developed an objective analysis technique to measure low-level winds around hurricanes from cloud motions derived from geostationary satellite images. The satellite-derived measurements compared favorably with wind measurements by NOAA reconnaissance aircraft.

During 1981, alternatives for deriving high-altitude wind measurements were evaluated to replace the costly film-loop method, which requires expensive photo processing. The two methods tested were an automatic computer-generated product and an interactive-computer method controlled by a meteorologist. Although testing and evaluation are not complete, NESS began using the interactive method in late 1981, to benefit from the cost savings until the testing was completed.

High-resolution multispectral data, obtained from the NOAA 6 and 7 Advanced Very-High-Resolution Radiometers, were used to test new methods for measuring sea surface temperatures globally from space. Preliminary results indicated that significant improvements could be made and that more high-quality temperature measurements were being obtained than with the method already in use. Operational use of the new technique began in November 1981.

A sea-surface-temperature composite chart, using visible and infrared digital data from GOES satellites, was made operational during 1981. The composite uses digital data at different observation times to form a more cloud-free sea-surface field of thermal-infrared temperatures. The composite field is used mainly for detecting ocean thermal fronts and eddies, and their movements, in high-gradient ocean and coastal zone areas of the United States. It is produced once a day for preselected areas of the coastal zone.





GOES 5 enhanced infrared image of tropical storm Dennis (top) over southern Florida on August 18, 1981. Insert (bottom) is an analysis of estimated rainfall.

Global Radiation. NESS research made considerable progress in the Nimbus 7 Earth Radiation Budget program. Two complete years of solar data have yielded a mean solar constant of 1375.6 watts per square meter with a standard deviation of 0.97 watts per square meter. Variations exceeding 0.2 percent over five to seven days were observed and were independently verified by an instrument on the Solar Maximum Mission satellite. A preliminary set of models for the angular distribution of reflected and emitted radiation appears to be an improvement on existing models.

A 67-month data set comprising mean monthly radiation budget estimates (albedo, outgoing radiation, absorbed solar energy) was extended with NOAA 6 and 7 data. These data have been extensively used by the Climate Analysis Center in diagnosing climatic conditions and by NESS in studying the radiation balance during the first GARP global experiment.

Environmental Warning. NOAA's National Hurricane Research Laboratory (NHRL) continued to use satellite and other remote-sensing data to support its hurricane research. Aircraft-borne microwave instruments measured wind speeds in Hurricanes Greta and Ella in 1978, and measurements were compared with Seasat scatterometer-derived figures. Seasat-derived winds were mostly within 10 percent of the aircraft-measured winds. The exception was near the region of maximum winds, where Seasat underestimated aircraft-measured winds by 20 percent because of poor spatial resolution. In a similar experiment during Hurricane Allen in 1980, satellite-derived winds were within 10 percent of the aircraft-measured winds up to 240 kilometers per hour and were of high spatial resolution--demonstrating that hurricane-force winds can be remotely measured.

NESS studied satellite images to improve warning services. The Miami Satellite Field Service Station continued to monitor Atlantic Ocean hurricanes for the NWS National Hurricane Center. The locations and maximum sustained winds for all hurricanes and other tropical disturbances were determined from satellite data, which were often the only information available. Hurricanes were located with an average accuracy of 32 km, and maximum sustained winds were estimated with an average accuracy of 18.5 km per hour. Center forecasters prepared advisories for the public, marine, and military interests. Similar information is provided by the San Francisco station for the eastern Pacific Ocean, by the Honolulu station for the central Pacific Ocean, and by NESS's Synoptic Analysis Branch for the western Pacific and Indian Oceans.

In support of NHRL's study to detect large cumulonimbus clouds called "supercells," NHRL used rapid-scan images from the GOES-East satellite to document the evolution and structure of these cells in developing tropical storms. The satellite images permitted interpretation of simultaneously obtained aircraft measurements.

Using GOES digital infrared images in other research, NOAA's Office of Weather Research and Modification estimated rainfall from convective clouds over the central United States for one month. The technique was tested under mesoscale conditions to develop stream-flow models. Satellite rain estimates compared favorably with rain-gauge and radar data. NASA and NOAA investigated the Florida sea-breeze regime. Rainfall computed for six study days showed that the rainfall patterns of the convergence zones in a sea-breeze model were similar to rainfall estimates from the satellite data.

NESS now routinely uses GOES images to estimate the amount of rainfall from thunderstorms, helping meteorologists and hydrologists predict floods. During 1981, NESS experimentally modified the technique to take into account unusual or more-difficult-to-predict thunderstorms--those occurring in dry environments, with high bases, or with warm tops. NESS also developed several automated experiments that use GOES data to analyze precipitation from tropical and extratropical storms, and improved techniques to estimate precipitation from enhanced nonconvective cloud images, for more accurate predictions in the western United States. Precipitation estimates were also attempted for the first time on winter storms along the West Coast.

NESS improved its operational satellite support to the National Weather Service Flash Flood Program by acquisition of the interactive flash-flood analyzer, to replace the time-consuming manual method of determining precipitation amounts from GOES data. The more rapid, more accurate analyzer can also disseminate products to NWS and other users simultaneously--a significant improvement, as flash floods occur with little advance warning, endangering lives and property. It is scheduled to become fully operational by March 1, 1983, replacing the costly photographic medium by cheaper, computer-driven, electronic data-display and analysis.

The Prototype Regional Observing and Forecasting Service continued to test techniques combining satellite, radar, and surface observations and ground-based atmospheric sounding data for improved short-term (up to 12-hour) metropolitan-area forecasts. First applications to severe storms and flash-flood warnings, using data collected during the spring and summer of 1981, showed great promise.

Satellite data aided fire fighters in the western United States and Alaska. "Hot spots" were found to be detectable by comparing bands three and four of the Advanced Very-High-Resolution Radiometer carried on NOAA 6 and 7. Images from these two bands were used to find forest fires, active volcanoes, and waste-gas flows from oil wells and steel plants.

The eruption of the Pavlof and the Shishaldin volcanoes in the Aleutians in September 1981 was first discovered by meteorologists at the Anchorage Satellite Field Services Station. Information about ash plume height, movement, and area coverage was provided to the U.S. Geological Survey and the Federal Aviation Administration Air Route Traffic Control Center. NESS also provided the Smithsonian Scientific Event Alert Network with timely information on new eruptions. The satellite data often are the first or only information the Smithsonian receives on eruptions.

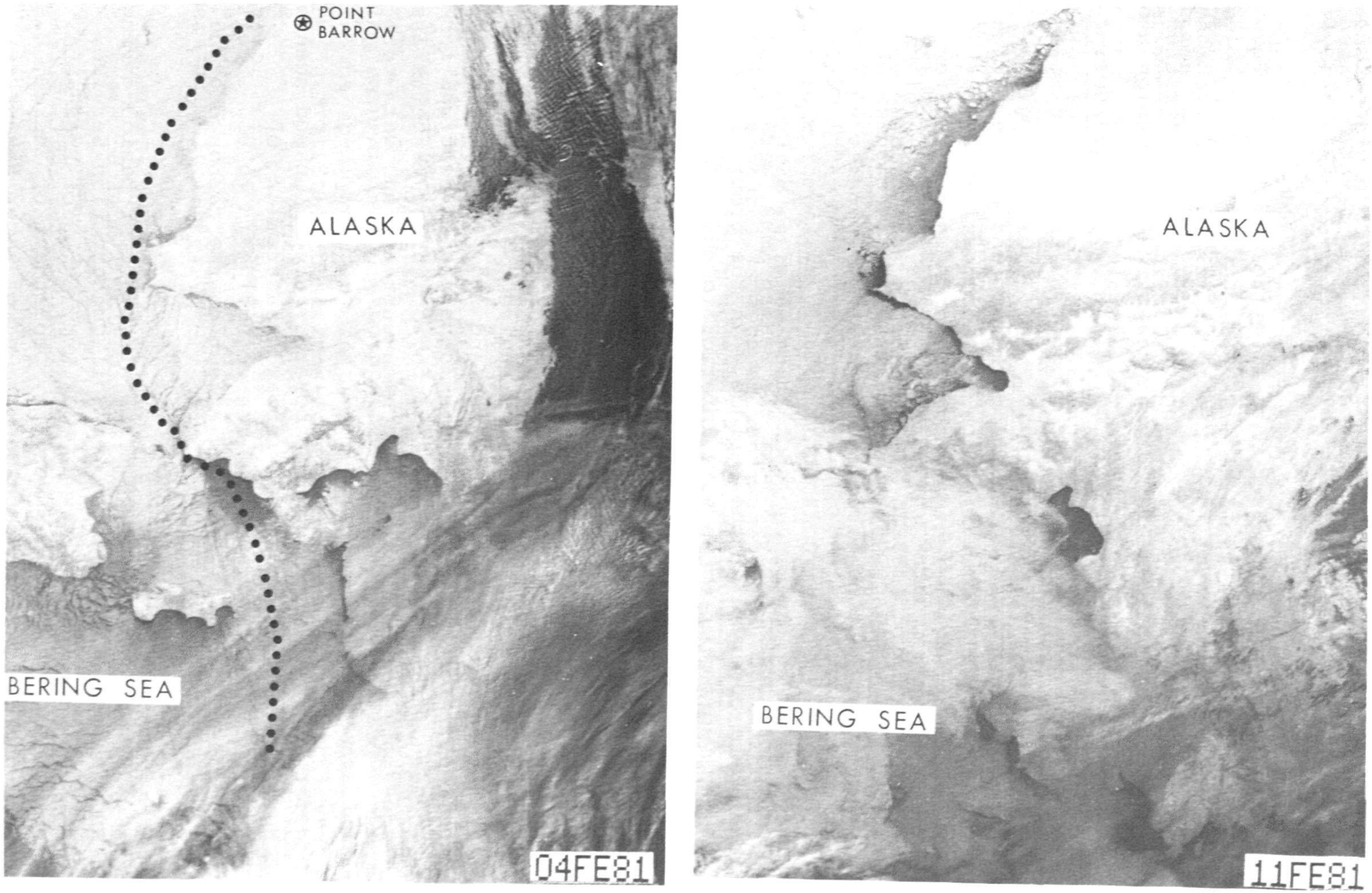
During 1981, the U.S. Navy-NOAA Ice Center provided special satellite analyses of ice conditions to the U.S. Coast Guard for the visit of the ice breaker Polar Sea to Alaska's north slope. Satellite ice observations also remained important in the U.S. Fish and Wildlife Service's study of the migration of marine mammals (walrus, whales, seals, and polar bears). Further satellite studies of ice patterns in Cook Inlet suggest a two-year light-ice and heavy-ice cycle. This information is particularly important for engineering and constructing dock facilities for transportation of coal from Alaska.

Devastating downslope winds have hit Anchorage, Alaska, half a dozen times in the last two years, causing more than $50 million worth of property damage. Studies of satellite and conventional data for these events have led to development of a technique that uses satellite images to alert National Weather Service forecasters of potential high-wind situations 24 hours in advance.

The Miami station expanded support to commercial fishermen and marine shippers by making available via automatic telecopier its regional analyses of thermal fronts defining the location of the Gulf of Mexico Loop Current and the Gulf Stream between Cape Hatteras and the central Gulf of Mexico. These analyses, prepared three times each week, now are widely used by marine shipping companies, who report fuel savings of as much as $8000 per day per ship. Large savings in fuel and time, and much improved catches, have been reported by commercial fishermen, who now go directly to thermal fronts that mark the preferred fishing areas. The information also is broadcast via the NOAA Weather Radio from all NWS Weather service offices along the Florida coast from Jacksonville to Key West.

Oceanography. NESS conducted several studies of oceanic circulation using satellite infrared measurements. In a joint investigation with the Lamont-Doherty Geophysical Observatory, aided by Argentinean ship hydrographic surveys, a large number of warm-core eddies were found south of the Brazil Current. A survey of currents off the coasts of Australia, made in cooperation with Australia, confirmed earlier hypotheses from biological indicators that a southward-flowing current exists along the western shore; the current turns eastward along the southern coast. In a collaborative study with Texas A&M University, a low-frequency counter-clockwise precession of a cold-core Gulf Stream ring was discovered by combining satellite infrared data with hydrographic observations. Analysis of five years of geostationary satellite infrared images showed the recurrence and variability of very long (1000-km wavelength) waves at the eastern equatorial Pacific thermal front. These results are used to test numerical models of ocean circulation.

Analysis of Defense Meteorological Satellite images of the Sulu Sea showed propagation characteristics of large-amplitude, nonlinear internal waves and how they are affected by bathymetry and the earth's rotation. Surface effects of the internal wave field appear as striations in the sunglint pattern. The internal waves occur in packets that originate in the Sulu Archipelago, travel northward over 400 km to Palawan Island, and disappear. They are characterized by wavelengths of 5 to 10 km, crest lengths in excess of 200 km, and phase velocities of 250 cm per second, making them among the largest and fastest internal waves ever observed. An intensive field experiment in the Sulu Sea examined the generation, propagation, and dissipation mechanisms that govern these waves. Fifteen



Polar-orbiting images of ice conditions in Alaskan waters on February 4 and 11, 1981. Dotted line (left) shows track of USCG icebreaker, Polar Sea.

packets of internal waves were documented with vertical amplitudes of 30 to 100 m and periods of 30 to 55 minutes. Each packet evolved from a broad thermocline depression generated by a tidally induced hydraulic flow over the Pearl Bank sill. The field data supported the interpretation based on satellite images.

Jet Propulsion Laboratory processed data from the 100 days of Seasat observations in 1978 to provide the first global maps of mean wind speed and wave height measured from satellites. Some 3.5 million observations were averaged into 2.5°-latitude by 7.5°-longitude areas, demonstrating the potential for providing synoptic-scale, global sea-state information useful to oceanographers, meteorologists, and climatologists.

Global measurements of atmospheric water vapor by the Seasat Scanning Multichannel Microwave Radiometer (SMMR) also were shown. The estimates were used to make path length and attenuation corrections in the active microwave radiometers: the altimeter, which provided estimates of windspeed and significant wave height at nadir; and the scatterometer, which gave estimates of the vector wind field near the surface. Global estimates of water vapor would be useful in climatological studies of the variability of the latent heat of vaporization that is transferred from ocean to the atmosphere.

Sea surface temperatures derived from the Seasat SMMR were compared with conventional data observed at the surface. In the tropical Pacific Ocean, the SMMR-derived temperatures were inferior to ship measurements in absolute accuracy, comparable in relative accuracy, and superior in uniformity of spatial coverage. With improved computer programs, the SMMR measurements are expected to be better than those from ships.

NESS processed data from the Coastal Zone Color Scanner on Nimbus 7 to develop computer programs for deriving phytoplankton pigment in the northwest Atlantic Ocean, where ships collected extensive biological and optical data. Agreement between data from the scanner and from the surface observations was excellent. Development of good atmospheric corrections for the scanner data produced images showing detailed phytoplankton patterns associated with large-scale oceanic features such as currents and warm-core rings.

NOAA's Pacific Marine Environmental Laboratory also compared scanner data over the North Pacific Ocean with shipboard measurements of chlorophyll and particle concentrations. The objective is to use satellite data to monitor ocean productivity and its effect on the carbon dioxide atmosphere-ocean exchange rate.

Hydrology. Snowcover data from 30 western U.S. river basins during the 1980-1981 snow season were given to the Soil Conservation Service, Water and Power Resources Administration, U.S. Army Corps of Engineers, U.S. Forest Service, National Weather Service, Department of Energy, U.S. Geological Survey, and California State Department of Water Resources. More than 600 satellite determinations of snowcover were made between November 1980 and July 1981. Snowpacks were well below average throughout most of this region, reflecting a season-long drought. Automation of snowmapping techniques using the NESS interactive systems was the subject of two pilot test reports released in June 1981. As a result, automated snowmapping for six Rocky Mountain river basins became operational at the Kansas City Satellite Field Services Station on December 1, 1981.

During 1981, software was developed to produce a Northern Hemisphere digital snow map by analyzing polar stereographic satellite images on a NESS interactive system. The derived tapes are then sent to the U.S. Department of Agriculture and the Johnson Space Center for early warning of winter wheat kill in high-latitude regions.

Agriculture. Information on global crop production is required for effective response to fluctuations in the world food supply. This information is useful to all sectors of the agricultural community, including individual farmers and ranchers, commodity analysts, agribusiness, and agricultural policy makers.

In the interagency Agriculture and Resources Inventory Surveys through Aerospace Remote Sensing (AgRISTARS), NESS is developing products from operational environmental satellite data that will supplement conventional weather observations and improve the accuracy of the Department of Agriculture's forecasts of crop production. During 1981, computer programs were developed to estimate precipitation, solar radiation, maximum and minimum temperatures, snowcover, and vegetative index from satellite data. Plans are to test the programs in an operational environment. Precipitation and solar radiation estimates were delivered to Agriculture on a test basis in 1981.

Since May 1981, NOAA polar-orbiting satellites have been making infrared observations over regions designated by Agriculture's Crop Commodity Assessment Division. The satellite data are used to produce a vegetative index. Coverage varies from one to nine days. On average, four sets of the infrared data are sent each morning to the Johnson Space Center for operational use. The NOAA 7 satellite, with its high sun-angle afternoon orbit, permits monitoring of high-latitude crops year around. NOAA and NASA are making a priority study of the Nile Delta crop region to develop scan-angle and atmospheric-attenuation corrections for the satellite data. The Agency for International Development, the Central Intelligence Agency, and the United Nations Food and Agriculture Organization also use these data. Additional applications are terrain classification and monitoring of deforestation and the spreading of deserts. Polar-satellite infrared data also provide valuable information on the variation of soil temperatures in the Alaskan interior during the summer.

Fisheries. A weekly, mesoscale, Alaskan sea surface temperature chart, prepared from polar-satellite infrared data, is distributed to some 200 government and private users. Additionally, it is transmitted over the National Weather Service Radiofacsimile Broadcast Service from Kodiak, Alaska, to vessel operators needing information on superstructure icing conditions and to commercial fishermen and fisheries researchers concerned with the arrival of commercial fish in Alaskan waters. Herring arrive at 4°C and red salmon at 7°C in Bristol Bay, silver salmon at 11°-13°C in southeast Alaska, and pink salmon at 11°C near Kodiak Island. The charts save travel time and reduce labor and fuel costs. The information also is used for local fish inventory and migration studies, for fish harvest forecasting, and for environmental impact studies and engineering specifications by oil companies, the Bureau of Land Management Outer Continental Shelf Program Office, and many other groups concerned with oil and gas lease sales.

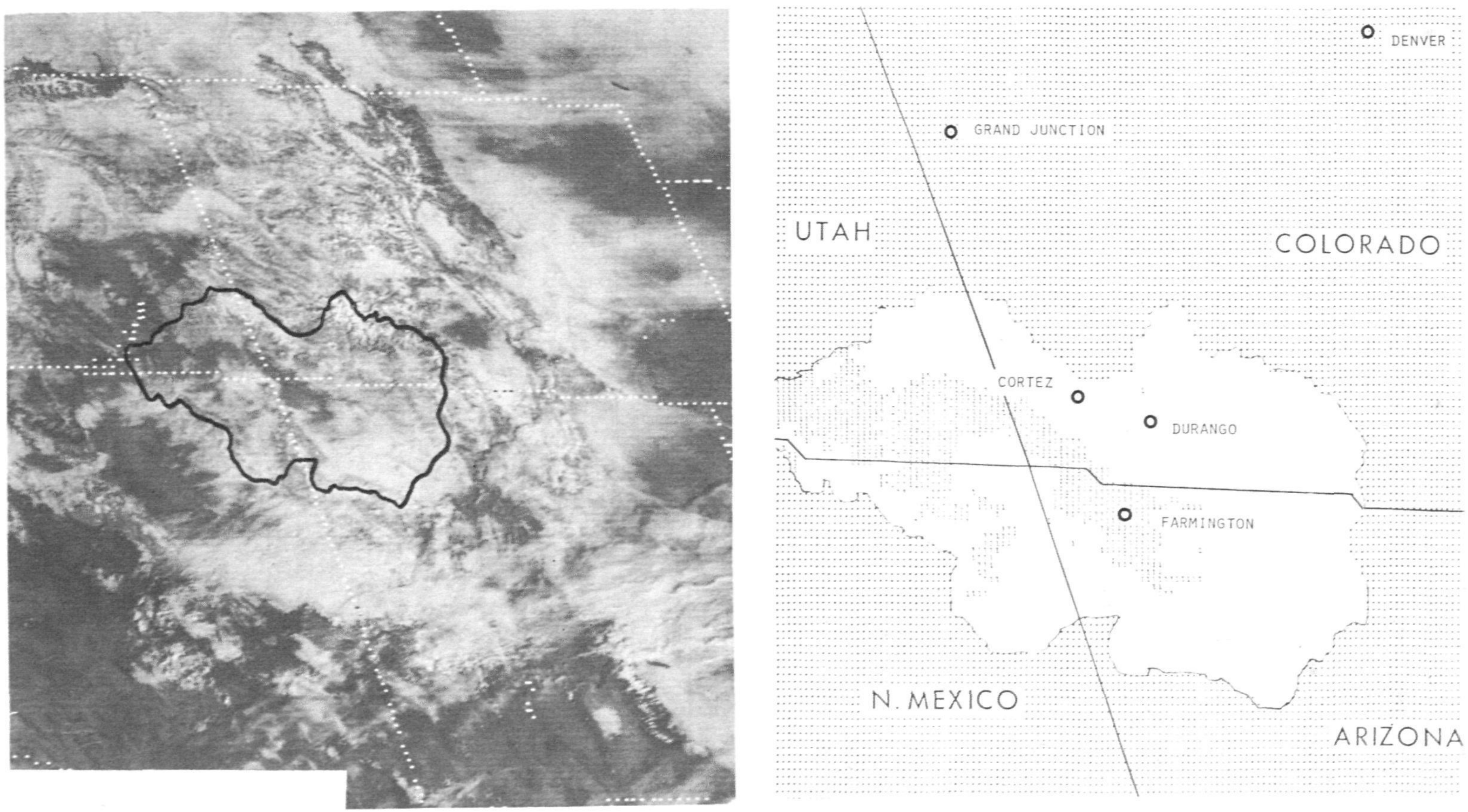
The National Marine Fisheries Service's first system for satellite data processing and analysis was installed at its Bay St. Louis, Mississippi, facility of the Southeast Fisheries Center in cooperation with NASA. Software, originally designed for Landsat data, was updated to process Nimbus 7 Coastal Zone Color Scanner, GOES, and NOAA temperature data. The system already has been used in a fisheries study by the University of Michigan and will be used in cooperative studies with the Northeast and Southwest Fisheries Centers, the state of Louisiana, U.S. Fish and Wildlife Service, and NASA.

A study began in 1981 to establish relationships between the extent and character of coastal wetland ecosystems and the health and productivity of recreationally and commercially valuable living marine resources. Conducted by the Northeast and Southeast Fisheries Centers, NASA, and the state of Louisiana, the study will use Landsat data to monitor changes in wetland ecosystems in marsh areas of Louisiana.

Operational products were developed using Seasat wind data as input to a Gulf of Mexico surface-transport model. Examples are the inventory of available data, the display of wind vectors, and the derivation of wind-induced properties of ocean circulation in the gulf. Model products such as wind-driven currents and transport and upwelling areas are useful for fisheries, particularly in studying the dispersal mechanisms for plankton. Ocean current data show trajectories and establish times required for passive life stages to drift from one location to another. Seasat provided new technology to monitor, model, and predict pathways by which offshore spawn of estuarine-dependent shellfish and finfish find their way into coastal nursery grounds.

During 1982, the Fisheries Service will use ocean color and thermal data from the Nimbus 7 Coastal Zone Color Scanner. Scanner indications of chlorophyll concentrations combined with temperature data may provide more insight into the large-scale distribution, abundance, and migration patterns of large pelagic fish such as bluefin tuna, billfish, and sharks.

An objective of the Fisheries Service is to achieve a zero net loss of habitat and productivity for critical marine estuaries and anadromous species by 1985. Using Landsat data, the Northeast Fisheries Center developed the Coastal Habitat Assessment and Research program to quantify changes in productivity, biomass, and areas of principal coastal zone habitats from North Carolina to Maine. The program will proceed in three phases: phase 1 will determine how many acres of wetlands exist and what vegetation types they contain; phase 2 will determine how many acres of wetlands have been



GOES 4 image (left) of snow cover. Automated digital analysis (right) shows 78 percent of area (blank portion) snow covered.

lost or gained in the past 10 years; and phase 3 will determine how the value and quality of coastal habitat is changing, from biomass and other properties.

The center also participated with the NASA Langley Research Center in the Nantucket Shoals experiment and in planning the National Science Foundation warm-core-ring studies. The Nantucket Shoals experiment used shipboard, in situ, and aircraft and satellite remote-sensing techniques to investigate the distribution and abundance of phytoplankton on the shoals in relation to rates of nutrient supply, growth, vertical mixing, and advective processes. The warm-core-ring studies seek to understand physical, chemical, and biological processes related to Gulf Stream warm core rings. The Fisheries Service is augmenting this experiment by studying the shelf-slope interface and is building a high-resolution picture transmission system in cooperation with NASA's Goddard Space Flight Center.

The application of satellite observations in marine fisheries research and management was being evaluated in studies at the Southwest Fisheries Center. Using satellite thermal-infrared images and extensive sampling of northern anchovy eggs and adults, one study found that no spawning occurred over large areas off California during the peak spawning period. In this study, only satellite data provided fishery scientists with a synoptic picture of the large-scale oceanographic events over the entire anchovy area during the peak season. Ocean color images from the Nimbus 7 color scanner assisted in describing habitats for coastal marine mammals in another study. The center also participated in an experimental, satellite-oriented, observation program for commercial fisheries sponsored by Jet Propulsion Laboratory and the National Weather Service.

<u>International Activities</u>. Two foreign governments contribute instruments to the NOAA polar-orbiting satellites. The French National Center for Space Studies provides the Argos satellite data-collection system; the British Meteorological Office provides the Stratospheric Sounding Unit, a component of the TIROS Operational Vertical Sounder. Fourteen countries operate 275 platforms through the Argos system. The majority of the platforms must be periodically replaced, and more than 2000 have been used since its inauguration. The U.S.-funded processing agreement as of 1981 supported 145 platform-years. The telephone communications system at Suitland, Maryland, which allows users direct access to their disc files in Toulouse, France, was being used by 27 subscribers.

Some 120 countries receive images and digital data directly from satellites operated by NOAA. Medium-resolution images are received in some 890 locations globally and high-resolution data in 25 countries. Geostationary satellites provide weather facsimile broadcasts to nearly 30 countries in the Western Hemisphere and to Australia and New Zealand; 3 nations other than the United States also receive high-resolution images. The GOES Data-Collection System also is used by several countries in the Western Hemisphere for relaying environmental data from remote platforms.

NOAA participates in an informal group known as Coordination on Geostationary Meteorological Satellites (CGMS), through which technical managers planning national geostationary meteorological satellites discuss common interests in design, operation, and use of their spacecraft. The European Space Agency (ESA), Japan, the Soviet Union, and India also participate. There are four operating satellites--two launched by the U.S. and one each by ESA and Japan. While independently designed and developed, they have met common meteorological mission objectives and have produced certain compatible products for worldwide users.

Present and prospective operators of national, land-remote-sensing satellites have established a similar group known as Coordination of Land Observation Satellites. This group--in which NOAA, NASA, and representatives from France and Japan participate--is considering coordination and harmonization of data products, satellite-to-ground telemetry, and spacecraft orbits to ensure maximum compatibility. During 1981, NOAA also coordinated U.S. participation in regional meetings in Africa, Asia, and South America to inform foreign users of products and services that will be available from the planned land-remote-sensing satellites.

Training. In 1981, the NESS Applications Laboratory instructed some 270 persons in satellite image interpretation. Two regional workshops for forecasters were held in Raleigh, North Carolina, and Slidell, Louisiana. Four classes at the National Weather Service Training Center were trained to estimate rainfall amounts from satellite images. In addition, training for Department of Defense meteorologists continued in 1981. Four classes at Offutt Air Force Base used satellite images to observe aviation weather problems and illustrate techniques of severe weather analysis. NESS held one extensive training session for Naval reservists.

Application of Space Technology to Geodesy and Geodynamics. The National Geodetic Survey, a component of the National Ocean Survey, continued to work with NASA to apply space technology to geodesy and geodynamics. Development of a new-generation polar-motion and universal-time-monitoring network continued. The network will consist of three radio astronomy observatories, equipped with the most advanced instrumentation for Very-Long-Baseline Interferometry (VLBI) and a data-reduction and analysis center. Two stations are now operational--in Fort Davis, Texas, and Westford, Massachusetts--making weekly observations. Detailed comparisons with satellite laser-ranging determinations indicate that the network is achieving its design goal of 10-cm accuracy in determining pole position. This level of accuracy was achieved with observing times of 24 hours or less. Other techniques (satellite laser, satellite doppler, and optical techniques) require days to weeks of observing to achieve comparable accuracy.

Development of Global Positioning System geodetic receivers--in the coordinated approach agreed on by NASA, the U.S. Geological Survey, and the Defense Mapping Agency--continued toward a goal of deploying prototypes by the end of 1983, and NASA and NOAA's National Geodetic Survey established the Crustal Dynamics Project to apply space technology to understanding earth dynamics. The project supports the national program in earthquake hazard reduction, as well as national and international research in global geodynamics.

Altimetry data from the Geodynamics Experimental Ocean Satellite (GEOS 3) were used to determine the mesocale variability of the sea surface height in the western north Atlantic Ocean in and around the Gulf Stream meander region. The results agreed quantitatively with results obtained by conventional ocean-going research ships--demonstrating the potential of satellite data to supplement ship observations. Seasat and GEOS 3 radar-altimeter determinations of tidal constituents and mean sea surface height in the Atlantic also showed reasonably good agreement with each other, as did comparison of the tidal data with deep-sea tide-gauge measurements.

Space Support Activities

Warnings and Forecasts. The NOAA- and USAF-operated Space Environment Services Center is the national and world warning agency for disturbances on the sun, in interplanetary space, in the upper atmosphere, and in the earth's magnetic field. A major portion of the real-time data come from space environment monitors on NOAA's polar-orbiting and geostationary environmental satellites. In 1981, a significant improvement in short-term warning capability used new data from NASA's third International Sun-Earth Explorer(ISEE) satellite. The technique permits an accurate 25- to 50-minute advance warning of the beginning of geomagnetic storms. Warnings of radiation hazards from solar activity for the Space Shuttle began with its first flight in April 1981.

NOAA polar-orbiting satellites measure the total energy deposited by ionized particles precipitating downward into the earth's atmosphere in the auroral regions. Processing routines were completed sufficiently during 1981 to permit the first extensive access to the data and to make data available for real-time use in the center. A new computer system being procured will assemble, store, display, and distribute these space environment data.

Space and Atmospheric Research

Magnetospheric Physics. NOAA's Space Environment Laboratory developed sophisticated techniques for displaying data from experiments aboard the ISEE satellites. The techniques have been applied to the complete ISEE 1 data set, and processing of ISEE 2 data was under way. Analysis of observed characteristics of energetic particles in the geomagnetic tail permitted laboratory scientists to model a physically self-consistent mechanism for acceleration of charged particles in the geomagnetic tail and their deposition in the earth's auroral regions. This mechanism represents a significant source for energization of magnetospheric particles.

Aeronautical Programs

Aeronautical Charting. The National Ocean Survey produces air navigation charts to meet civilian and certain military requirements. The responsibility includes the timely collection and compilation of flight data to keep pace with the increasing demand created by advanced technology, new electronic aids to navigation, and changes in air traffic control regulations. Substantial progress was made during 1981 in evaluating Landsat images for delineating cultural and hydrographic features to update visual aeronautical charts.

Radar Techniques. NOAA's National Severe Storms Laboratory in Norman, Oklahoma, was combining observations made using a dual-doppler weather radar system, 444-m meteorologically instrumented TV tower, surface observation network, and instrumented aircraft to expand doppler radar's potential. The detection of aviation weather hazards such as gust fronts and turbulence is possible by doppler radar. A joint program with the multiagency Next Generation Radar Joint System Program Office investigated techniques for acquiring, processing, and displaying the pertinent data. These comprehensive studies are to improve guidance to aircraft near severe weather and for public warnings. A cooperative study with the Federal Aviation Administration in the validation of the first-generation, airborne, doppler weather radars is included in the program.

U.S. Environmental Satellites 1960-1981

Satellite	Purpose (1)	Launch	Average Altitude (km) (2)	Ceased Operation	Remarks (3)
TIROS 1	R	04/01/60	720	06/19/60	First weather satellite providing cloud cover photography
TIROS 2	R	11/23/60	672	02/01/61	
TIROS 3	R	07/12/61	760	10/30/61	
TIROS 4	R	02/08/62	773	06/12/62	
TIROS 5	R	06/19/62	778	05/05/63	
TIROS 6	R	09/18/62	694	10/11/63	
TIROS 7	R	06/19/63	645	02/03/66	
TIROS 8	R	12/21/63	749	01/22/66	First APT satellite.
Nimbus 1	R	08/28/64	S/677	09/23/64	Carried AVCS, APT, and High Resolution Infrared Radiometer for night pictures.
TIROS 9	R	01/22/65	S/1630	02/15/67	First TIROS satellite in Sun-synchronous orbit.
TIROS 10	0	07/01/65	S/792	07/03/66	
ESSA 1	0	02/03/66	S/765	05/08/67	First satellite in the operational system; carried 2 wide-angle TV cameras.
ESSA 2	0	02/28/66	S/1376	10/16/70	Carried APT cameras. APT carried on all even-numbered ESSA satellites.
Nimbus 2	R	05/15/66	S/1136	01/18/69	
ESSA 3	0	10/02/66	S/1427	10/09/68	Carried first AVCS cameras. AVCS carried on all odd-numbered ESSA satellites.
ATS 1	R	12/06/66	G/35,765	10/16/72 (pictures)	WEFAX discontinued December 31, 1978.
ESSA 4	0	01/26/67	S/1373	12/06/67	
ATS 2	R	04/05/67	-	-	Unstable attitude-data not useful.
ESSA 5	0	04/20/67	S/1379	02/20/70	
ATS 3	R	11/05/67	G/35,815	10/30/75 (pictures)	WEFAX discontinued December 31, 1978.

Satellite	Purpose (1)	Launch	Average Altitude (km) (2)	Ceased Operation	Remarks (3)
ESSA 6	0	11/10/67	S/1437	11/04/69	
ESSA 7	0	08/16/68	S/1440	07/19/69	
ESSA 8	0	12/15/68	S/1429	03/12/76	
ESSA 9	0	02/26/69	S/1456	11/15/73	
Nimbus 3	R	04/14/69	S/1100	01/22/72	Provided first vertical temperature profile data of the atmosphere on a global basis.
ITOS 1	R/0	01/23/70	S/1456	06/17/71	Second generation prototype.
Nimbus 4	R	04/08/70	S/1108	09/30/80	
NOAA 1	0	12/11/70	S/1438	08/19/71	First NOAA-funded second generation satellite.
ITOS B	0	10/21/71	-	-	Failed to orbit.
Landsat 1	R	07/23/72	S/918	02/16/78	
NOAA 2	0	10/15/72	S/1460	01/30/75	First operational satellite to carry all scanning radiometers.
Nimbus 5	R	12/12/72	S/1110	-	Still providing data.
ITOS E	0	07/16/73	-	-	Failed to orbit.
NOAA 3	0	11/06/73	S/1510	08/31/76	First operational satellite to permit direct broadcast of VTPR data.
SMS 1	R/0	05/17/74	G/35,788	01/29/81	Deactivated.
NOAA 4	0	11/15/74	S/1460	11/18/78	Deactivated.
Landsat 2	R	01/22/75	S/918	-	
SMS 2	R/0	02/06/75	G/35,800	-	VISSR failed 08/05/81; limited operational support at 100°W.
Nimbus 6	R	06/12/75	S/1110	-	
GOES 1	0	10/16/75	G/35,783	-	First NOAA operational geostationary satellite; 127°W on standby.
NOAA 5	0	07/29/76	S/1511	07/16/79	Deactivated.
GOES 2	0	06/16/77	G/35,785	-	Second NOAA operational geostationary satellite; 107°W on standby.
Landsat 3	R	03/05/78	S/918	-	First Landsat with infrared capability.
GOES 3	0	06/16/78	G/35,790	-	Third NOAA operational geostationary satellite; 90°W on standby.
Seasat 1	R	06/26/78	850	10/10/78	Electrical failure.

Satellite	Purpose (1)	Launch	Average Altitude (km) (2)	Ceased Operation	Remarks (3)
TIROS-N	R/O	10/13/78	S/850	02/27/81	Deactivated.
Nimbus 7	R	10/24/78	S/954	-	Carrying Coastal Zone Color Scanner.
NOAA 6	O	06/27/79	S/814	-	First NOAA-funded TIROS-N system satellite.
NOAA B	O	05/30/80	-	-	Failed to achieve an operational orbit.
GOES 4	O	09/09/80	G/35,791	-	First geostationary satellite to carry the VISSR Atmospheric Sounder (VAS); GOES West at 135°W.
GOES 5	O	05/22/81	G/35,786	-	GOES East at 75°W; also carries VAS.
NOAA 7	O	06/23/81	S/850	-	Second NOAA-funded TIROS-N system satellite.

(1) R - Research, O - Operations, R/O - Operational Prototype.

(2) S - Sun-synchronous, G - Geosynchronous.

(3) APT - Automatic Picture Transmission, AVCS - Advanced Vidicon Camera System,
WEFAX - Weather Facsimile, VTPR - Vertical Temperature Profile Radiometer
VISSR - Visible Infrared Spin-Scan Radiometer.
VAS - VISSR Atmospheric Sounder.