APPENDIX A

DEPARTMENT OF COMMERCE WEATHER PROGRAMS

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The National Oceanic and Atmospheric Administration (NOAA) is the principal meteorological agenc of the federal government. By law, NOAA is responsible for reporting the weather of the United State providing weather and flood warnings and forecasts to the general public, developing and furnishin applied weather services, and recording the climate of the United States. This mission is carried ou within NOAA by the National Weather Service (NWS); the National Environmental Satellite, Data, an Information Service (NESDIS); the Office of Oceanic and Atmospheric Research (OAR); the Nationa Ocean Service (NOS); and the Office of NOAA Corps Operations (NC).

NATIONAL WEATHER SERVICE

The National Weather Service (NWS) has the principal responsibility for the plans and operations of the basic weather services and certain specific applied services. The primary mission of NWS is to help ensure the safety and welfare of the general public with respect to the effects of weather and to further the conduct of governmental and commercial activities which are affected by weather. In support of this mission, NWS:

- Issues warnings and forecasts of weather, flood, and ocean conditions.
- Observes and reports the weather and the river and ocean conditions of the United States and its possessions.
- Develops and operates national meteorological, hydrological, and oceanic service systems.
- Performs applied meteorological and hydrological research.
- Assists in developing community awareness and educational materials concerning weather related natural disasters.
- Participates in international hydrometeorological activities, including the exchange, coding and monitoring of data and forecasts, and also including the installation and repair of hydrometeorological equipment and systems overseas under the Voluntary Cooperation Program.

The basic enabling legislation and authority for weather services are summarized as follows:

- Organic Act of 1890 created the U.S. Weather Bureau in the Department of Agriculture.
- Enabling Act of 1919 allowed the U.S. Weather Bureau to enter into cooperative agreements for providing agriculture weather services.
- Flood Control Act of 1938 authorized the establishment, operation, and maintenance of the Hydroclimatic Network by the Weather Bureau for Flood Control; on July 1, 1940, the Weather Bureau was transferred from the Department of Agriculture to the Department of Commerce.
- Federal Aviation Act of 1958 outlined duties of the Secretary of Commerce for provision of weather observations and services to aviation.
- Reorganization Plan 2 of 1965 placed the "National Weather Service" (NWS) in the newly created Environmental Science Services Administration (ESSA).
- Reorganization Plan 4 of 1970 made the NWS a part of the newly created National Oceanic and Atmospheric Administration (NOAA).

SERVICES

NWS provides around-the-clock weather and flood warning and forecast services to the public for the protection of life and property and to meet the needs of all segments of the economy. Weather services are provided by a nationwide network of offices that collect data, prepare state and local warnings and forecasts, and disseminate information to the population both directly

and indirectly through the mass media. Data, analyses, forecasts, and outlooks used by field forecasters to prepare local forecasts are centrally processed by the National Centers for Environmental Prediction (NCEP). The NWS core mission also depends on the study, development, and testing of new methods for improving basic warning and forecast capabilities through research.

Weather Warnings and Forecasts. Both Weather Service Forecast Offices (WSFO) and Weather Service Offices (WSO) issue local warnings for severe weather, such as hurricanes, tornadoes, severe thunderstorms, flash floods, and extreme winter weather. WSFOs prepare forecasts for zones which are comprised of typically one or more counties that experience similar weather. Each WSFO has forecast responsibility for several zones which, together, comprise an area the size of an average state. WSFOs issue zone forecasts 4 times daily for a period out to 48 hours and a generalized statewide forecast twice daily, including an extended 5-day forecast on a daily basis. WSFOs also provide the main field forecast support for the marine and aviation programs as well as guidance for the fire weather program.

All counties in the United States are assigned to specific WSOs or WSFOs for warning purposes. These offices issue and distribute local warnings of severe weather for their assigned counties. WSOs adapt generalized weather forecasts to local areas and issue severe weather and flash flood warnings. In preparing local warnings and forecasts, WSFOs use forecast guidance prepared by NCEP, which is based on worldwide meteorological observations. Two of NCEP's science-based centers--the Storm Prediction Center and the National Hurricane Center/Tropical Prediction Center--provide specialized central support for the local warning program.

Weather Service Meteorological Observatories (WSMO) are additional sources of data for surface observations, upper air observations, and/or radar data. These observations are also used in the NCEP database for generating guidance products used by field forecasters.

Aviation Weather Services. The NWS provides a broad range of services in support of the aviation community. Fifty-two WSFOs prepare site-specific airport terminal forecasts 3 times per day with amendments as needed for over 500 public-use airports in the 50 states and in the Caribbean. These offices also produce about 300 individual route-oriented forecasts 3 times a day for the 48 contiguous states. WSOs also take observations to meet local aviation requirements.

NCEP's Aviation Weather Center prepares Area Forecasts 3 times daily describing general aviation weather conditions over the lower 48 states. This unit also issues in-flight advisories of hazardous weather conditions associated with thunderstorms, icing, turbulence, strong low-level winds, and broad areas of low clouds and/or restricted visibility. In Alaska and Hawaii, these products are issued by WSFOs.

River and Flood Warnings and Forecasts. River Forecast Centers (RFC) prepare guidance used by WSFOs and WSOs to issue flash flood watches, warnings, and river forecasts. RFCs provide forecasts of river stage and flow and related products and services for use by water resources managers and other users. Most WSFOs and WSOs support the RFCs by collecting and relaying hydrologic data. NCEP provides central support to RFCs by forecasting the movement of large storms that are causing significant precipitation.

Marine Weather Services. Using weather analyses and forecast guidance provided by NCEP's Marine Prediction Center, marine weather forecasters at coastal and Great Lakes WSFOs issue wind, wave, weather, and ice warnings, forecasts, and other information for the population living and working along the sea coast, off-shore, on the Great Lakes, and on the high seas. Principal products include small craft advisories; gale, storm, tropical cyclone, and storm surge warnings; coastal, off-shore, and high seas forecasts; sea and swell forecasts; sea and lake advisories; and special weather forecasts to aid in the containment and clean up of oil spills and other hazardous substances in the marine environment. In support of marine weather services, the NWS operates the National Data Buoy Center (NDBC), which provides real-time operations, data acquisition and data processing, and distribution of meteorological and oceanographic data from moored and drifting buoys and automated observing stations at selected coastal locations. NDBC also provides systems integration, deployment, maintenance and repair, and redeployment of data buoys and coastal stations. The NWS, through its Port Meteorological Officer Program, also coordinates and manages data acquisition from cooperative merchant ships under the international Voluntary Observing Ship program sponsored by the World Meteorological Organization.

Fire Weather Services. Designated NWS offices provide weather warning, forecast, and advisory services

to federal, state, and local wildland management agencies to support wildfire control. Localized weather forecasts are issued, as required, during all wildfire. NWS offices also provide site-specific forecasts and advisories to federal natural resource agencies for prescribed burning and smoke management, insect and disease control, planting and cultivating new growth, preservation of watersheds, and promotion of wildlife habitat and recreational facilities.

Tsunami Warnings. Tsunami watches and warnings for Pacific Ocean areas and Alaska are prepared and issued by the Tsunami Warning Center at Ewa Beach, Hawaii, and the regional center at Palmer, Alaska. NWS collects and analyzes observational data from an international network of seismological observatories and sea-level observing stations which operate on a cooperative basis. The centers use the data to prepare watches and warnings covering all U.S. territories and states bordering on the Pacific Ocean and disseminate them to WSFOs, federal and state disaster agencies, military organizations, private broadcast media, and other facilities that furnish warning information to the public.

Over the last several decades, NWS has made major improvements in forecasting synoptic-scale (large-scale, slowly evolving) weather. As modernization efforts continue, further improvements will be realized in the severe weather and flood warnings program with continuing improvements in larger scale, centrally prepared weather guidance products for Day II and beyond, implementation of NWS systems upgrades, advanced observations from the planned geostationary and polar-orbiting satellites, and the development of mesoscale predictive techniques for NWS field operations. Integral to the modernization effort, NWS is reorganizing its field structure to focus more on warnings and short-range forecasts, and, in FY 1995, NMC was restructured to serve a broader mission required by the NWS modernization. The modernized operations concept includes a vertically integrated forecast process in which national centers provide products based on output from numerical models, statistical adjustments to model fields, and value-added products prepared by national center forecasts. This product suite will be transmitted to the modernized Weather Forecast Offices (WFO) in digital form, where forecasters will use them to prepare local forecast products. Under the new, modernized office structure, the responsibilities of the WSFOs and the WSOs will be subsumed by the WFOs.

National Centers for Environmental Prediction (NCEP)

Improved technologies allowed NOAA to reorganize the National Meteorological Center (NMC) into NCEP with seven science-based, service-oriented centers that generate environmental prediction products and two central support centers that develop and operate numerical models on which predictions are based. The structure includes an evolutionary operational numerical model suite, from which forecast products are derived by skilled forecasters, and a supporting research and development program, which emphasizes the relationship between NCEP and the broader scientific community.

The nine national centers that comprise NCEP are:

Hydrometeorological Prediction Center (HPC). The HPC, located at NCEP headquarters in Camp Springs, Maryland, supports the hydrometeorological forecast functions of the NWS. The HPC incorporates the latest in technological support, maintaining an up-to-the-minute monitoring of all precipitation-related events, such as rain, snow, and ice, across the contiguous United States. While basic weather forecasts are prepared mainly for NWS field office guidance, they are also used by the entire meteorological community. Specifically, the National Precipitation Prediction Unit produces forecasts of rainfall and snowfall amounts out to 72 hours. The HPC also prepares analyses of weather conditions at sea level for North America every 3 hours and for the Northern Hemisphere every 6 hours. The HPC also has coastal-marine forecast guidance responsibilities originally planned for a separate Marine Prediction Center.

Storm Prediction Center (SPC). The SPC, located in Norman, Oklahoma, is the primary NWS center of expertise for forecasting hazardous weather and economically disruptive weather events. It provides short-term guidance products for hazardous weather over the contiguous United States and coordinates with NWS field offices on the short-term aspects of hazardous weather, such as flash floods, thunderstorms, tornadoes, winter storms, blizzards, and freezing precipitation. The SPC draws some of its heritage from the Severe Local Storms Unit of the former National Severe Storms Forecast Center (NSSFC) but differs in that SPC's mission is broader. The SPC also provides internal scientific support and techniques development. This support includes researching, developing, evaluating, and testing forecast methods.

Aviation Weather Center (AWC). The AWC, located in Kansas City, Missouri, enhances aviation safety by issuing warnings, forecasts, and analyses of hazardous weather for aviation interests. The AWC identifies existing or imminent weather hazards to aircraft in flight and creates warnings for transmission to the aviation community and originates operational forecasts for weather conditions that will affect domestic and international aviation interests out to 2 days. The AWC also collaborates with universities, governmental research laboratories, Federal Aviation Administration facilities, international meteorological watch offices, and other NWS components to maintain a leading edge in aviation meteorology hazards training, operations, and forecast techniques development. These functions were formerly handled by three collaborating NWS offices.

Tropical Prediction Center (TPC)/National Hurricane Center (NHC). The TPC, located at Florida International University in Miami, Florida, employs rapid advances in technology and research to issue increasingly accurate and timely watches, warnings, forecasts, and analyses for tropical weather conditions to save lives and protect property. To fulfill national and international responsibilities, the TPC prepares tropical storm and hurricane watches and warnings, tropical aviation and marine warnings and forecasts, and tropical analyses. The NHC remains an integral part of TPC and will continue its responsibility of tracking and forecasting tropical cyclones. The hurricane forecasting and warning programs remain critical for the protection of life and property along the vulnerable areas of the North Atlantic Ocean, Caribbean Sea, Gulf of Mexico, and the eastern North Pacific Ocean. The TPC also has a responsibility to conduct forecast techniques development as necessary to sustain an acceptable level of forecast accuracy and public service. This includes conducting studies and developing and evaluating forecast models.

Climate Prediction Center (CPC). The CPC, located in Camp Springs, Maryland, provides climate services to users in government, the research community, private industry, and the public both in this country and abroad. Services include operational prediction of climate variability, monitoring of the climate system and development of databases for determining current climate anomalies and trends, and analysis and assessment of their origins and linkages to the rest of the climate system. These services cover climate time scales ranging from weeks to seasons, extending into the future as far as technically feasible, and cover the domain of land, ocean, and atmosphere, extending to the stratosphere. The CPC supports and stimulates the application of climate information and services with particular attention to applications in agriculture, energy, transportation, water resources, and health. It monitors, analyzes, and, where possible, predicts large-scale climate variations, such as the El Niño and the Great Flood of 1993, as well as numerous regional climate fluctuations. To support these services, CPC engages in diagnostic research and studies of model output to improve monitoring, analysis, and predictions of the physical climate system. A major milestone occurred in January 1995, when CPC issued the first official long-lead outlooks for the United States out to a year in advance. This effort is part of a plan for delivery of U.S. national climate services for socioeconomic benefit and improved decision-making.

Space Environment Center (SEC). The SEC, located in Boulder, Colorado, provides national and international forecasts, alerts, and warnings of extraordinary conditions in the space environment, solar radio noise, solar energetic particles, solar X-ray radiation, geomagnetic activity, and conditions of stratospheric warming. The SEC observes, assesses, and predicts activity in the space environment to promote public safety and to mitigate economic loss that could result from disruption of satellite operations, communications and navigation systems, and electric power distribution grids. The SEC issues specific predictions of the activity level of space weather for the next 3 days and more general predictions up to several weeks in advance. Weekly summaries of observed solar-terrestrial conditions are also published. The SEC supports theoretical and experimental research to understand the fundamental physical processes governing the space environment and the development of operational techniques and processes. Research activities focus on areas where advanced applications can be developed to help improve the Nation's space weather service.

Environmental Modeling Center (EMC). The EMC, located in Camp Springs, Maryland, improves NCEP's numerical weather, marine, and climatic predictions through a broad program of data assimilation and computer modeling. In support of the NCEP operational mission to provide ocean prediction, mesoscale prediction (thunderstorms, hurricanes, tornadoes, etc.), and global prediction, EMC develops, adapts, improves, and monitors data assimilation systems and models of the atmosphere, ocean, and atmosphere/ocean system using advanced modeling methods developed internally, as well as cooperatively

with scientists from universities, the international scientific community, NOAA laboratories, and other government agencies. The EMC integrates research and technology through its Model Test Facility (MTF). The MTF serves as an efficient and effective interface between NCEP and the scientific community which may develop ideas, models, and techniques that will improve NCEP products. The MTF provides consultation, programming, and computer resources to outside scientists using the NCEP system and coordinates initial evaluations of their work. The EMC conducts applied research and development and publishes research results in various media for dissemination to the world meteorological and oceanographic community.

NCEP Central Operations (NCO). The NCO, located in Camp Springs, Maryland, is responsible for all aspects of NCEP operations, including access to real-time data, and its quality control and use in numerical weather prediction systems. The NCO provides management, procurement, development, installation, maintenance, and operation of all computing and communications-related services which link the individual NCEP activities together. The NCO is the focal point for the establishment and execution of policies, standards, procedures, and documentation for computing and communications within the entire NCEP organization. The NCO houses and runs the supercomputer facility and implements and monitors the management of all operational modifications to NCEP products to ensure the reliability of scheduled services. The NCO provides the technical transition between the research and development of numerical weather and climate prediction models and their operational use. The NCO also manages the NCEP databases for use by numerical weather and climate prediction systems and other operational and developmental efforts of NCEP. In addition, NCO provides 24-hour information services and operational support for NCEP computing systems, including the network which ties together internal NCEP communications, NWS mainframe and supercomputer systems, workstations, graphics plotters, and personal computers.

SUPPORTING RESEARCH

The NWS conducts applied research, building upon the more basic research conducted by NOAA laboratories and the academic community. Applied meteorological and hydrological research is integral to providing more timely and accurate weather and flood warning and forecast services to the U.S. public.

Meteorological Research. The NWS conducts meteorological research to develop, test, evaluate, and improve numerical models and analysis/forecast techniques used in weather and climate prediction including:

- Techniques for predicting mesoscale phenomena (e.g., heavy precipitation, tornadoes, and severe thunderstorms). These techniques will be developed and improved to use digital data from new observing systems such as the Next Generation Weather Radar (NEXRAD) with Doppler capability, and geostationary satellites with higher resolution (GOES-NEXT).
- Models to improve hurricane tracking, hurricane probability estimates, and tropical analyses.
- Storm surge models to assist in developing hurricane evacuation plans for additional coastal basins.

Hydrological Research. The NWS develops improved hydrologic and hydrometeorological models and procedures in support of the national flood forecasting and water resources forecasting programs including:

- Improvements to the Extended Streamflow Prediction model and its complementary models in the NWS River Forecast System.
- Specialized flood and flash flood forecasting procedures using linked hydrological and meteorological models.
- Algorithms to combine WSR-88D precipitation estimates with data from satellites and other ground-based observation systems.

MODERNIZATION

A Strategic Plan for the Modernization and Associated Restructuring of the NWS was submitted to Congress in 1989. Implementation of the plan will optimize efficiency and effectiveness of the mesoscale warning and forecast program and will include an operational demonstration and evaluation program as required by Public Law 102-567 to refine operational procedures and resolve implementation issues best addressed through actual field experience. Continued improvements in larger scale, centrally prepared weather guidance products for Day II and beyond through advanced forecasting models and the requested increased computer processing capability are essential to successful

implementation of mesoscale forecasting in NWS field operations, where field forecasters will concentrate on the small-scale, short-lived processes that occur in the 0 to 36-hour timescale.

The National Implementation Plan will provide a planning framework and general strategies for accomplishing the transition as well as advanced notification of when implementation activities are scheduled to occur at each site. The interrelationships of all of the activities--facilities preparation, staffing augmentation, training, commissioning of systems, and realigning operations and services--have begun so that the demonstration can begin in 1996. In addition to preparations for the demonstration, nationwide planning and implementation have begun. Facilities construction is ongoing; training for field personnel is being conducted with necessary backup personnel to cover operational shifts; software development continues; new communications are being established; and all NWS offices have developed and are updating detailed site plans for the transition. The NWS modernization effort is a complex mix of internal NWS activities and multiple contractor efforts. Internal activities provide land, facilities, software, training, staffing, and new operational procedures.

Modernization and Associated Restructuring. The NWS has begun this process of change prompted by two factors: the need to apply advances in hydrometeorological science and technology to operational forecasting and the need to replace obsolete and increasingly unreliable equipment. These factors offer the opportunity to improve severe weather warnings, flood warnings, and forecasts through the acquisition of the following new technologically advanced systems:

- Automated Surface Observing System (ASOS) to reduce time-consuming manual observations, provide continuous weather watch, and permit increased productivity of staff.
- Next Generation Weather Radar (NEXRAD) with Doppler capability and sophisticated software to provide nationwide coverage for timely and accurate detection of severe weather and floods.
- Advanced Weather Interactive Processing System (AWIPS) to enable local forecasters to integrate, process, and transmit high-volume radar, satellite, upper air, surface observation data and guidance information.
- Computer Facility Upgrades to accommodate advanced numerical weather prediction models and increased data to improve accuracy of forecast guidance.

These systems upgrades, coupled with observations from planned, advanced geostationary and polar-orbiting satellites and newly developed mesoscale forecasting techniques, will greatly improve the timeliness and accuracy of severe weather and flood warnings to the U.S. public. Improved capability to detect and predict the small-scale, short-lived (mesoscale) phenomena which cause the most destructive weather events will increase warning lead times for severe thunderstorms, tornadoes, high winds, and flash floods, as well as reduce false warning.

NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE

The National Environmental Satellite, Data, and Information Service (NESDIS) manages United States civil operational environmental satellite systems, as well as global databases for meteorology, oceanography, solid-earth geophysics, and solar-terrestrial sciences. From these sources, NESDIS develops and distributes environmental data and information products and services critical to the protection of life and property, the national economy, energy development and distribution, global food supplies, and development and management of environmental resources.

NESDIS was established as a NOAA line office on December 1, 1982. It was formed by the merger of the former National Environmental Satellite Service (NESS) and Environmental Data and Information Service (EDIS).

NESDIS operates polar-orbiting satellites in sun-synchronous orbits with equatorial crossing times in the early morning (circa 7:30 a.m. LST) and early afternoon (circa 1:40 p.m. LST). These satellites collect global data four times per day that provide atmospheric and surface measurements in support of short-term weather forecasting and longer-term global climate change research. An agreement to be finalized with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) will give

EUMETSAT responsibility for the morning segment of the polar environmental mission (circa 9:30 a.m. LST), with U.S.-provided payload instruments and sensors, beginning early in the next decade.

On October 3, 1994, NOAA, DOD, and the National Aeronautics and Space Administration (NASA) created an Integrated Program Office (IPO) to develop, manage, acquire and operate the national polar-orbiting meteorological satellite system, subsequently designated the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The IPO is organizationally located within NOAA and is headed by a System Program Director responsible to the NPOESS Executive Committee. This Committee, which includes senior representatives from the three agencies, serves as a board of directors to ensure that the overall program plans meet the needs of the three participating agencies.

The Integrated Program Office concept provides each of the participating agencies with lead responsibility for one of three primary functional areas. NOAA has overall responsibility for the converged system and is responsible to the IPO for satellite operations. NOAA is also the primary interface with the international and civil user communities. DOD is responsible to support the IPO for major systems acquisitions including launch support. NASA has a primary responsibility for facilitating the development and incorporation of new cost-effective technologies into the converged system. Although each agency provides certain key personnel in their lead role, each functional division is staffed by tri-agency work teams to maintain the integrated approach.

The first converged satellite is expected to be available sometime toward the middle to latter half of the next decade depending on when the current NOAA and DMSP programmed satellite assets are exhausted. NPOESS will provide standard meteorological data, oceanographic, environmental, climatic, space environmental remote sensing information, as well as continuing to provide surface data collection and search and rescue capability. The IPO, in consultation with the NOAA and DMSP program offices is also studying additional potential cost effective approaches to maximize user satisfaction during the transition to NPOESS while guaranteeing continued non-interrupted data services.

NESDIS is also responsible for operating two Geostationary Operational Environmental Satellites (GOES). One monitors the Atlantic Ocean, the U.S. East and Gulf Coasts, and the U.S. Midwest; the other monitors the Pacific Ocean and U.S. West Coast.

The first of a new series of NOAA geostationary satellites, GOES-8, was successfully launched on April 13, 1994, and subsequently moved to its new operating position of 75°W. GOES-9 was launched on May 23, 1995 and after extensive testing was repositioned at 135°W. GOES-10 was successfully launched on April 25, 1997. The instruments were initialized on May 7th, and the first test images began May 8. The first full-disk visible image was captured May 13. GOES-10 was to be placed at 105°W, stored "sleeping" on-orbit, facing away from the Sun in what is called the ZAP mode (Z-Axis Precession, one rotation per year relative to the Earth, for storage on-orbit facing steadily away from the Sun). It is planned to be activated only upon the failure of GOES-8 or GOES-9. However, GOES-10 is currently in safe hold mode due to its third and most serious solar array anomaly on May 27. After on-line engineers determined that the array had stopped and was at the two degree limit off the sun, the array stepping was powered off and the spacecraft commanded to safe hold mode. NASA began a test to move the solar array 1.5 degrees in the reverse direction each night for three successive nights beginning July 16. If the array eventually makes a few turns "counterclockwise" without stopping, the entire spacecraft will be flipped over and operated with the solar array pointing north instead of south.

ENVIRONMENTAL SATELLITE SERVICES

The Office of Satellite Operations (OSO) directs the operation of NOAA's environmental satellites and the acquisition of remotely sensed environmental data. It manages the Satellite Operations Control Center (SOCC) and Command and Data Acquisition (CDA) stations, which command and control, track, and acquire data from these environmental satellites.

OSO will take over the command, control, and communications function of the DOD's Defense Meteorological Satellite Program (DMSP) constellation in the spring of 1998. This combination of control functions will coincide with the planned closure of the U.S. Air Force Satellite Operational Control Centers at Fairchild Air Force Base in Washington and Offutt Air Force Base in Nebraska. The mission of DMSP is to provide meteorological and special sensor data to users in support of worldwide DOD missions. DMSP will be operated from the Satellite Operations Control Center (SOCC) at Suitland, MD. SOCC is the primary center for normal operations, mission planning, engineering, launch and early orbit support, and anomaly resolution.

A new ground system is being developed for DMSP called IPACS (Integrated Polar Acquisition and Control Subsystem). The hardware is scheduled to be installed October of 1997. Training and system testing shall run until the beginning of 1998 with System Acceptance Test ending early March. Operations testing will be completed in April/May 1998 with SOCC in full control of the constellation.

The Office of Satellite Data Processing and Distribution (OSDPD) directs the operations of NESDIS central ground data processing facilities. It processes and distributes current weather satellite data and derived products to the National Weather Service (NWS) and other domestic and foreign users.

The NWS Satellite Field Distribution Facilities (SFDF) distribute processed geostationary and polar orbiting satellite products to regional NWS offices and other federal, state, and private sector agencies. The products also are made available to private groups at their expense. SFDFs are located in Washington, D.C., Miami, Florida, Kansas City, Missouri, Honolulu, Hawaii, San Francisco, California, and Anchorage, Alaska. The Kansas City, Miami, San Francisco, Anchorage, and Honolulu SFDFs also have the capability of receiving data broadcast directly from the polar-orbiting satellites via the High Resolution Picture Transmission (HRPT) Image Processing System (see "Polar-Orbiting Systems" below.)

The International COSPAS-SARSAT Program now includes participants from six continents. In 1996, Algeria, Madagascar, and Peru became associated with the program, bringing the number of participating states to twenty-nine.

NESDIS continued its support of the COSPAS-SARSAT Program through provision of satellites, ground stations, and alert data distribution services. Russia, the United States, France, and Canada provide the space segment and related ground systems for COSPAS-SARSAT. NOAA operates and maintains the United States SARSAT Mission Control Center and seven ground stations. The ground stations receive Doppler signals directly from the satellites and process the information to provide the location of distress transmissions.

In April 1996, the COSPAS-SARSAT Council agreed to a management plan and timetable for the development of Geostationary Earth Orbit Search and Rescue (GEOSAR) satellite systems as a supplement to the existing Cospas-Sarsat polar-orbiting system. Cospas-Sarsat intends to adopt an operational GEOSAR space segment by late 1998. GEOSAR systems will provide instantaneous alerting capability and could significantly decrease rescue times.

In April 1996, the Cospas-Sarsat Council also agreed to implement new emergency beacon location protocols to provide precise location within the beacon message. Therefore, by 1998, new Cospas-Sarsat emergency beacons will provide precision location information through systems such as the United States Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS).

Arctic Drifting Buoy Program. The United States Interagency Arctic Buoy Program (USIABP) was established in 1992 to provide the management structure and coordination necessary to maintain a baseline network of drifting buoys. Buoys within the array provide sufficient spatial resolution to define surface synoptic scale atmospheric pressure, air temperature, and sea-ice drift fields. Data are used in real-time for operational weather and ice forecasting and for research in the Global Climate Change Program. The USIABP is a collaborative program that draws operating funds and services from the collective contributions of eight government agencies and/or programs. These organizations include: the Naval Oceanographic Office, ONR, NASA, NSF, and NOAA's NESDIS, OAR, and OGP.

The Office of Research and Applications (ORA) provides guidance and direction for NESDIS research and applications activities. It coordinates the efforts of the Climate Research and Applications Division, Atmospheric Research and Applications Division, and Oceanic Research and Applications Division. These Divisions conduct studies on the use of satellite data to monitor environmental characteristics and change and develop algorithms to produce satellite products for applications to operational weather and ocean analyses and prediction. Further, ORA participates in the development of new spacecraft and sensors for future systems. It also carries out a vigorous program to calibrate and validate satellite data to ensure its quality for long-term studies. Staff from these Divisions also conduct a strong technology transfer program through scientific presentations, technical reports, Internet based tutorials, and training workshops at domestic and international sites.

Polar-Orbiting Systems

These satellites increase the accuracy of weather forecasting by providing quantitative data required for improved numerical weather forecast models. Currently, the primary operational spacecraft are NOAA-14 and NOAA-12. NOAA-9 and NOAA-11 also provide data from operational sensors. NOAA polar satellites carry instruments to provide atmospheric temperature and moisture profiles. They also provide multi-channel images and carry a data collection and platform location system, and a Search and Rescue Satellite-Aided Tracking (SARSAT) subsystem. The SARSAT subsystem is used to detect and locate distress alerts from maritime, aviation, and land-based users.

The NOAA-series satellites carry four primary instrument systems. The Advanced Very High Resolution Radiometer (AVHRR) provides data for real-time transmission to both Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) users and for storage on the spacecraft tape recorders for later playback. The AVHRR instrument provides stored and direct-readout radiometer data for day and night cloud cover, sea surface temperatures, vegetation indices, and snow and ice mapping.

The TIROS-N Operational Vertical Sounder (TOVS) system combines data from several complementary sounding instruments on the spacecraft. These instruments are the High Resolution Infrared Sounder (HIRS/2), the Stratospheric Sounding Unit (SSU), and the Microwave Sounding Unit (MSU). HIRS/2, the primary instrument providing tropospheric data, is sensitive to energy from the visible to the carbon dioxide absorption region of the infrared (IR) spectrum. The SSU instrument, which is sensitive to energy in the carbon dioxide absorption portion of the infrared spectrum, provides temperature information from the stratosphere. This instrument is provided by the Meteorological Office of the United Kingdom. The third instrument, the MSU, is sensitive to energy in the oxygen absorption region of the microwave spectrum and is used in conjunction with the two IR instruments. The microwave data permit computations to be made in the presence of clouds.

The Data Collection System (DCS) is provided by the Centre National d'Etudes Spatiales of France and is called the ARGOS DCS. The ARGOS DCS provides a means to locate and collect data from fixed and moving platforms. An upgrade to allow forward message downlinking is being considered for the NOAA-N' satellite.

The Space Environment Monitor (SEM) measures solar proton flux, alpha particle and electron flux density, and energy spectrum and total particulate energy distribution at spacecraft altitude. The two sensors included within this instrument are the Total Energy Detector (TED) and the Medium Energy Proton and Electron Detector (MEPED), in addition to a common data processing unit. This instrument augments the measurements made by NOAA's geostationary satellites.

In addition to the four primary instrument systems, the "afternoon" NOAA series spacecraft carry the Solar Backscatter Ultraviolet Radiometer (SBUV/2). SBUV/2 is a non-scanning (fixed nadir viewing) spectrometer designed to measure scene radiance and solar spectral irradiance from 160 nanometers to 400 nanometers. Data obtained from the instrument are used to compute the amount and vertical distribution of ozone in the Earth's atmosphere on the sunlit side of the Earth.

The ground system required to receive large volumes of digital data from NOAA satellites consists of two major subsystems--the Polar Acquisition and Control Subsystem (PACS) and the Central Environmental Satellite Computer System (CEMSCS). The PACS includes the Wallops, Virginia, and Fairbanks, Alaska, CDA stations and the SOCC at Suitland, Maryland. All the CEMSCS components are in the NOAA facility at Suitland.

PACS is used to command and control the spacecraft, monitor its health via housekeeping telemetry, and retrieve and transmit the spacecraft environmental data to the CEMSCS processing and data handling facility. The delivery of NOAA system data from the CDAs to Suitland is accomplished by using the General Electric American Communications, Inc. commercial satellite communications network. This system, which includes Earth stations at Suitland, Wallops, and Fairbanks, delivers the data to SOCC. These data are immediately passed on to the CEMSCS for processing. The CEMSCS ingests the raw satellite data and pre-processes and stores them along with appended auxiliary information, such as Earth location and quality control parameters. The data processed by the CEMSCS are used for environmental products and operational weather predictions which are disseminated to users throughout the world.

Geostationary Satellite Program

Two operational geostationary satellites, GOES-8 (75°W) and GOES-9 (135°W), now cover virtually the entire western hemisphere for operational meteorological services. New operating schedules allow acquisition and distribution of imagery from the satellites four times per hour over much of North America in Routine mode, and eight times per hour over the continuous U.S. during severe weather situations.

The projected launch schedule and associated instruments for geostationary satellites are shown in Table A.1.

The GOES satellites host an imager capable of detecting atmospheric, sea surface, and land properties in five spectral bands including the 3.9 micron (μ) and 12.0μ wavelengths. GOES satellites transmit all five spectral bands simultaneously, affording the user community continuous views of atmospheric measurements in various wavelengths, each with its own meteorological and hydrological application. GOES spacecraft were designed for flexible scanning of the Earth; a variety of scans or sector coverage can be scheduled within a 30-minute time frame. For example, the full earth disk is scanned once every three hours and requires the entire 30-minute time period. Depending on weather, 30-minute periods during the 2˝ hours after the full disk scan may be a mixture of 15 minute interval (routine weather) or 7˝ minute interval (severe weather) scans over the contiguous United States. To further support mesoscale and microscale analyses, 1000 km x 1000 km coverage can also be scanned at one minute intervals to capture rapidly developing and dynamic environmental phenomena.

The five channels and respective resolutions are as follows:

- Channel 1 (Visible, .55μ to .75μ)--1 km.
- Channel 2 (Infrared, 3.8μ to 4.0μ)--4 km.
- Channel 3 (Water Vapor, 6.5μ to 7.0μ)--8 km.
- Channel 4 (Infrared, 10.2μ to 11.2μ)--4 km.
- Channel 5 (Infrared, 11.5μ to 12.5μ)--4 km.

The GOES-8 and GOES-9 sounder, consisting of 19 spectral channels is used for measurements of atmospheric temperature and moisture profiles, surface and cloud top temperatures, and ozone distribution. Products derived from the sounder include precipitable water and lifted index--a measurement of atmospheric stability. Comparable to the imager, the sounder is capable of providing various scan coverages, such as full Earth imagery, sectorized imagery, and local imagery. An independent sounder platform, governed under its own schedule, leads to an expansion of sounder-data coverage and an increase in the frequency of transmissions.

The GOES also carries a DCS which is used to collect and relay environmental data observed by a variety of remotely located platforms, such as river and tide gages, seismometers, buoys, ships, and automatic weather stations. GOES satellites rebroadcast imagery, meteorological analyses, and other environmental data to remote locations using the WEFAX system. Data are collected for warnings of solar activity using SEM. This block of instruments is more extensive than on the polar spacecraft. The GOES SEM instruments include X-ray monitors that detect solar flares, energetic particle sensors, and three-component vector magnetometers to measure changes in the ambient magnetic field. Real-time SEM data are used to

TABLE A.1 PROJECTED SATELLITE LAUNCH SCHEDULE

POLAR-ORBITING SYSTEM

Satellite Designator	Planned Launch Date*
NOAA K	CY 1998
NOAA L	CY 2000
NOAA M	CY 2001
METOP-1	CY 2002
NOAA N	CY 2004
METOP-2	CY 2006
NOAA N'	CY 2007
NPOESS-1	CY 2009
NPOESS-2	CY 2010
METOP-3	CY 2011
NPOESS-3	CY 2014
METOP-4	CY 2015
NPOESS-4	CY 2016
NPOESS-5	CY 2018

GEOSTATIONARY SYSTEM

Satellite Designator	Planned Launch Date*
GOES M	CY 2000
GOES L	CY 2002 (Failure)
GOES N	CY 2002
GOES O	CY 2005
GOES P	CY 2007
GOES Q	CY 2010

NOAA Instruments for NOAA Polar-Orbiter and METOP Series

AVHRR	Advanced Very High Resolution Radiometer
SEM	Space Environment Monitor
SBUV	Solar Backscatter Ultraviolet Radiometer (NOAA pm mission only)
HIRS	High Resolution Infrared Sounder
SAR	Search and Rescue System (Antenna)
DCS	ARGOS Data Collection System
AMSU-A	Advanced Microwave Sounding Unit-A
AMSU-B	Advanced Microwave Sounding Unit-B

Instruments for NPOESS Series

VIIRS	Visible/Infrared Imager/Radiometer Suite
CMIS	Conical Microwave Imager/Sounder
CrIMSS	Cross-track Infrared/Microwave Sounder Suite
OMPS	Ozone Mapper/Profiler Suite
SES	Space Environment Suite
DCS	Data Collection System
SARSAT	Search and Rescue Satellite Aided Tracking System
ERBS	Earth Radiation Budget Sensor
TSIS	Total Solar Irradiance Sensor
ALT	Altimeter (Dual Frequency radar altimeter)

Instruments for GOES-Next Series

Imager	
Sounder	
SEM	Space Environment Monitor
SXI	Solar X-Ray Imager (GOES L or M)
SAR	Search and Rescue
DCS	Data Collection System

*Launch date depends on performance of prior spacecraft and is subject to change.

support operational NOAA and DOD space environment forecasts and alerts. Data from GOES SEM sensors are archived by the National Geophysical Data Center and provided to retrospective users on-line via Internet and on a variety of computer media.

A system similar technically to the DCS, but used for a different purpose, is the SARSAT transponder. The operational SARSAT transponders on GOES-8 and GOES-9 are capable of providing an immediate distress alert. While the present GOES system is incapable of providing location of the distress signal, it provides advance warning to the SARSAT Mission Control Center which then begins to verify the location of the alert through other means. Future COSPAS-SARSAT distress beacons, utilizing Global Positioning System (GPS), will have the capability to provide location information in the distress message. Remapped GOES-8 and GOES-9 images for the NWS AWIPS began flowing to "Pathfinder" sites at Boston and Pittsburgh via the point-to-multipoint data feed known as NOAAPORT in 1995. NWS will deploy another 14 AWIPS sites in 1996, and the remaining 100 or so in the following two years. NOAAPORT delivers GOES imagery available to forecasters within seconds of satellite scanning and makes it a valuable new real-time capability.

As AWIPS development and deployment proceed, NESDIS will continue to supply digital GOES images to a group of NWS sites equipped with the RAMM Branch Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS)--a PC-based image display and analysis system. These sites acquire the images via the Internet for demonstration, evaluation, and familiarization purposes. RAMSDIS enables forecasters to perform operations such as looping, enhancement curve changes, and local image recombination.

Satellite Communications System (SATCOM)

The NESDIS Telecommunications System is a complex network of voice, teletype, and data-grade transmissions sent via satellites, microwave, and terrestrial cable services. A major component of the system is the Office of Satellite Operations (OSO) which consists of the SOCC and two CDA stations at Wallops, Virginia, and Fairbanks, Alaska. OSO is responsible for the operation and safety of NOAA polar and geostationary satellites and for providing satellite data to OSDPD.

Another major component is the Environmental Satellite Distribution/Interactive Processing Center (ESD/IPC) in Camp Springs, Maryland. The ESD/IPC is connected in turn with the Fairbanks and Wallops CDA stations and the six SFDFs.

A third major component, managed and operated by OSDPD and NOAA's National Climatic Data Center (NCDC), is the NOAA Operational Satellite Active Archive (SAA) for satellite data and metadata access, display, and electronic transfer. The SAA offers the user a wide range of capabilities, including data catalog and inventory search, AVHRR image browse, on-line data selection and file transfer protocol (FTP), and off-line data selection and delivery. On-line system documentation, data guides, and help files will assist the novice user and provide valuable time-saving tips to all users. While developed as an independent system, the SAA serves as NOAA's initial interoperable interface to NASA's Earth Observing System Data and Information System (EOSDIS). In 1997, DMSP special sensor products and RADARSAT products for authorized subscribers, were made available to users.

SUPPORTING RESEARCH PROGRAM

Temperature and Moisture Soundings

A new radiative transfer algorithm has been developed that is fundamentally more accurate than previous methods, especially for channels affected by water vapor. In ongoing work, this algorithm is being adapted for use by NCEP to directly assimilate the satellite-observed radiances into the operational analysis. Once completed, NCEP will be able to assimilate radiances from the NOAA and DMSP polar orbiting satellites and the geostationary satellites. The algorithm will also be used in data impact studies to assist in finding the instrument suite for NPOESS that will have the greatest positive impact on numerical forecasts.

Ozone

FY 1998 is expected to be a peak year for stratospheric ozone depletion after which a slow recovery begins. Real time TIROS Operational Vertical Sounder (TOVS) ozone maps continue to provide many scientific organizations (as well as the general public) with ready information about the status of the ozone shield. 1998 represents the 20th year of continuous ozone coverage by the TIROS Operational Vertical Sounder (TOVS) that stretches from pole to pole. There is expected to be continuing cooperation with WMO's weekly monitoring

of the Antarctic ozone hole. TOVS special sensitivity to lower stratospheric ozone variations provides it with unique capabilities for accurately evaluating and tracking lower stratospheric ozone depletions such as the Antarctic hole. While the 1996 ozone hole was not as big as previous holes (i.e., those influenced by Mt. Pinatubo debris) it was clear from the TOVS data that this hole lasted longer that any hole on record. TOVS early reports concerning the longevity of the 1996 were later confirmed by data from the Solar Backscatter Ultraviolet (SBUV/2) instrument.

Validation and analysis of total ozone amount and vertical ozone profiles continue on the products from the NOAA-9, -11 and -14 SBUV/2 instruments. The six-year data set from NOAA-11 has undergone a reprocessing utilizing the most recent and extensive characterization of the instrument in-orbit performance. Reprocessing of the approximate 10-year set of observations with the NOAA-9 instrument will be done this year. The NOAA-11 data set will be merged with the NASA Nimbus-7 SBUV data set and will be put on a readily available CD-ROM as a joint NOAA-NASA effort.

GPS/MET Soundings

NOAA/NESDIS will continue to evaluate soundings of temperature and moisture derived from the GPS for Meteorology (GPS/MET) satellite operated by the University Corporation for Atmospheric Research (UCAR). Vertical temperature profiles available since the 1995 launch of this instrument have excellent vertical resolution (1 km) but poor horizontal resolution (250 km). They show reasonable agreement with conventional observations between 5 km and 20 km in altitude, and may be particularly effective for determination of the height and temperature of the tropopause in data-sparse areas such as oceans and undeveloped land regions. The goal of this activity is to assess whether GPS observations may prove useful as complements to conventional observations for operational weather forecasting and for climate monitoring. NESDIS is cooperating with the Integrated Program Office (IPO) to provide specifications for a GPS limb sounder intended primarily to observe the ionosphere, but which would also be capable of sampling the stratosphere and troposphere. NESDIS will cooperate with NWS to develop algorithms for the assimilation of GPS observations into numerical weather prediction models with the goal of assessing the impact that these data would have on forecasting skill.

Data Continuity

Studies continue on evaluating the continuity of data obtained by similar (or identical) instruments on successive satellites. The issue of maintaining accurate continuity over many years is critical to the study of climate parameters over long-term decadal scales. This is especially true of parameters such as ozone, sea surface temperature and atmospheric temperatures.

Clouds from AVHRR

The means for globally detecting multiple-layered cloud types and specifying cloud amount from the AVHRR on a pixel-scale level has been under development for several years and has been recently enhanced using a dynamic thresholding scheme. Following a thorough validation of the resulting products, algorithms will be developed and refined for determining the optical and microphysical properties of the clouds. Models employed by the NCEP could be greatly enhanced with information on the amount and properties of the layer clouds.

Aerosols

Currently, the aerosol optical thickness (AOT) is derived from a single channel on the AVHRR. Investigations (supported by the NASA CERES project) have shown that information from a second channel that will be present on the NOAA-K series of satellites could provide information relating to the aerosol size distribution. This should yield more accurate estimates of the AOT. Empirical studies will be conducted as soon as the data are available.

Pathfinder

Climate data sets of cloud amount, aerosol optical thickness over the oceans, and the Earth's radiation budget for clear and cloudy skies are being retrospectively generated from fourteen years of AVHRR data as part of the NOAA-NASA Pathfinder program. A second phase of this program is being planned, where multiple-layered cloud data will be used. AOT over the land, shortwave radiation budgets at the surface, a precipitation index, and optical and microphysical properties of clouds will be generated, in addition to those products generated during the first phase.

Effort of Land Surface Properties on Temperature Records

Research activities will continue on the use of satellite-derived data to characterize the land surface properties associated with the network of land-based

meteorological observation stations. The influence of land surface properties on observed temperature has been documented. The goal of this activity is to characterize the land surface properties and identify adjustments to the observed temperature data that account for the bias introduced by the land surface features that surround the observation stations. This effort will utilize data acquired by the NOAA-AVHRR, DMSP-OLS, and Landsat-MSS and -ETM instruments. This activity includes collaboration with scientists at NOAA's National Climatic Data Center (the archive of surface meteorological observation data), National Geophysical Data Center (the archive of DMSP-OLS data) and the USGS EROS Data Center (the archive of current Landsat-MSS data and the future archive of Landsat-7 ETM data).

Satellite Validation of Forecast Models

The accuracy of weather forecast model calculations of cloud cover, cloud altitude, and insolation is unknown, but these quantities are important to forecasts of near-surface temperature and humidity. The GOES cloud and surface radiation products being produced for the Global Energy and Water-Balance Experiment (GEWEX) will be used to validate and then to improve the model algorithms. The model cloud and radiation estimates will be extracted and mapped to the same map projection as the satellite products and made available for study.

Interagency Cooperation

United States Department of Agriculture

Goal: Design an AVHRR-based Drought Monitoring System for Northern Hemisphere

The system will be designed for use by the USDA analysts, decision makers, and scientists. It will consist of a set of AVHRR-based data files and software delivered to a USDA server. It will provide drought information for the major areas of interest to USDA. The system is an operational implementation of recently developed algorithms based on new approaches to combine the visible, near infrared, and thermal bands of AVHRR. When the system is implemented, the USDA specialists can access in real time NOAA/AVHRR data, produce images and time series, compare them with any data since 1985, and use them for more accurate detection of drought onset and areal coverage; for improved analysis of impact assessment; for evaluating moisture- and temperature-related vegetation stress, which is important in developing drought mitigation strategies; distinguishing between two major types of drought: meteorological and agricultural; identifying areas with a late start of the growing season; detecting post-flood events leading to vegetation stress; general conditions of vegetation growth.

International Cooperation

Government of Kazakh (Space Research Institute)

Goal: Monitoring Seasonal Dynamics of Rangeland from NOAA-14 Polar-Orbiting Satellite

The Vegetation and Temperature Condition Indices (VCI/TCI) designed recently for AVHRR data will be calibrated and used for monitoring vegetation health of areas of Kazakh rangeland. This information will be added to and in some areas will substitute for weather-based estimates of pasture conditions for grazing for big herds of sheep. The necessity for this information became apparent in recent years following a deterioration of the weather-watch system due to the difficult economic situation in the country after the breakup of the USSR.

Government of Poland (Institute of Geodezy and Cartography)

Goal: Diagnosis of Vegetation Health in Poland

AVHRR-based algorithms for estimation of weather impacts on vegetation will be calibrated using ground measurement. The results will be used to estimate vegetation health and diagnose net primary production of agricultural land. NOAA/AVHRR data will be also adjusted to land use and technological activities using high resolution satellite data (Landsat, Spot).

Support of GOES-K and -L Launches

The radiometric performance and calibration of each meteorological satellite instrument needs to be thoroughly characterized during the months following launch to insure that it produces data with the accuracy, precision, and sensitivity needed for its mission. NESDIS will collaborate with NASA to evaluate the performance of the GOES-K Imager and Sounder. Characteristics such as signal-to-noise ratio and measurement precision will be determined by analysis of in-orbit observations. Special attention will be directed towards characterizing and (when possible) mitigating the two inherent radiometric anomalies known to affect the infrared channels of the GOES I-M Imagers: (1) Weak artificial east-west striping in images, believed to be a consequence of "1/f noise" in the outputs of the detectors. The striping is uncorrectable in the ground processing. The magnitude of these stripes is of the order of 0.1K in the 11-μm channel of the GOES-8

Imager and somewhat less in the same channel of the GOES-9 Imager. For GOES-8, the striping is intense enough to produce slight degradation in some quantitative products. (2) An artificial east-west gradient in the data, caused by a polarization-induced variation of the emissivity of the instruments' scan mirrors with scan angle. Affecting the channels at wavelengths greater than 5 μm, this gradient can produce a spurious difference of approximately one degree Kelvin between views of the extreme east and west edges of the Earth's disk. The ground calibration processing system now incorporates an algorithm to account for this phenomenon in all the GOES I-M instruments. Coefficients for applying the algorithm to the GOES-K instruments will be generated from special measurements that are part of the GOES-K checkouts.

Before the launch of the GOES-L satellite, a test to demonstrate that the outputs of the instruments on the satellite are compatible with the ground processing system will be performed. Taped data from thermal/vacuum tests of the instruments will be sent through the ground system, and the results of the processing will be evaluated. In addition to demonstrating compatibility between the instruments and the ground system, this will also confirm the validity of the ground processing and give a preview of the radiometric performance of the instruments expected on orbit.

Support of NOAA-K Launch

Following the launch of NOAA-K, NESDIS will collaborate with NASA in the checkouts of the Advanced Very High Resolution Radiometer (AVHRR), High Resolution Infrared Sounder (HIRS), and Advanced Microwave Sounding Units-A and -B (AMSU-A and -B) aboard the polar-orbiting NOAA-K satellite. Special attention will be directed towards the AMSU-A and -B on NOAA-K, because they are the first of a new generation of total-power microwave radiometers, replacing the Microwave Sounding Units (MSU) and the Stratospheric Sounding Units (SSU) flying on the current polar-orbiting satellites. The new AMSU instruments are designed to provide increased accuracy in temperature and humidity retrievals. They will receive a thorough post-launch calibration and evaluation. This will include checking instrument performance against specifications and comparing with pre-launch test results. Long-term trends of the various instrument and blackbody temperatures will also be determined.

Each AMSU-A instrument is composed of two separate units: AMSU-A2 with two channels at 23.8 and 31.4 GHz; and AMSU-A1 with twelve channels in the range of 50.3 to 57.3 GHz and one channel at 89.0 GHz. The AMSU-B has five channels with frequencies centered on 89, 150, and 183 ± 1, 183 ± 3, and 183 ± 7 GHz, respectively. AMSU-B, which is provided by the United Kingdom Meteorological Office, provides soundings of humidity from surface to 200 millibars (mb). AMSU-A has a nominal field of view of 3.3^{o} (48 km on surface at nadir) and AMSU-B a field of view of 1.1^{o} (16 km on surface at nadir). AMSU-A (AMSU-B) samples 30 (90) Earth views, covering $\pm 48.95^{o}$ from the sub-satellite point.

The AMSU-A1 uses two antenna systems, providing observations in the twelve oxygen band channels (3-14) for retrieving the atmospheric temperature profile from the Earth's surface to about 42 kilometer (km), or from 1000 to 2 mb. The remaining three channels (1 and 2 from A2 and 15 from A1) will aid the retrieval of temperature soundings by correction of surface emissivity, atmospheric liquid water, and total precipitable water. These window channels also provide information on precipitation, sea ice, and snow coverage.

Calibration of Visible and Near-Infrared Channels of Advanced Very High Resolution Radiometer

Characterization of the in-orbit performance of meteorological satellite sensors is essential to ensure the accuracy and continuity of long-term records of satellite-derived geophysical products. As the Advanced Very High Resolution Radiometer (AVHRR) has been a major source of products such as vegetation index, aerosols over the global oceans, sea surface temperature, and cloud morphology, several activities have been planned in the area of calibration of the AVHRR during FY 1998. They include (a) refinement of vicarious calibration techniques to account for the in-orbit degradation of the visible and near-infrared channels; (b) evaluation of the feasibility of using the AVHRR as a transfer vicarious calibration standard to characterize the in-orbit performance of other meteorological satellite sensors (e.g., the Along Track Scanning Radiometer; the GOES Imager); and (c) characterization of desert sites as vicarious calibration targets. Both formal and informal plans for collaboration in the above areas have been finalized with the Rutherford Appleton Laboratory, Didcot, United Kingdom; National Satellite Meteorology Center, China Meteorological Administration, Beijing, People's Republic of China; and the National Aeronautics and Space Administration (NASA). In

addition, effective NOAA representation on the Working Group on Calibration and Validation, Committee on Earth Observations Satellites, has resulted in mutually beneficial interaction with the global meteorological satellite community and recognition of the importance and relevance of the planned activities to programs such as the Global Climate Observing System, the Global Ocean Observing System, the Global Terrestrial Observing System, the International Geosphere Biosphere Programme, and the International Global Observing Strategy.

National Polar-orbiting Operational Environmental Satellite System (NPOESS)

ORA is supporting the NPOESS Integrated Program Office in studies of potential instrument concepts for NPOESS. These studies include a VIS/IR imager representing a synergistic combination of the AVHRR and the DOD Block 6 Operational Multispectral Imaging Suite; a conical scanning microwave imager/sounder; an advanced IR sounder; ozone profile and total amount sensors; Earth radiation budget and solar irradiance instruments; passive microwave polarimetry for sea surface wind vectors; evaluation of GPS occultation measurements as complements to NPOESS temperature and H_2O soundings; and synthetic aperture radiometer technology for sea surface salinity and soil moisture.

ENVIRONMENTAL DATA CENTERS

National Climatic Data Center (NCDC)

NCDC has the principal responsibility to manage the national climatological data program, including data and information services. To meet this responsibility, NCDC:

- Performs all data management functions regarding retrospective meteorological data, including data from in-situ and remote sensing sources (satellites, radars, etc.). Such functions include acquisition, archiving, retrieval, indexing, quality assessment, evaluation, synthesis, dissemination, and publication of data collected by global and national observation networks or systems. Meteorological data that have enduring value to the Nation and are sufficient to describe the climate are included.
- Designs and implements new systems, as necessary, for ingesting, processing, quality control and archiving of new data streams from the NWS modernization program.
- Operates as a designated Agency Records Center for processing, storage, and servicing of retrospective meteorological data records.
- Prepares and provides special products and services to users, as required, as a basis for regulatory standards and policy decisions.
- Maintains national and global databases for analyses of long-term climate trends and for monitoring global change.
- Provides facilities, data processing support, data exchange, and expertise, as required, to meet U.S. commitments to foreign nations, international organizations, and to the World Meteorological Organization's (WMO) programs.
- Operates the World Data Center-A (WDC-A) for Meteorology under the auspices of the International Council of Scientific Unions. In this capacity, NCDC archives the data collected by internationally sponsored research programs and actively exchanges climate data with foreign countries.

NCDC is the archive for meteorological data sets from World Climate Research Program and WMO World Climate Data and Monitoring Program projects, such as the Tropical Ocean-Global Atmosphere (TOGA) Program, the Global Precipitation Climatology Program (GPCP), the International Satellite Cloud Climatology Program (ISCCP), etc.

Climate Data Management

NCDC currently ingests, via telecommunications, five data sets (1 minute data, 5 minute observations, hourly observations, daily summary and systems log information) from over 360 commissioned ASOS sites. NCDC uses these data to produce Local Climatological Data (LCD) publications and digital products for a variety of users. Data volumes are growing rapidly as a result of continuing ASOS commissionings. In late 1997, the NCDC will implement a more robust ingest system to ensure a more complete ASOS data set.

- Easy on-line access, visualization and download capabilities of environmental data and metadata continues to be one of the highest priorities for NCDC. More datasets and metadata have been added for access from the NCDC Home Page. Over the past year, NCDC has expanded CLIMVIS, the system which was awarded the 'Best WWW Page of NESDIS' in 1996, by adding access to one of NCDC's most popular data set - the Global Historical Climate Network (GHCN). CLIMVIS is an interactive WWW graphics system, which dynamically generates time series, contour and vector plots in real time using NOAA's environmental data archived at NCDC. This system

also allows the user to download data in image form or in textual form. A World Wide Web version of the Climate Services System (CLISERV) is now on-line(*http://www4.ncdc.noaa.gov/cliserv/dimain.html*). CLISERV allows on-line queries to all digital NCDC metadata from a single access system. The current Web version allows access to station history, data set documentation, and the TD-3200 series inventories. Also available in the Web version is the ability to download unedited files of major U.S. weather station's monthly summaries and synoptic/hourly observations for the current and previous month. This data is published in the Local Climatological Data publication. NCDC has developed several other systems for user access and visualization on the web. This wealth of information and tools is definitely advantageous to the user, but the user must learn each tool and each method of access. Therefore, NCDC is currently planning development of a system which will dramatically expand the data sets provided on-line and seamlessly tie together NOAAServer, NCDC Online Store and most of NCDC WWW systems to create a centralized data/metadata access tool. This system will be developed in phases starting in 1998.

- WSR-88D Level III products from 117 NWS sites are being received and archived. Three additional sites are planned for operation before the end of FY 98. Of the 158 WSR-88D sites operated by NWS, DOD and FAA, 145 sites are providing Level II data to NCDC. To aid users in accessing these data, NCDC is providing services on the World-Wide Web. The services include Level II and III inventories, updated weekly, background information about the WSR-88D network, software for reading and displaying NEXRAD data, storm event directories, and links to related web sites. NCDC has also provided national mosaic images of reflectivity data which users can browse and download. Users may also select and view a 12-hour loop of the mosaic images.

- The Global Historical Climatology Network (GHCN) is a cooperative data collection and quality assurance project between the DOE/CDIAC, NESDIS/NCDC and Arizona State University dealing with global monthly temperature, pressure, and precipitation data. The GHCN version 1, consisting of monthly temperature, precipitation, and pressure data was released in 1992 and work has since progressed on version 2. Global monthly temperature data for version 2 has been completed and includes a maximum/minimum temperature component. This version includes many more global stations extending back to the 19th century. The data for version 2 is quality controlled using sophisticated algorithms and is homogeneity-adjusted, using newly established, peer-reviewed techniques. Population metadata is available in order to more accurately determine global temperature trends that are free of urban heat island biases. In FY 1997 and early FY 1998, a complete version 2 will be released with the addition of precipitation and pressure data. A near-real-time update and analysis system is being developed and will be implemented in the same time frame to keep the data set current as new data are received.

- NCDC completed a comprehensive project involving the WMO regarding the collection, compilation, and quality assurance of WMO standard climate normals for the globe for the period 1961-90. More than 130 countries sent in normals data for a wide range of climatological parameters. The NCDC developed a publication-ready file for the WMO Secretariat in 1996 and the publication was printed and distributed by the WMO in FY 1997. To close out this project, NCDC is producing a CD-ROM of the WMO standard normals which will be distributed to all WMO member countries in early FY 1998.

- For FY 1998, NCDC will complete the production of the publication *Climatography #20 of the United States*. Since the advent of the Internet and distribution of products via the Web, it has been decided that the publication will not be produced in hard copy but rather offered to users via the NCDC Home Page. This publication is based on normals data collected for 1961-90 for selected U.S. sites and includes such parameters as degree days, precipitation probability, freeze data, growing degree units, daily maximum and minimum temperature, monthly temperature means, extremes, days with selected meteorological elements, and precipitation totals. The NCDC is also working with the Unified Climate Access Network (UCAN) project and Regional Climate Centers to ensure that the information offered to the public for this publication is standard and that redundancy is kept to a minimum.

- The United States Historical Climatology Network (USHCN) is a joint project between the DOE/CDIAC and NESDIS/NCDC. Monthly data sets of numerous climatological variables have been prepared and quality controlled with many inherent biases removed. An update system, completed in 1995, has been performing retrospective updates to the data set, shortly after the end of each month. In addition, a gridded daily maximum/minimum temperature and precipitation data set for North America is being developed and will be completed in FY 1998.

- NCDC is developing the capability to produce global monthly land surface temperatures from a blend of *in situ* and satellite-derived data. The satellite data being used are from the SSM/I instruments flown on the DMSP satellites. A climatology of SSM/I data has been built at NCDC and work is continuing on the refinement of the algorithms that identify the temperature over various land surfaces. As part of this work, the surface wetness signal must be identified and removed from the retrievals to provide accurate temperature assessments. Derived surface wetness fields are also of potentially important use for hydrological applications.

- The NCDC functions as the Surface Reference Data Center (SRDC) for the World Climate Research Program Global Precipitation Climatology Project (GPCP). The SRDC is supported by NOAA OGP which is supporting precipitation validation within the GPCP. The SRDC has provided support to GPCP by collecting and validating surface-based precipitation station data from a number of globally distributed test-site areas. During FY 1997, the capability was developed for interactive access through the Internet to the SRDC data and comparison techniques for other user-derived data sets. Additional analyses for GPCP test sites will continue in FY 1998.

- The Comprehensive Ocean-Atmosphere Data Set (COADS) project is a multi-year/multi-agency program funded by Office of Global Programs (OGP) and ESDIM to provide an updated reference data set covering the world's ocean environment. In FY 1997 via a cooperative effort among NCDC, ERL and NCAR, the following accomplishments were achieved: (1) the data period of record was updated through 1995, (2) an additional 250,000 observations from the late 1920s were quality controlled from the U.S. Merchant Marine Collection (1912-1946), (3) the 1.4 million Maury (1792-1910) records digitized in China were being prepared for placement on CD-ROM for a rather rapid distribution in the keying format for evaluation and recom-mendations on the conversion to the COADS format, (4) Release 1b data for the NCEP/NCAR reanalysis project were reprocessed for the period 1950-1979, (5) an International Workshop on historical marine data was sponsored and planned by NOAA, the UK Hadley Centre and the WMO, (6) much effort went into evaluating where the future GTS marine reports will be generated for COADS (NCEP and FNMOC have started providing the GTS data in BUFR which has proven to have a number of problems for basic archiving), (7) the first shipment of marine data from the Film Optical Sensing Device for Input to Computer (FOSDIC) film were recovered and provided to NCDC for evaluation, and, (8) preliminary specifications for converting the U.S. Merchant Marine, Ice Island, and Maury Collections were completed in FY 1997.

- The Comprehensive Aerological Reference Data Set (CARDS) project completed the building of a data base containing daily global upper air observations processed through Complex Quality Control Version 2 for the period 1948-1990. It is composed of 23GB of data for a total of 2500 stations. Data from 20 different sources were combined to form this database. A 188 station baseline of core climatological stations was identified. Detailed year-month climatological statistics were developed for individual stations and for a 5 degree grid. In FY 1998, the CARDS project will complete the building of the upper air data base through 1997 and will make the data base available on both exabyte and cartridge tapes.

Climate Data Services.

The demand for basic climatic data and information services continues to increase. NCDC will service over 170,000 requests for data and information during FY 1997. In addition, over 1.3 million accesses to on-line data and information will be handled by the Center's automated systems. Currently, over 30 climate data sets are accessible on-line. This number is expected to increase significantly over FY 1998 as NCDC is making a concerted effort to service more requests automatically

through the Internet. NCDC's Homepage is frequently updated with new products and capabilities. A new on-line ordering system has been implemented which allows customers to browse data products and place orders on-line. Technical reports detailing severe weather events are made available through NCDC's web site. These reports are published soon after the associated weather event and contain summary and statistical information along with related satellite and radar imagery. Customers may view NCDC's web site by accessing the following URL address: *http://www.ncdc.noaa.gov*.

NCDC, in conjunction with the University of Wisconsin, is developing a new Geostationary Satellite Archive System (GSAS). This new system will store data on state-of-the-art high density tape media making it more readily available to customers. The GSAS will also provide the most recent four days of data from both GOES satellites. It is scheduled to be operational on October 1, 1997. In conjunction with the GSAS, NCDC has implemented a GOES Browser system on its web site which allows customers to peruse GOES imagery on-line for the period of 1992 to present.

There continues to be a demand for climate data and information products on CD-ROM media. NCDC has released 52 CD-ROM volumes. Included in these releases are NCDC's first monthly subscription CD-ROM product, a 3 volume set containing the majority of the global surface and upper air charts produced by NCEP and archived at NCDC. During FY 1998, NCDC expects to release an additional 30 volumes, including current printed publications and a Windows 95 version of the International Station Meteorological Climate Summary CD-ROM.

National Oceanographic Data Center (NODC)

NODC supports climatic services and research through its data management and data services activities. The NODC provides data management for major climate-related studies, such as the TOGA program, the World Ocean Circulation Experiment (WOCE), and the Joint Global Ocean Flux Study (JGOFS). NODC also provides data products and services individually to researchers as well as to members of the operational marine community, e.g., the Navy, Coast Guard, and shipping industry.

National Geophysical Data Center (NGDC)

NGDC participates in a number of national and international programs that provide data for research in meteorology, climatology and space weather. NGDC provides data processing, management, archival and service programs concerned with atmospheric emissions recorded by satellite instruments, as well as indirect or proxy measures of past climates. NGDC also provides services for supporting data sets including the cryosphere.

Climate Data Management and Services

At NGDC, NOAA established a program to assemble global information on paleoclimate and to cooperate in research projects to employ the combined global paleoclimate database for climate model verification and climate change studies. NGDC has acquired many paleoclimate databases derived from tree-rings, pollen and macrofossils, lake and bog sediments, marine sediments, ice cores, and other geological and biological sources. Paleoclimate databases can be displayed and searched using custom software that is being distributed to the research community. Objectives of the program are to cooperate with researchers to describe the global patterns of annual-to-millennial scale climate change, to understand the causes of climate change, to separate man-induced climate change from the natural variability, and to validate the models that are used to predict future climates. Support for this program from the NOAA Climate and Global Change Program (CGCP) is continuing.

NGDC prepares, manages, archives and services research-quality data sets from the complete set of scientific instruments on operational Defense Meteorological Satellite Program (DMSP) satellites. DMSP instruments use remote-sensing techniques to infer the horizontal and vertical structure of the lower and upper regions of the atmosphere. NGDC's processing system is very extensive. The archival data sets are visible-to-near infrared, thermal infrared, and microwave imagery, microwave soundings of atmospheric temperature and water vapor, and in situ measurements of ionospheric plasma parameters and the Earth's magnetic field. NGDC provides an on-line search and browse system called the Space Physics Interactive Data Resource, tape copies and publication quality prints. Software tools used to analyze DMSP imagery and soundings are data display routines, pixel geolocate routines, and programs to derive additional geophysical parameters.

The National Snow and Ice Data Center (NSIDC) at the University of Colorado, and associated with NGDC, maintains several cryosphere-related data sets of interest

to meteorology and climatology. These include a collection of historical photographs of glaciers, temperature, pressure, and position data from satellite-queried drifting buoys placed on the central Arctic pack ice, and data from the NOAA snow cover and DOD-NOAA sea ice chart digitizing programs. NSIDC provides data management services for the Second Greenland Ice Sheet Program and the National Science Foundation (NSF) funded Arctic System Science Ocean-Atmosphere-Ice Interaction research programs. In addition, NSIDC has developed gridded sea ice products (sea ice concentration and multi-year ice fraction) based upon passive microwave data collected by the Scanning Multi-channel Microwave Radiometer on Nimbus 7 and the DMSP Special Sensor Microwave Imager. The passive microwave data sets are being distributed on CD-ROM. In addition, NSIDC serves cryospheric and polar users of DMSP data from the NGDC digital archive. Under NOAA funding, NSIDC is acquiring snow cover, glacier, and sea ice records from former Soviet Union scientists and institutes.

Long-term, global records of variations in solar energy are archived at NGDC are the principle databases available to support research into the impact of changing solar energy output affecting Earth and climate change. Satellite instruments now monitor total solar irradiance and spectral irradiance at a few selected wavelengths before modification by the Earth's atmosphere. However, historical and proxy data sets from the archives are required to provide longer term records that describe the past output of solar energy. Data services include tape copies and
on-line access.

Space Weather Data Management and Services

NGDC builds, manages, archives and services the national archive of space environmental data that are collected to monitor the space environment. These data describe the temporal history of the upper atmosphere, the ionosphere, the magnetosphere, interplanetary space, and the sun. The key databases are measurements of the Earth's magnetic field, remote sensing of the ionosphere, in situ measurements of particles and fields in space, and solar imagery recorded at different wavelengths. NOAA's POES and GOES programs and DOD's DMSP program provide space environment monitoring data to NGDC. Ground-based monitoring programs contributing data to NGDC are operated by NOAA, NSF, USGS, DOD, and academia. International data contributions are received by the World Data Center for Solar-Terrestrial Physics operated by NGDC. Data services include tape copies, on-line search and browse, and display software. Reduced volume data sets are also available on CD-ROM.

ENVIRONMENTAL RESEARCH LABORATORIES

The R&D programs of the Environmental Research Laboratories (ERL) support NOAA meteorological, oceanographic, and space services and are oriented toward providing, understanding, and developing techniques and technologies to form the basis for improvements in the Nation's weather services. These important functions encompass the missions of several ERL laboratories.

Special emphasis is placed on improving severe weather and hurricane warnings and forecasts and improved utilization of data and numerical products. Severe weather includes any major natural hazard, such as flash floods, strong winds, thunderstorms (including tornadoes, lightning and hail), heavy snowstorms, extreme cold or drought, and geomagnetic storms. ERL laboratories will continue to conduct both in-house and cooperative research with other NOAA components, joint institutes, and universities.

Observing Technology. The Environmental Technology Laboratory (ETL), formerly the Wave Propagation Laboratory, develops and experimentally evaluates new environmental remote-sensing concepts and systems. ETL also improves the Nation's atmospheric research and warning and forecasting services through the transfer of remote-sensing technology.

As an outcome of ETL research, ERL's Forecast Systems Laboratory (FSL) is operating the wind profiling Doppler radars that make up the Wind Profiler Demonstration Network (WPDN). This network, located mainly in the central United States, is providing hourly winds aloft data to weather forecasters and is helping improve weather warnings and forecasts.

During FY 1998, FSL will be developing and installing three 449 MHz wind profilers in Alaska. One of these three will be converted from the 403 MHz profiler at Homer, Alaska. The other two will be specifically developed for the Alaska region. The profilers will support volcano plume tracking, which has been shown to be a serious problem for aircraft operations and weather forecasting activities in Alaska.

FSL will continue to develop ground-based GPS technology for measuring water vapor in the atmosphere. Initially, processing of the data will be after-the-fact and in the laboratory but eventually in real time. Additional sensors will be established at the National Data Buoy Center in Mississippi and at various Coast Guard sites throughout the United States.

During FY 1998, ETL will continue development of new sensors and techniques for combining observing systems synergistically and economically. Specific efforts include the development and integration of the radio-acoustic sounding system (RASS) into wind profilers to augment their capability with temperature profiles and continuing development of techniques that can integrate the data from ground-based and satellite-borne profiling systems for more effective use of this data in forecasts. ETL and FSL will continue investigating the use of inexpensive GPS receivers to achieve real-time, continuous observations of total atmospheric water vapor.

ETL will also continue development of Lidars and infrared Doppler multi-frequency radars as research tools to improve our knowledge of atmospheric winds, turbulence, and moisture processes. Development of dual-polarization Doppler and multi-frequency radars and passive radiometers will also be undertaken to study convective storms and their precursors, including in-cloud and entrainment processes. ETL will also continue research in the area of ocean remote sensing, including theoretical and experimental studies of rough surface scattering processes.

Tropical Atmospheric Research. The Tropical Dynamics and Climate Program of the Aeronomy Laboratory (AL) is using a network of remote-sensing wind profilers in a long term study of tropical circulation and its impact on global climate. The Trans-Pacific Profiler Network consists of an array of wind profilers and Integrated Sounding Systems that make continuous measurements of atmospheric winds and other parameters in the tropical Pacific. In addition to 50 MHz wind profilers, the network is incorporating 915 MHz lower tropospheric wind profilers recently developed at AL. The observations, which extend from the boundary layer to the lower stratosphere, reveal the relationship between atmospheric vertical motions and convective systems in the tropics. Precipitation measurements can be made with sufficient vertical resolution to categorize precipitation in deep and shallow convective systems and in stratiform conditions. The network will (1) provide valuable improvements to the boundary layer and convective

parameterization schemes used in general circulation models and (2) contribute to climate forecasting by furthering the understanding of the coupled ocean-atmosphere dynamics that governs the El Niño-Southern Oscillation (ENSO) phenomenon, the dominant component of interannual climate change.

Routine wind observations are made at Christmas Island using a 50 MHz and 915 MHz profiler. Lower tropospheric wind measurements using 915 MHz profilers are made at San Cristobal, Ecuador, and Tarawa, Kiribati. In addition, surface and upper air measurements are being made at Nauru and Manus Island, Papua New Guinea, using Integrated Sounding Systems installed by AL. Recently, a shipboard wind profiler has been brought into operation to provide measurements throughout the equatorial Pacific as the ship tends to buoys in the Tropical Atmospheric Ocean (TAO) array. An additional profiler will be installed on the R/V Ron Brown to gather data during the Pan American Climate Studies (PACS) field program in the eastern tropical Pacific in August 1997. Data from these systems are used by NCEP and the European Center for Medium Range Weather Forecasting in their operational analysis and forecast products. The data are also used by climate researchers to support investigations of the variability of tropical atmospheric circulation systems.

Severe Weather Analysis and Forecasting Research. The National Severe Storms Laboratory (NSSL) in Norman, Oklahoma, and the Forecast Systems Laboratory in Boulder, Colorado, focus on research to understand and forecast severe weather systems and their associated hazards, such as tornadoes, hail, high winds, heavy rain and snow, lightning, and ice storms. The parameters of storm development and intensification are identified and studied by incorporating observations from Doppler weather radar, satellites, remote-sensing wind profilers, instrumented aircraft, and lightning-location networks. Work is being expanded to include assessment and improvement of numerical models to forecast severe weather systems.

NSSL provides significant technical and scientific support, including research and development, for the WSR-88D program. In FY 1998, NSSL will continue to develop techniques in cooperation with the NWS to forecast and warn of weather hazards to aviation and the general public. Work with the resultant data from the 1994-1995 VORTEX experiment will lead to new understanding of severe thunderstorms, improved ways to model and predict these storms, and new generation algorithms for severe storm detection. Immediate technology transfer will be effected by close association with the WSFOs, particularly those in Norman, Oklahoma; and Phoenix, Arizona; Melbourne, Florida; Pittsburgh, Pennsylvania; Cleveland, Ohio; Jackson, Mississippi; Minneapolis, Minnesota; Fort Worth, Texas; Denver, Colorado; and Salt Lake City, Utah.

In addition, NSSL is working closely with the NWS WSR-88D Operational Support Facility to re-host the Radar Product Generator to an open system platform. The re-hosting will continue for the next several years and will result in improved capabilities for the WSR-88D. The new system will ease the incorporation of new applications, speed technology transfer, allow for incorporation of new hardware technology and increase the portability of the software. The NSSL is also starting work on the re-host of the Radar Data Acquisition system.

Also, ERL will continue to transfer knowledge of Doppler radar applications, severe weather systems, and heavy rainfall events; much of the transfer is through courses at the NWS training center. Visits and interactions with NWS centers, regional headquarters, and forecast offices continue and FSL and NSSL are participating directly in training programs such as the COMET in Boulder and the WSR-88D Operational Support Facility in Norman.

Improvement of short-range (1-12 hour) forecasting will be accomplished by the development and evaluation of new local data system technologies and techniques, many of which can be incorporated into operational weather forecasting in the near term. FSL develops and evaluates prototype workstations for forecast office environments. Specifically, FSL has and will continue to develop capabilities to allow the forecaster to integrate, view, and manipulate observations from current and planned meteorological sensing systems using computer-assisted data display and synthesis techniques. By maintaining state-of-the-art capability for use in research and development of operational techniques, it continues to provide a mechanism to evaluate weather service requirements for AWIPS.

FSL will continue its emphasis on data application from GOES, Doppler radar, Aeronautical Radio Incorporated (ARINC) Communications Addressing

and Reporting System (ACARS), and the WPDN as inputs to quantitative analysis and prediction models, such as the Mesoscale Analysis and Prediction System and the Local Analysis and Prediction Systems. FSL is expanding service improvement efforts to include non-severe as well as severe weather to assist NWS modernization and restructuring and to help upgrade NCEP operations.

A multi-year program of coastal meteorology research continues at the Pacific Marine Environmental Laboratory (PMEL). This program also involves ETL and NSSL, the NWS Forecast Office in Seattle, NCAR, and the University of Washington. Support for the program is also being provided by the Office of Naval Research (ONR) and NSF. This research improves understanding of the effects of prominent terrain on U.S. West Coast weather, with the ultimate goal of providing improved forecasts of coastal winds, sea state, and storm surges. The emphasis is on the upstream effects of the coastal terrain in the storm environment when the background forcing is strong and the coastal forecasts are most critical. The approach involves special field observations and diagnostic studies using experimental numerical simulations. Field work featuring a NOAA WP-3 research aircraft in FY 1994 and 1996, for example, has yielded meteorological data for the Pacific Northwest coast with low-level winds of up to 85 knots, in the vicinity of two of the strongest cold fronts ever observed in detail over the ocean. The case studies from this work provide immediate insights on the influences of the coastal terrain on landfalling storms, and high quality data sets for numerical model initialization and validation. The results have been improved forecasts of Northwest weather.

Mesometeorology and Precipitation Forecasting and Warning Research. NSSL and FSL develop techniques to improve short-term forecasts of significant weather events. Through detailed case studies and regional climatologies, scientists from these two laboratories have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storms complexes. Studies underway include the precipitation structure of mesoscale convective systems, interactions between mesoconvective systems and the larger environment, using satellites to infer storm development and rainfall, and winter storm forecasting procedures. In FY 1998, NSSL will continue to use polarization information to improve radar procedures for rainfall estimation.

In addition, NSSL is working with the NWS Storm Prediction Center (SPC) to improve SPC abilities to provide winter weather guidance. NSSL prepared a climatology of freezing rain for the forecasters and investigated using short-range ensemble forecasts for freezing rain events. In FY 1998, NSSL and SPC will provide experimental forecasts of winter weather events to improve our understanding and refine our ability to provide severe winter weather guidance products.

Midlatitude Mesoscale Meteorology Research. At the Aeronomy Laboratory, the Atmospheric Dynamics Program combines observational and theoretical studies of mesoscale, high frequency atmospheric processes, focusing on internal gravity waves and vertical air motion. By improving the understanding of these dynamical processes, the research contributes to improvements in weather forecasting and the transfer of advanced meteorological measurement technology to operational use. Data for the studies is obtained from the 50 and 915 MHz wind-profiler radars at the Flatland Meteorological Observatory, which make continuous horizontal and vertical wind measurements in the very flat terrain near Champaign-Urbana, Illinois. The observatory also includes a 915 MHz RASS to measure temperature, an array of 24 digital barometers spread over Illinois, and standard surface and balloon-borne instruments. The research has shown that all enhancements of gravity-wave energy are associated with meteorological events, such as fronts, convection, or jet streams, and that such events always cause enhancements. In 1995, a multi-year program was initiated to study the dynamics of the atmospheric boundary layer, including measurements of the vertical entrainment velocity, which is of great importance to the vertical transport of trace species into the free atmosphere.

Hurricane Analysis and Prediction Research. The Hurricane Research Division (HRD) of the Atlantic Oceanographic and Meteorological Laboratory (AOML) explores hurricanes in dedicated research flights aboard the WP-3D aircraft operated by NOAA's Aircraft Operations Center (AOC). The P-3s carry a suite of instruments to measure a wide range of meteorological quantities, including standard flight-level data, remotely sensed surface winds, vertical soundings, radar reflectivity, and Doppler radar winds. In addition to the airborne observations, HRD develops techniques for real-time analysis and display of hurricane data, especially of surface winds. It also

carries out modeling and theoretical studies closely tied to the observational program and studies interannual and interdecadal changes in hurricane activity.

AOC's newly commissioned Gulfstream IV (G-IV) jet will operate in the hurricane environment for the first time during the 1997 season. The G-IV will extend the envelop of observations throughout the depth of the troposphere. Use of these aircraft presents an unprecedented opportunity for better understanding and forecasting of hurricanes through detailed observations. Of special interest are the hurricanes' inner core and the oceanographic and upper tropospheric synoptic-scale forcings that control intensity and motion.

The motivation for acquisition of the G-IV was a statistically rigorous demonstration, based upon more than a decade of experiments with the P-3s, that intensive observations of the flows surrounding hurricanes can produce dramatic (16-30 percent) reductions in track forecast errors. The forecast system currently has limited skill in prediction of intensity. Though continuing research with the expanded aircraft fleet, the Nation can realize the experimentally demonstrated potential for improvement as much more accurate routine operational track forecasts. A second, equally significant, outcome is the promise of dynamically based, skillful intensity forecasts. Because hurricanes inflict costs on the United States economy of billions of dollars per year, even incremental improvements in forecasts have large benefit to expenditure ratios.

In addition to HRD research activities, the ERL scientists carry out hurricane research at the Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey. GFDL's Hurricane Dynamics group performs hurricane modeling research to study the genesis, development, and decay of tropical storms using multi-nested three-dimensional computer models of the hurricane system and its surrounding environment.

In the early 1990's, this research model proved so successful for simulation of observed storm behavior that the NWS adopted a version of it for use in operational forecasting. During the extraordinarily active 1995 and 1996 seasons, the GFDL model provided the most reliable hurricane-track forecast guidance available and contributed substantially to the dramatic error reduction in official forecasts that has occurred since its introduction.

Numerical Analysis and Prediction Modeling. As part of its weather research activities, GFDL conducts long lead-time research to understand the predictability of weather on both large and small scales and to translate this understanding into improved numerical weather prediction models. Three groups at GFDL are engaged in weather research activities: Experimental Prediction, Mesoscale Dynamics, and Hurricane Dynamics (described above).

Experimental Prediction at GFDL develops and improves numerical models of the atmosphere-ocean-land system in order to produce useful weather forecasts with lead times ranging from weeks to seasons and beyond. The group is pursuing several avenues of research to achieve such improvements. First, GFDL scientists are investigating methods of stochastic dynamic prediction in order to extract as much forecast information as possible from numerical prediction models, given imperfectly observed initial conditions. In addition, laboratory scientists are developing methods for the assimilation of ocean observations into prediction models in order to improve the forecast of the atmosphere and the ocean.

Mesoscale Dynamics at GFDL develops and utilizes atmospheric models with limited spatial domains to understand mesoscale phenomena and the interaction of these regional scale features with the atmosphere's larger-scale synoptic processes. As part of these research activities, GFDL scientists investigate the practical limits of forecast models to predict the behavior of these mesoscale features through model sensitivity studies. The FSL implemented a Rapid Update Cycle (RUC) at NCEP in 1994. The RUC gives a new analysis of surface and atmospheric conditions every three hours as well as short-range predictions for the next 12 hours. This information is useful to forecasters at local NWS offices around the country and also supports commercial and general aviation.

A higher-resolution, higher-frequency version of the RUC will be implemented at NCEP during FY 1998. The new version will operate at 40-km horizontal resolution with 40 vertical levels at one-hour frequency. For the hourly updates, full use will be made of hourly wind profiles, the WSR-88D (Doppler radar) velocity azimuth display, numerous automated aircraft reports, and surface observations. The new RUC also includes explicit forecasts of different cloud water, ice crystal content, rain, snow, and graupel

(snow pellets). It exploits a new, multi-level soil and vegetation model to improve forecasts at the earth's surface and, in-turn, allowing improved forecast of atmospheric conditions near the surface.

Air Quality Research. The Air Resources Laboratory (ARL) carries out research on processes that affect the quality of the atmosphere, primarily in the context of air pollution, deposition, and emergency preparedness; much of this work is in collaboration with other agencies, such as DOE, Environmental Protection Agency (EPA), and DOD.

The ARL Headquarters Division in Silver Spring, Maryland, develops models for air quality prediction, for use in special forecasting (both weather and air quality) programs and in emergency response. The Atmospheric Sciences Modeling Division, in Research Triangle Park, North Carolina, develops predictive models on local, regional, and global scales, for assessing changes in air quality and air pollution exposure, as affected by ecosystem management and regulations. This work is primarily to provide technical guidance to the EPA on air pollution control strategies for attainment and maintenance of ambient air quality standards. The Atmospheric Turbulence and Diffusion Division, in Oak Ridge, Tennessee, conducts studies to improve understanding of atmospheric transport, diffusion, and air-surface exchange processes, and to develop new predictive models. The Field Research Division, in Idaho Falls, Idaho, designs and conducts field studies to evaluate the performance of transport and dispersion models, over local, regional, and continental scales. The Special Operations and Research Division, in Las Vegas, Nevada, conducts research on problems of mutual interest to NOAA and DOE, that relate to the Nevada Test Site, its atmospheric environment, and its emergency preparedness and emergency response activities. (Note: See the DOE discussion in Appendix D for more details).

ARL operates two national networks that focus research on the needs of the next generation of predictive models. The Atmospheric Integrated Research Monitoring Network (AIRMoN) is a nested-network, with sites of varying complexity addressing evolving scientific issues of wet and dry deposition from the atmosphere. A major current item for scientific attention is the atmospheric deposition of nitrogen compounds and its role in promoting eutrophication of ecosystems, primarily coastal. The ARL-run Integrated Surface Irradiance Study serves as the national array of monitoring stations for solar radiation (and ultraviolet-B), with a subset of more advanced stations (the SURFRAD array) where both incoming and outgoing radiation components are monitored. This work is coupled with ARL research on atmospheric aerosols and with the development of new, automatic methods for measuring cloud cover.

ARL also provides forecast support to NOAA's emergency response systems, with emphasis on nuclear and volcanic events. For this application, ARL develops and couples advanced mesoscale models with the forecast products of the NWS to provide a basis for trajectory and dispersion calculations. Users also may access these products through the Internet.

The Aeronomy Laboratory (AL) conducts research on air quality as part of its tropospheric chemistry program. A primary focus is on understanding the processes of near-surface ozone formation in rural regions. Field experiments, laboratory work, and numerical modeling studies assess the relative roles of natural hydrocarbons emitted from vegetation, anthropogenic hydrocarbons, and nitrogen oxides in controlling ozone production. A series of field experiments have been conducted in recent years in the southeastern United States, a heavily vegetated region which frequently experiences elevated levels of ozone. Since 1994, these field studies have expanded to include measurements from an aircraft platform, the NOAA WP-3D, in addition to ground-based observations. In certain areas, analysis of the data has linked ozone production most strongly to anthropogenic nitrogen oxides and natural, but not manmade, hydrocarbons. It has also underscored the regional nature of the ozone formation process and suggested that some municipalities are affected by events beyond their control. These results have implications for the efforts of states to develop strategies to improve air quality in the region.

Ozone production on the global scale is being studied by AL in the North Atlantic Regional Experiment. The study has been undertaken in response to the growing realization that long-range transport of "greenhouse" ozone may influence atmospheric composition and climate on an interhemispheric scale. Comprehensive chemical and dynamical measurements, made from both ground-based and from airborne platforms during several field missions of this experiment, track the changing composition of air masses containing

pollutants from eastern North America as these air masses are carried into the North Atlantic. Results indicate that the quantity of ozone generated photochemically from anthropogenic emissions on the North American continent exceeds that injected from the stratosphere. This conclusion supports the contention that ozone derived from anthropogenic pollution has a hemisphere-wide effect at northern temperate latitudes.

ETL uses its suite of remote sensors, including a mobile profiler network, airborne and ground-based ozone Lidars, Doppler Lidar, and supporting turbulence instrumentation, to understand and better model the transport, transformation, and fate of primary and secondary pollutants in both rural and urban environments, as well as in complex orography.

Space Environment Services. NOAA and the Air Force jointly operate the National Space Weather Operations group in NOAA's Space Environment Center (SEC) in Boulder, Colorado. The SEC, working closely with the Air Force's 55th Space Weather Squadron (55 SWS), provides forecasts, alerts, indices, and summaries of disturbances occurring on the Sun, in space, in the geomagnetic environment, and in the upper atmosphere. The services are used by DOD, DOT, DOC, DOI, DOE, NASA, NSF, commercial users, and the research community:

- To optimize the operation of technical systems that are adversely affected by disturbances in the space environment.
- To carry out research in the solar-terrestrial environment.

Examples of the adverse effects include loss or reduced efficiency of communication systems, radiation hazards to personnel and systems in high altitude aircraft and in space, degradation of surveillance and monitoring systems for defense, errors in navigation systems, perturbations of satellite orbits, and disruptions in power distribution networks.

SEC serves as the international World Warning Agency for the solar-terrestrial environment. It collects international data--X ray, sunspot, corona, magnetic, etc.--in real time and from these data provides International URSIgram and World Days Service and meets additional specific needs of other government agencies. SEC distributes (receives) data to (from) other countries and issues a consensus set of daily forecasts for international use.

SEC operates with observations received from agencies that contribute their data and, in return, receive the synthesized and integrated services to meet their needs. Agencies making major contributions of data include: DOD, NASA, DOC, NSF, DOE, and DOI. SEC cooperates directly with NESDIS to receive solar X-ray, particle, in-situ magnetic field, and plasma data from the Space Environment Monitors on GOES and the polar-orbiting NOAA satellites.

Data are collected, stored, and displayed for analysis and products and distributed through the Space Environment Laboratory Data Acquisition and Display System (SELDADS). Services are also provided via digital data links (primarily operated by other agencies), and by radio broadcast, mail, recorded telephone messages available to commercial dial-up users, and low-cost commercial satellite broadcast service.

Voluntary Observing Ship (VOS) Program. OAR operates a global VOS Program that provides real-time meteorological and oceanographic data from selected vessels. Data are collected with the Shipboard Environmental Data Acquisition System, which transmits the information to NOAA via the GOES system. The information is then disseminated nationally and internationally using existing data networks. Presently, there are over 120 vessels in the program which record and transmit surface meteorological information four times per day at synoptic hours. Of these vessels, about 60 also are equipped to collect expendable bathythermograph data.

Southern Hemisphere Drifting Buoy Program. In support of Global Climate Observing System (GCOS) requirements, OAR, in cooperation with NWS, OGP, AOML, and the Scripps Institution of Oceanography, maintains a network of approximately 100 meteorological drifting buoys in the Southern Hemisphere. The buoys measure sea level atmospheric pressure, air temperature, and sea water temperature. Observations are obtained through the ARGOS data collection and platform location system on-board the NOAA polar-orbiting satellites.

Tropical Atmosphere Ocean (TAO) Moored Array. OAR is a partner with OGP in the implementation of the TAO moored-buoy array. TAO is a basin-wide array of moored ATLAS buoys deployed in the tropical Pacific that report surface wind, air temperature, sea surface temperature, 10 subsurface temperatures to a maximum depth of 500 meters, and 2 subsurface pressures in real-time via

the ARGOS system. There are 70 buoys deployed. The array is operated by the TAO Project Office located at PMEL in Seattle, Washington, which has responsibility for management of project operations and logistics. While the principal objective is to support research objectives, the real-time availability of data makes it extremely valuable to operational meteorological centers.

Military. The U.S. Air Force operates the 55th Space Weather Squadron (55 SWS) in Colorado Springs, Colorado, to provide space weather support to DOD assets. The 55 SWS operates and maintains the solar observing network with sites at Palehua, Hawaii; Learmouth, Australia; San Vito, Italy; Ramey, Puerto Rico; Sagamore Hill, Massachusetts; and Holloman AFB, New Mexico. The 55 SWS shares space weather support responsibilities with its civilian counterpart the SEC.

NATIONAL OCEAN SERVICE

The National Ocean Service (NOS) develops, implements, and manages programs in physical, biological, chemical, and geological oceanography and establishes a scientific information base on which to support the development of national policy for the oceans and their users. NOS efforts are coordinated with marine programs administered by the other components of NOAA. Operational ocean observing activities administered by NOS include water-level programs and real-time currents/current prediction programs.

National Water-Level Observation Network (NWLON). NOS operates and maintains the NWLON for the collection of water-level data, as well as other oceanographic and meteorological data. The NWLON consists of 189 stations located in U.S. coastal areas and the Great Lakes. Through its strategic locations and data dissemination capabilities, NWLON supports a number of NOAA and other federal programs, such as the NOS Tide Prediction Program, NWS Tsunami Warning System and storm surge warning/forecast activities, Climate and Global Change Program, and the U.S. Army Corps of Engineers lake-level regulation, dredging operations, and coastal construction efforts.

Physical Oceanographic Real-Time System (PORTS). PORTS is a data acquisition and dissemination system which integrates a number of important meteorological and oceanographic parameters, including currents, water levels, and marine winds. Traditional NOAA tide and current prediction tables provide only the astronomical tides and currents and do not always meet the needs of users who must also consider the non-tidal effects of river flow, winds, and other meteorological forces. PORTS measures and integrates these important data and provides a data dissemination system that includes telephone voice response, as well as modem access.

OFFICE OF NOAA CORPS OPERATIONS
AIRCRAFT OPERATIONS CENTER

The Aircraft Operations Center (AOC) supports several NOAA missions, in particular, it operates a fleet of aircraft which are used to support NOAA's research and development programs to improve weather, marine, and climate services. It also provides weather reconnaissance support to NOAA programs, other federal agencies, and international programs approved by the Aircraft Allocation Council. Light aircraft provide aerial photography for nautical and aeronautical charting and living marine resources surveys.

AOC was established in October 1983 to consolidate the management of all aircraft used by NOAA. Fourteen aircraft located throughout the United States are managed by AOC at MacDill AFB in Tampa, Florida.

NOAA's atmospheric and oceanographic research and reconnaissance operations are supported by two fully instrumented WP-3D aircraft which carry state-of-the-art environmental research equipment. The aircraft research and navigation systems provide detailed spatial and temporal observations of a wide range of atmospheric and oceanic parameters. AOC develops and calibrates specialized instruments, integrates user-supplied instruments into the automated systems, and processes and analyzes data sets from various field programs.

AOC aircraft provide high density/accuracy hurricane data to the National Hurricane Center in near real time. Storm data are transmitted via the aircraft satellite data link to update hurricane track/intensity analyses and forecasts. The AOC aircraft have primary responsibility for reconnaissance of tropical storms and hurricanes over foreign airspace that may be restricted for military operations. AOC also augments Air Force Reserve operational aircraft reconnaissance when storms are within 24 hours of landfall of the continental United States and whenever DOC needs exceed DOD resources. In addition, AOC provides a quick response capability for investigation of storm activity east of 80° longitude from August 1 through September 30 each year.

The AOC is scheduled to begin the operation of the new high altitude jet for hurricane surveillance, which is expected to improve hurricane track predictions by 20 percent or more, saving about $10 million per hurricane in warning and preparedness costs. With some additional instrumentation, the jet will become a prototype for the next generation hurricane reconnaissance aircraft, as well as serving as a platform for air chemistry and other research in the upper troposphere, from 25,000 to 45,000 feet, which is above the WP-3D's altitude limit.