# ..ıe Federal Plan for Meteorological Services and Supporting Research

## FISCAL YEAR 1998

OFCM

OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGY

FCM P1-1997

U.S. DEPARTMENT OF COMMERCE/National Oceanic and Atmospheric Administration

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# The Federal Plan for Meteorological Services and Supporting Research

FISCAL YEAR 1998

FEDERAL COORDINATOR
FOR
METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

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# PREFACE

Since 1965, the Office of the Federal Coordinator has developed a federal plan which articulates the meteorological services provided and supporting research conducted by agencies of the federal government. As in the past, it provides Congress and the Executive Branch a comprehensive plan for meteorological services and supporting research within the federal meteorological community. "Supporting" research is defined as those research and development (R&D) programs that directly support and improve meteorological services. The plan reviews agency programs for FY 1997 and documents proposed programs for FY 1998. The plan's narratives, timelines, and schedules reflect a date as of June 1997. Consequently, the new OFCM organizational changes are not reported in this edition.

Section 1 is an overview and general summary of the entire document. Section 2 describes interagency cooperation that is essential to meet the federal government's requirements for meteorological services. Section 3 summarizes a discussion of resources requested in the President's budget for FY 1998 as compared to those resources that Congress appropriated for FY 1997. This budget information along with other significant aspects are summarized in graphical and table formats and are current as of the end of June 1997. The emphasis is on changes in resources and the associated changes in programs. Section 4 is a review article entitled *Owning The Weather--An Army Force Multiplier*. Appendices A through D describe individual agency weather activities and programs; Appendix E describes the World Weather Program; Appendix F contains a list of acronyms; and Appendix G lists the topics of our feature articles from prior years.

The policy and program guidance for coordinating weather activities and programs is provided by the interagency committees shown on the inside front cover. These committees and the supporting organizational structure shown on the inside of the back cover conduct systematic and continuous reviews of federal programs and requirements for meteorological services and supporting research according to guidelines initially set forth in the Office of Management and Budget Circular A-62.

This edition of the Federal Plan continues modifications to format and presentation of information initiated two years ago. The focus of Section 2 is now on OFCM's coordination and planning activities for the past year rather than descriptive, historical program information. In conjunction with these modifications that we've initiated, I solicit your comments and feedback regarding additional enhancements. These comments may be directed to either myself or the staff editors.

In FY 1997, OFCM established a Web site--*WWW.OFCM.GOV*. In addition to the latest version of the Federal Plan, we intend to convert and make available for viewing and distribution new as well as previous OFCM publications. We look forward to your suggestions to assist us in improving our web site.

Julian M. Wright, Jr.
Federal Coordinator for Meteorological
Services and Supporting Research

THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES
AND SUPPORTING RESEARCH, FISCAL YEAR 1998

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# EXECUTIVE SUMMARY

The President's fiscal year (FY) 1998 budget requests $2.38 billion for meteorological services and supporting research. Of the total requested, $2.03 billion is designated for operations and $350 million for supporting research. The FY 1998 budget proposal, by agency, is shown in Table 1.1.

As in prior years, the Departments of Commerce (DOC), Defense (DOD), and Transportation (DOT) are projected to receive approximately 92 percent of the funds. The distribution among the three departments remain the same with DOC claiming the largest portion at 51 percent and DOD and DOT following with approximately 21.6 percent and 18.8 percent, respectively. All other federal agencies account for the remaining 8.8 percent.

In comparison to the $2.33 billion appropriated in FY 1997, the FY 1998 request represents an increase of 1.9 percent. DOC's request represents an increase of 1.7 percent, DOD's an increase of 1.4 percent, and DOT's an increase of 3.6 percent. The DOD's overall FY 1997 to 1998 increase includes the continued decline in the Army's funding levels for operations and supporting research (a combined decrease of 10.3 percent). In addition, the Air Force's Defense Meteorological Satellite Program request for operations and supporting research decreases by 7.2 percent. On the other hand, the Navy and Air Force requests for operations and supporting research increase by 10.7 and 1.2 percent, respectively.

Although FY 1998 funding levels for operations in the three departments continues to increase, albeit single-digit percentage increases, funding for supporting research decreases in all three departments when compared to FY 1997 levels. The largest decrease of 62 percent occurs in the DOT's Federal Aviation Administration (FAA).

The National Aeronautics and Space Administration's (NASA) overall budget increase is less than one-half percent. The Department of Agriculture realizes a small increase of 2.1 percent. The Nuclear Regulatory Commission's request reflects a decrease of 18.1 percent.

Table 1.1. Federal Budget for Meteorological Operations and Supporting Research, FY 1998 (in thousands of dollars)

| Agency | Operations | % of TOTAL | Supporting Research | % of TOTAL | TOTAL | % of TOTAL |
|---|---|---|---|---|---|---|
| Agriculture | $12,553 | 0.6 | $15,591 | 4.5 | $28,144 | 1.2 |
| Commerce | 1,132,490 | 55.9 | 80,240 | 22.9 | 1,212,730 | 51.0 |
| Defense | 434,746 | 21.4 | 78,558 | 22.4 | 513,304 | 21.6 |
| Interior | 800 | 0.0 | 0 | 0.0 | 800 | 0.0 |
| Transportation | 441,537 | 21.8 | 6,317 | 1.8 | 447,854 | 18.8 |
| EPA | 0 | 0.0 | 5,700 | 1.6 | 5,700 | 0.2 |
| NASA | 4,459 | 0.2 | 163,750 | 46.8 | 168,209 | 7.1 |
| NRC | 298 | 0.0 | 0 | 0.0 | 298 | 0.0 |
| TOTAL | 2,026,884 | 100.0 | 350,156 | 100.0 | 2,377,039 | 100.0 |

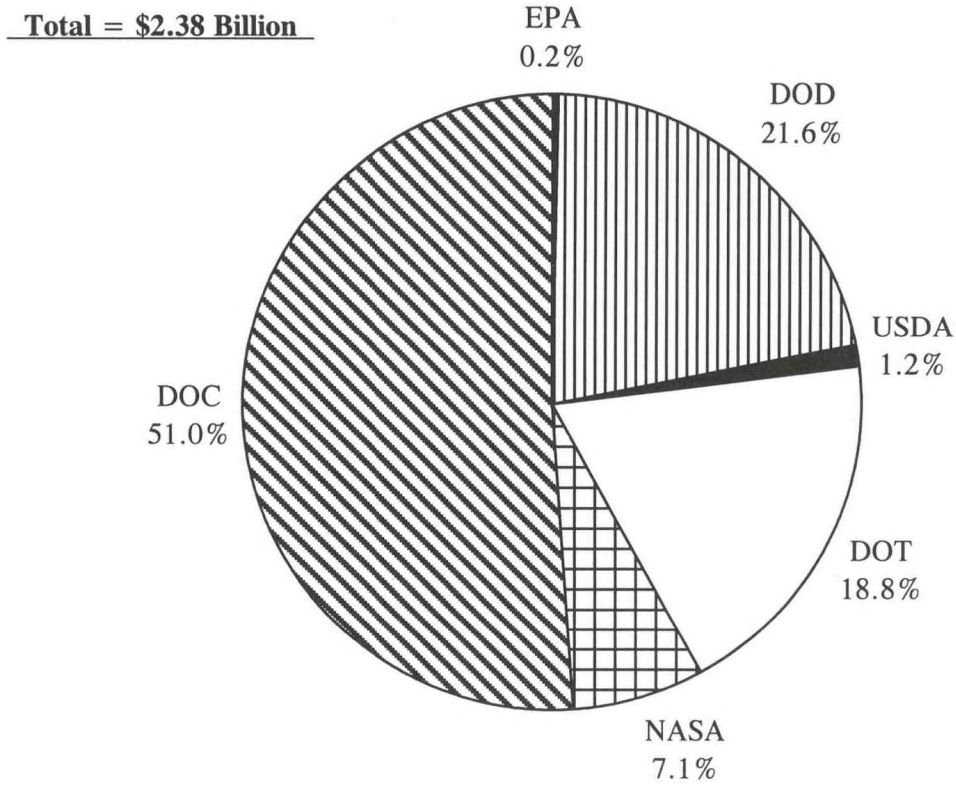


Figure 1.1 Agency Percent of Total Federal Budget for Meteorological Operations and Supporting Research, FY 1998

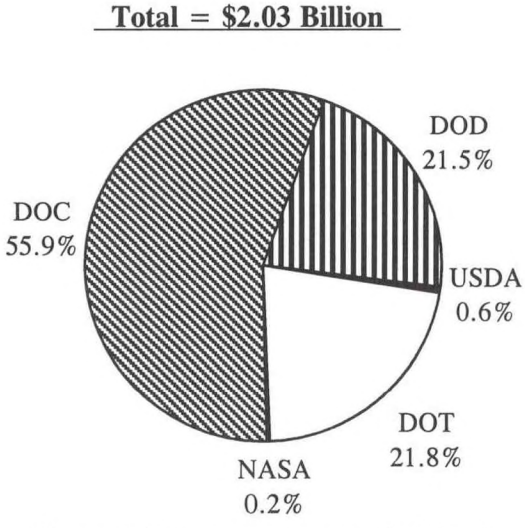


Figure 1.2 Agency Percent of Federal Budget for Meteorological Operations, FY 1998

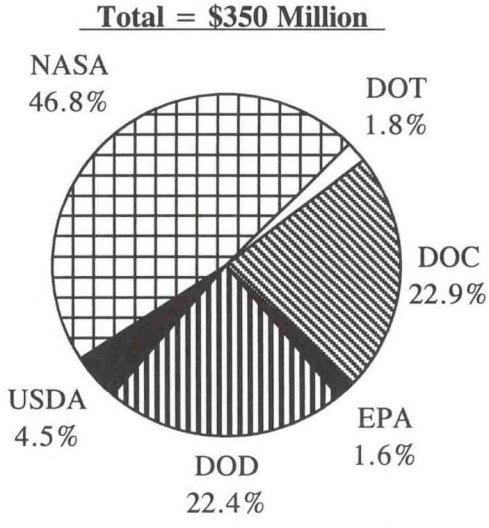


Figure 1.3 Agency Percent of Federal Budget for Supporting Research, FY 1998

Figure 1.1 depicts each agency's proportion of the proposed FY 1998 federal budget for meteorological operations and supporting research. Each agency's portion of the proposed funding for meteorological operations is shown in Figure 1.2. Of the $2.03 billion requested for meteorological operations, DOC, DOD, and DOT account for 99 percent of the funds. Figure 1.3 depicts each agency's portion of the proposed federal supporting research budget. Unlike operations, DOC, DOD, and NASA account for the major share (92 percent) of the supporting research budget.

All agencies project a personnel total of 20,833 full-time equivalent (FTE) to be employed in federal meteorological operations in FY 1998. This figure represents a decrease of 3.7 percent from the 21,638 FTE employed in FY 1997.

Major Programs of DOC, DOD, and DOT

The required funding for major weather system acquisition programs for DOC, DOD, and DOT continues to decline from the previous year's level.

Next Generation Weather Radar (NEXRAD). The NEXRAD Program which began in FY 1981 was responsible for procurement, installation, and operation of the Weather Surveillance Radar-1988 Doppler (WSR-88D). The first limited production WSR-88D system was installed at Oklahoma City, Oklahoma in May 1990 and commissioned 4 years later in February 1994. The original program plan called for a total of 161 radars. In response to a National Research Council report, three additional radars were added and raised the total to 164 radar sites.

By agency, as of June 1997, the DOC/National Weather Service has 117 commissioned sites, the DOD/USAF has 18 commissioned, and the DOT/FAA has 2 commissioned sites. Five other sites are dedicated to supporting maintenance, training, and testing activities.

Automated Surface Observing System (ASOS). The ASOS program, began in 1983, as a joint development effort between the DOC, DOD, and DOT/FAA. Installation of ASOS units started in 1991. As of August 1997, a total of 952 units have been purchased. The NWS has purchased 313 units, installed 287 units, and accepted 273 units. The FAA has purchased 539 units, installed 522 units, and accepted 513 units. The Navy has purchased 77 units, installed 76 units, and accepted 76 units. The Air Force has purchased 23 units, installed 21 units, and accepted 21 units. Collectively, the NWS and FAA have commissioned 405 units--NWS 230 and FAA 175.

Automated Weather Information Systems (AWIS). The DOC, DOD, and DOT require AWISs to facilitate the collection, processing, and interpretation of meteorological data. AWISs are being procured to provide an automated, high-speed, user-friendly man/machine interface to access and process large volumes of sophisticated meteorological data. AWIS supports the timely production of accurate and geographically precise warnings, forecasts, and special tailored products. They also provide the communications capability for expeditious product dissemination.

Major agency systems classified as AWISs are: NOAA's Advanced Weather Interactive Processing System (AWIPS), the FAA's Weather and Radar Processor (WARP), the Air Force's Automated Weather Distribution System (AWDS), and the Navy's Naval Oceanographic Data Distribution and Expansion System (NODDES) and Navy Integrated Tactical Environmental Subsystem (NITES).

In February 1997, the Secretary of Commerce approved the limited production AWIPS which authorized NOAA to procure and install 21 systems in calendar year 1997. A decision on the remaining AWIPS units will be sought after the operational test and evaluation of AWIPS Build 3. Commissioning of AWIPS Build 4 units is expected in 1998.

Other Agency Programs

For FY 1998, the Department of Agriculture (USDA) requested $28.14 million for meteorological operations and supporting research. Operationally, the USDA supports specialized weather observation networks and also conducts an active supporting research program to ensure an abundance of high-quality agricultural commodities while minimizing the adverse effects of agriculture on the environment.

The Department of Interior's (DOI) FY 1998 request is $800,000 primarily to support the Bureau of Land Management's remote automatic weather station (RAWS) program.

The budget request for the Environmental Protection Agency (EPA) decreases to $5.7 million to provide user-appropriate and scientifically credible air-quality meteorological programs to support regulatory applications.

NASA's FY 1998 request is $168.2 million primarily for supporting research associated with the Mission to Planet Earth (MTPE) program. These funding levels are composed of the estimated meteorology share of the supporting research and analysis programs, to include the Earth Observing System (EOS) and Earth Probe instruments, EOS science, and the EOS Data and Information Systems (EOSDIS).

The Nuclear Regulatory Commission's (NRC) request for $298,000 is mainly for operations. The NRC will dedicate these funds to obtain and analyze meteorological data and information related to the safe operation of nuclear facilities, and the protection of the environment, public health, and safety.

Federal Coordination Activities

In response to a National Research Council report and recommendation, the National Aviation Weather Program Council (NAWPC) tasked the Aviation Weather Joint Action Group (JAG) to prepare a strategic plan for aviation weather. The JAG completed and subsequently distributed ***The National Aviation Weather Strategic Plan*** (August 1997). As a follow up to the strategic plan, the JAG is actively preparing an implementation plan.

Acting upon an ICMSSR recommendation, the OFCM prepared and developed a proposal to streamline the interagency council, committee, and working group coordinating structure. In April 1997, the Federal Coordinator briefed ICMSSR on the proposal and received acceptance. The final step is to seek FCMSSR approval at the September 1997 meeting. The streamlining will reduce the number of groups within OFCM's coordinating structure from 46 to 34.

In March 1997, OFCM hosted the 51st Interdepartmental Hurricane Conference (IHC) in Miami, Florida. The 52nd IHC is scheduled for January 26-30, 1998 in Clearwater Beach, Florida.

The FY 1998 featured article is entitled "*Owning the Weather--An Army Force Multiplier*" and was provided by the Department of the Army.

SECTION 2

# FEDERAL COORDINATION AND PLANNING

## BASIS FOR FEDERAL COORDINATION PROCESS

In 1963, Congress and the Executive Office of the President expressed concern about the adequacy of coordination of federal meteorological activities. In response, Congress directed in Section 304 of Public Law 87-843--the Appropriations Act for State, Justice, Commerce, and Related Agencies--that the Bureau of the Budget prepare an annual horizontal budget for all meteorological programs in the federal agencies.

The Bureau of the Budget (now the Office of Management and Budget) issued a report entitled "Survey of Federal Meteorological Activities" (1963). The report described each agency's program in some detail, particularly its operational services, and detailed the relationship between the programs of the various agencies. The report revealed close cooperation but little evidence of systematic coordination. Based on this study, the Bureau of the Budget issued a set of ground rules to be followed in the coordination process. It established a permanent general philosophy for assignment and assessment of agency roles in the field of meteorology and set certain goals to be achieved by the coordination process. The Bureau of the Budget tasked the Department of Commerce (DOC) to establish the coordinating mechanism in concert with the other federal agencies. It also reaffirmed the concept of having a central agency--the DOC-- responsible for providing common meteorological facilities and services and clarified the responsibilities of other agencies for providing meteorological services specific to their own needs.

The implementation of these directives by DOC led to the creation of the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) which operates with policy guidance from the Federal Committee for Meteorological Services and Supporting Research. The principal work in the coordination of meteorological activities and in the preparation and maintenance of federal plans is accomplished by the OFCM staff with the advice and assistance of the Interdepartmental Committee for Meteorological Services and Supporting Research, and over 30 program councils, committees, and working groups.

## MISSION AND STAFFING OF THE OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGY (OFCM)

The mission of the OFCM is to ensure the effective use of federal meteorological resources by leading the systematic coordination of operational weather requirements and services, and supporting research, among the federal agencies. To discharge its mission, the OFCM has meshed its objectives with the objectives of the agencies that provide the services and perform the research. They include:

- Documenting agency programs and activities in a series of national plans and reports that enable agencies to revise/adjust their individual ongoing programs and provide a means for communicating new ideas and approaches to fulfill requirements.
- Providing structure and program to promote continuity in the development and coordination of interagency plans and procedures for meteorological services and supporting research activities.
- Preparing analyses, summaries, or evaluations of agency meteorological programs and plans that provide a factual basis for the Executive and Legislative branches to make appropriate decisions related to the allocation of funds.
- Reviewing federal weather programs and federal requirements for meteorological services and supporting research. This review may suggest additions or revisions to current or proposed programs or identify opportunities for improved efficiency, reliability, or cost avoidance through coordinated actions or integrated programs.

In 1979, a General Accounting Office (GAO) report, "The Federal Weather Program Must Have Stronger Central Direction," LCD-80-10, recommended stronger centralized planning and direction for federal weather activities. Pursuant to GAO's recommendation, DOC increased the permanent

professional staff from one to seven and assigned an additional professional staff member as the DOC representative. DOC also provides administrative support to the OFCM and provides approximately one-half of the OFCM's annual operating budget. The Department of Defense (DOD) currently provides two senior staff officers-- one Air Force and one Navy--and contributes approximately one-fourth of the annual budget. The Department of Transportation (DOT) Federal Aviation Administration (FAA) provides one professional staff member and also provides approximately one-fourth of the annual operating budget. These four agency representatives are designated Assistant Federal Coordinators for liaison to their respective agencies. In all, 14 meteorologists, oceanographers, physical scientists, and administrative and computer-support personnel are assigned to the OFCM staff.

## COORDINATION OF MULTIAGENCY PROGRAMS

The Federal Committee for Meteorological Services and Supporting Research (FCMSSR), established in 1964, provides high-level agency representation and policy guidance to the Federal Coordinator in resolving agency differences that arise during the coordination of meteorological activities and the preparation of federal plans. The Under Secretary of Commerce for Oceans and Atmosphere, who is also the Administrator of the National Oceanic and Atmospheric Administration (NOAA), serves as the FCMSSR Chair.

The 13 federal agencies that engage in meteorological activities or have a need for meteorological services are represented on FCMSSR. The FCMSSR membership includes: DOC, DOD, DOT, the Departments of Agriculture (USDA), Energy (DOE), Interior (DOI), and State (DOS), and the Environmental Protection Agency (EPA), Federal Emergency Management Agency (FEMA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), National Transportation Safety Board (NTSB), and the U.S. Nuclear Regulatory Commission (NRC). In addition, the Office of Management and Budget (OMB) is represented.

OMB and FCMSSR provide guidance at the policy level to the Federal Coordinator. At the program management level, guidance from the agencies is provided by the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR). Under ICMSSR, there are six standing committees: Basic Services, Operational Processing Centers, Automated Weather Information Systems, Aviation Services, Operational Environmental Satellites, and Space Environment Forecasting.

Also within the OFCM structure, there are seven program councils (PC) to coordinate specific interagency cooperative programs. There seven PCs are:

- Next Generation Weather Radar.
- Joint Automated Weather Observations.
- Automated Weather Information Systems.
- Aircraft Icing.
- Aviation Weather.
- National Space Weather.
- Improved Weather Reconnaissance.

Each of the PCs is comprised of decision-level representatives from the agencies directly concerned with the specific program area. The Federal Coordinator serves as the chairperson of each PC.

During FY 1997, the OFCM prepared and developed a proposal to streamline the interagency council, committee, and working group coordinating structure. In April 1997, ICMSSR accepted the proposed revisions and authorized OFCM to seek FCMSSR approval. The next FCMSSR meeting is scheduled for September 1997.

### Next Generation Weather Radar (NEXRAD)

A major milestone in United States weather modernization programs was achieved during July 1996 with delivery of Weather Surveillance Radar-1988 Doppler (WSR-88D) number 161, the last system in the basic Next Generation Weather Radar (NEXRAD) procurement schedule. In response to a National Research Council report, three additional radars have been delivered which raises the total to 164 systems. Five of the 164 WSR-88D systems have been allocated to support training, maintenance, and testing activities; 123 are deployed at National Weather Service (NWS) sites within the contiguous 48 states, 29 are deployed

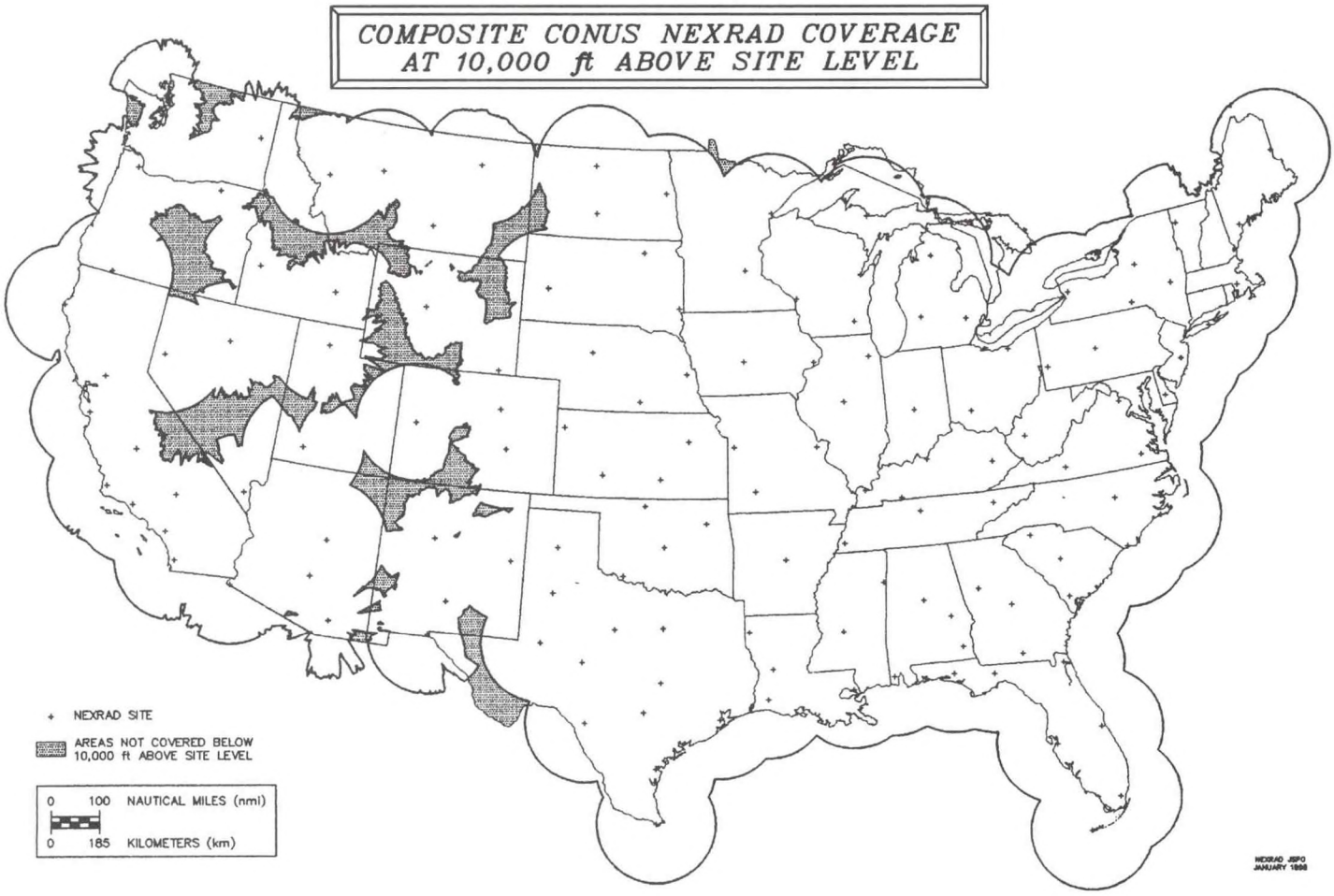


Figure 2-1 WSR-88D Continental United States Coverage

to DOD operational sites in the U.S. and overseas, and 12 were installed by the FAA in Alaska and Hawaii. As of August 1997, 137 WSR-88D units have been commissioned as the official site on the national network of weather radars--a little over three years since commissioning began during 1994.

The WSR-88D is a computerized Doppler weather radar developed to meet the needs of DOC, DOD, and DOT for improved ability to detect and maintain surveillance of hazardous weather. This need was defined in an OFCM-sponsored study in the late 1970's. It led, in 1979, to the establishment of a Joint System Program Office to develop and procure the new Doppler radar under policy guidance and oversight of the triagency NEXRAD Program Council.

The WSR-88D system's advanced technology provides automated Doppler signal processing, computerized processing of data by sophisticated meteorological software algorithms, state-of-the-art ergonomically designed operator workstations, and a high-capacity, processor-driven communications capability. The system is modular in design, upgradeable, and has a long life-cycle expectancy. NEXRAD's advanced weather radar products meet the needs of the three Departments for accurate information on the location, severity, and movement of hazardous weather.

The NWS uses the WSR-88D for more than forecasts and warnings of severe weather. The WSR-88D also provides rainfall analysis capability for improved river stage and flood forecasts and for data to support effective management of water resources. This advance in water resources management reaches beyond flood control to impact areas, such as river navigation, drinking water supplies, pollution

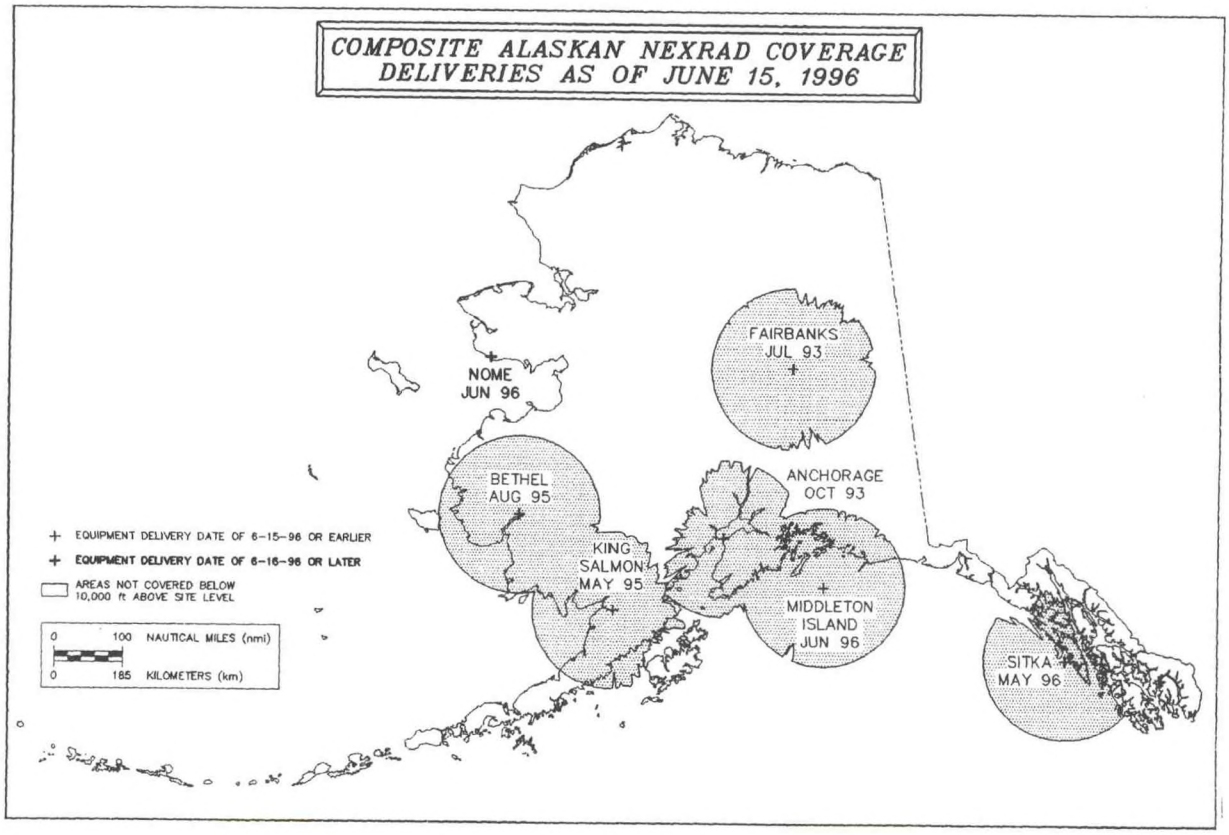


Figure 2-2 WSR-88D Alaskan Coverage

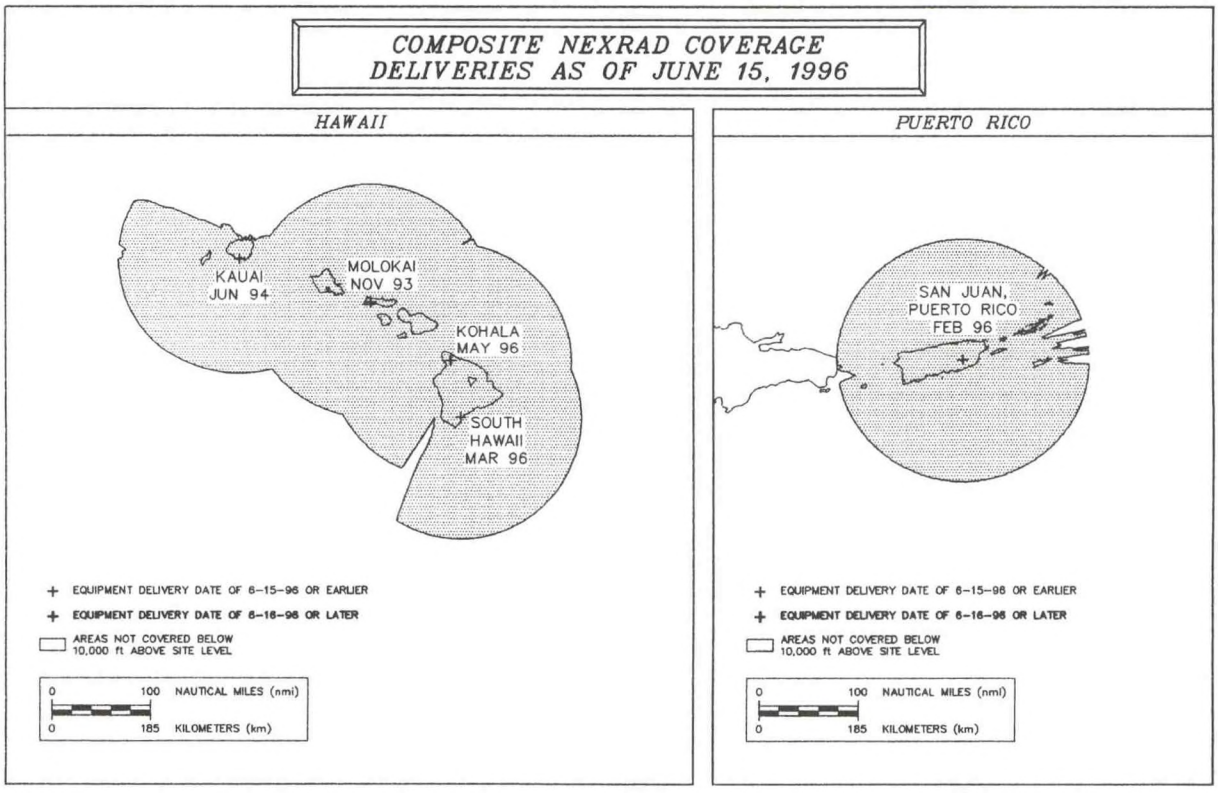


Figure 2-3 WSR-88D Hawaiian and Puerto Rican Coverage

management, and water-based recreation--all with beneficial economic consequences. The DOD will use WSR-88D data to support military operations and protect defense assets in the United States, the Azores, and at key Pacific locations. The FAA uses the data to improve flight safety and to manage traffic more efficiently within the National Airspace System. The National Climatic Data Center provides historical archiving of the WSR-88D data.

In January 1993, the NEXRAD Program Management Committee (PMC) was established to provide operational management of the WRS-88D program. Chartered by the NEXRAD Program Council (NPC), the PMC is a tri-agency committee comprised of representatives from the DOC (NWS), DOD (AWS and Naval Meteorology and Oceanography Command (CNMOC)), and DOT (FAA). The PMC is chaired by the Director, NWS Office of Systems Operations. The PMC responsibilities focus on effective and efficient WSR-88D operations and configuration management. Issues which cannot be resolved by the PMC are referred to the NPC for resolution.

On-going and planned activities for FY 1998 include development of an open systems architecture, relocation of the Griffis AFB radar, and work on the interfaces with the FAA's Weather and Radar Processor (WARP) and the NWS' Advanced Weather Interactive Processing System (AWIPS).

Automated Surface Weather Observations

As of August 1997, a total of 952 units have been purchased as part of the base program. The NWS has purchased 313 units, installed 287 units, and accepted 273 units. The FAA has purchased 539 units, installed 522 units, and accepted 513 units. The Navy has purchased 77 units, installed 76 units, and accepted 76 units. The Air Force has purchased 23 units, installed 21 units, and accepted 21 units. Collectively, the NWS and FAA have commissioned 405 units--NWS 230 and FAA 175.

In May 1997, the NWS formed the ASOS Program Management Committee (PMC), a tri-agency committee comprised of representatives from the NWS, FAA, and DOD, and chaired by the NWS ASOS Program Manager. The purpose of the PMC is to provide broad operational management of the ASOS program and to serve as a high-level configuration control board for addressing complex ASOS change proposals. Generally, the committee will meet on a bimonthly basis, but may be convened as required to address urgent issues. Issues that cannot be resolved will be elevated to OFCM. OFCM will assemble the appropriate high-level interagency representatives to address and resolve the issues.

Planned ASOS activities for FY 1997-1998 include continuing with installations, acceptance, and commissioning of ASOS units, primarily for NWS and FAA. In addition, NWS, FAA, and DOD (under the auspices of the ASOS PMC) will continue enhancement, development, and testing efforts for selected sensors.

Automated Weather Information Systems

Automated Weather Information Systems (AWIS) are required by a number of federal agencies. AWISs are being procured to provide an automated, high-speed, user-friendly man/machine interface to access and process large volumes of sophisticated meteorological data. They support the timely production of accurate and geographically precise warnings, forecasts, and special tailored products. They also provide the communications capability for expeditious product dissemination.

Major agency systems classified as AWISs are: NWS's Advanced Weather Interactive Processing System (AWIPS), FAA's Weather and Radar Processor (WARP) and the Integrated Terminal Weather System (ITWS), Air Force's Automated Weather Distribution System (AWDS) and the Meteorological Information Standard Terminal (MIST), and Navy's Navy Integrated Tactical Environmental Subsystem (NITES). These systems include communications to collect and distribute raw data, information and processed products but exclude observation subsystems and the supercomputers at the major centers.

During the remainder of 1997, a limited production and installation of AWIPS will continue at NWS Weather Forecast Offices. Following additional operational test and evaluation, a decision will be sought for the additional systems with commissioning planned in 1998.

National Aviation Weather Program

The National Aviation Weather Program Council (NAWPC) was formed in 1989 and a supporting Joint Action Group (JAG) in 1990 to address aviation weather issues. Membership includes the Departments of Agriculture, Commerce, Defense, and Transportation as well as the National Transportation Safety Board and NASA. The first major undertaking of the JAG resulted in the publication of the ***National Aviation Weather Program Plan (NAWPP)*** in 1992 which outlined unmet user needs.

After some intervening time and prompted by recommendations from the National Research Council, the NAWPC tasked the JAG with the preparation of a National Aviation Weather Program Strategic Plan. The ***National Aviation Weather Program Strategic Plan*** was subsequently approved by the NAWPC in April 1997 and published and distributed in August 1997. Following completion of the Strategic Plan, the JAG was tasked by the NAWPC to develop an Implementation Plan. The JAG will be meeting regularly over the next several months with the goal of having a draft implementation plan by the end of February 1998.

National Space Weather Program Council (NSWPC)

At the January 1997 meeting, the NSWPC approved for publication the ***National Space Weather Program Implementation Plan***. The plan was distributed in the Spring 1997 with another version planned within about a year. The implementation plan builds on the ***National Space Weather Program Strategic Plan*** published in late 1995. The implementation plan covers research, modeling, and observation requirements, and provides guidance on priorities, agency roles and responsibilities, and program management. The council also considered the space weather aspects of the OFCM coordinating structure and recommended to ICMSSR the Committee for Space Environmental Forecasting and the Working Group for Space Weather be consolidated into the Committee for Space Weather. In addition, the council proposed the new committee be placed under the program council rather than ICMSSR.

The National Science Foundation again requested research to support the National Space Weather Program. The scientific community will share nearly $1 million in research money acquired from multiple agencies and identified as National Space Weather Program funding.

Improved Weather Reconnaissance System (IWRS)

The Improved Weather Reconnaissance Program Council (IWRPC) was formed to manage the acquisition of the IWRS. Currently, the Air Force Reserve Command's 53rd Weather Reconnaissance Squadron (53 WRS) operates ten WC-130H aircraft equipped with the IWRS, which provides an automated, accurate, high-density, data-gathering capability in support of tropical cyclone and winter storm forecasting operations. The 53 WRS has a Congressionally mandated charter to provide hurricane reconnaissance in support of the NWS's National Hurricane Center/Tropical Prediction Center. With the successful completion of the IWRS program, the IWRPC continues to meet at least annually to evaluate the operational effectiveness of the IWRS and to evaluate/approve proposals for IWRS improvements and upgrades. In March 1997, the IWRPC met, in conjunction with the 51st Interdepartmental Hurricane Conference, to review the status of ongoing projects and enhancements.

The Air Force and the IWRPC are actively pursuing the acquisition of the Global Positioning System (GPS)-based Atmospheric Vertical Profiling System (AVAPS) to replace the Lightweight Omega Digital Dropwindsonde System (LOD2), which will become obsolete with the demise of the Omega radionavigation system on September 30, 1997. Two prototype AVAPS systems were installed by the National Center for Atmospheric Research (NCAR) in June 1997, and test and evaluation phase is currently underway. While the 53 WRS will not achieve full operational capability by September 30, 1997, some limited capability to provide vertical atmospheric soundings will exist. Current plans call for the 53 WRS to receive three "slick" (no weather equipment) C-130J models--the likely successor to the WC-130H--in January 1998 to be used for aircrew familiarization and training. The C-130J sports a "glass cockpit," is GPS equipped, and promises significantly enhanced performance. The first (3) WC-130Js will be received in October 1998, and the three "slick" C-130Js will be returned to be weather equipped. During the 1999 hurricane season, the 53 WRS will fly a mixed fleet of J and H models.

Atmospheric Transport and Diffusion

The Working Group for Atmospheric Transport and Diffusion (WG/ATD) met several times during FY 1997 to work on a new directory for atmospheric transport and diffusion models, equipment and projects. The new directory will be an update and consolidation of two previous directories; one produced in CY 1993 by the OFCM and the other produced in CY 1995 by the Department of Energy. The projected publication date for the new directory is the 2nd quarter of FY 1998.

In the proposal to streamline the Federal coordinating structure, the WG/ATD will be aligned under the Committee for Weather Operations and Services.

Basic Services

The Committee for Basic Services (CBS) met on October 25, 1996 and received briefings on: (1) the activities and plans of the working groups for which CBS has oversight; (2) the history, status, and plans of the Federal Lightning Detection Program; (3) the snow data requirements at the United States Department of Agriculture, and (4) the streamlined Federal coordinating structure.

A major piece of the OFCM's proposal to streamline the Federal coordinating structure is based upon a restructured CBS. The CBS will be divided into two committees--the Committee for Observing Systems and the Committee for Weather Operations and Services. This realignment achieves one objective of the streamlining which was to decrease a committee's oversight of working groups through a smaller span of control.

Climate Services

The Working Group for Climate Services (WG/CS) was formed in an effort to provide a focal point for federal involvement in climate change, ozone depletion, seasonal to interannual forecasting, and climatological applications. The WG/CS has provided a unique forum, bringing together an extremely diverse group of agencies which conduct a very broad scope of activities related to climatology. The exchange of information at working group meetings has been invaluable, and the WG/CS is looking into methodologies for providing some unity to their various climate services efforts. The working group is assessing the impacts of the NWS' future efforts to downsize the upper air observing system.

Under the proposal to streamline the Federal coordinating structure, the WG/CS will be aligned with the Committee for Weather Operations and Services.

Doppler Radar Meteorological Observations

The Working Group for Doppler Radar Meteorological Observations (WG/DRMO) is continuing the revision and updating of ***FMH-11, Part A: System Concepts, Responsibilities, and Procedures***. During the past year, several drafts have been circulated among the member agencies for comments and revisions. A final draft is being prepared for review and publication in late 1997. In the future, the group plans to revise each of the four parts of the FMH-11 handbook. The majority of the coordination is being conducted via correspondence and electronic mail; no meetings have been held.

Under the proposal to streamline the Federal coordinating structure, the WG/DRMO will be aligned with the new NEXRAD Program Council. The working group will also monitor the responsibilities of the Working Group for Radar Meteorological Observations (see Radar Meteorological Observations).

Hydrometeorology

The Working Group for Hydrometeorology (WG/HM) has been addressing areas for mutual cooperation and coordination in hydrometeorology. One of its first tasks has been the development of a handbook for automated flood warning systems. The "Handbook on Automated Local Flood Warning Systems" describes local flood warning systems in terms of types, standards, requirements, implementation, and maintenance. The NWS finalized and published the document in February 1997.

In the proposal to streamline the Federal coordinating structure, the WG/HM will be aligned under the Committee for Weather Operations and Services.

Lightning Detection Systems

The Working Group for Lightning Detection Systems (WG/LDS) met in May 1997 to: (a) discuss the status of the ***Handbook on Lightning Strike***

***Locating Systems***, (b) review the status of the National Weather Service's lightning data contract, and (c) examine the requirements for space-based lightning data. The first draft of the Handbook is scheduled to be completed by the end of 1997. In the interim, a preliminary abbreviated-version will be available this fall. A NASA goal is to get a lightning detection instrument in geostationary orbit by early in the 21st century. To support this goal, the Working Group is coordinating agency requirements for space-based total lightning data. There is also an effort underway by the MIT's Lincoln Lab to articulate and, where possible, quantify operational benefits of space-based total lightning data.

In 1996, Federal agencies consolidated their agency plans for another procurement of lightning data; the original NWS contract ended in September 1996. The group assisted in drafting a statement of work which was incorporated into the RFP subsequently issued by the NWS. The new contract with Global Atmospherics Inc. (GAI) began on October 1, 1996 for FY 1997 through FY 2001. Agencies participating in the contract include DOA, DOD (USAF, USA, and USN), DOI (BLM), DOT (FAA and Volpe Center), NASA, and NWS.

Under the proposal to streamline the Federal coordinating structure, the WG/LDS will be aligned with the Committee for Observing Systems.

Marine Environmental Services

The Working Group for Marine Environmental Services (WG/MES) published the ***Federal Plan for Marine Environmental Data, Services, and Supporting Research (June 1996)*** with the objective to define a responsive national policy for marine environmental services. The plan will serve as a mechanism for interagency cooperation in marine data collection efforts.

Under the proposal to streamline the Federal coordinating structure, the WG/MES will be aligned with the Committee for Weather Operations and Services.

Meteorological Codes

During FY 1997, the WG/MC (1) finalized a modification to the non-convective low-level windshear group in TAF (FM 51-X Ext); (2) coordinated a National/International Originating Center code figure within GRIB (FM 92-X) for the Naval Oceanographic Office at Stennis Space Center, Mississippi; and (3) approved and forwarded to WMO an exception to TESAC (FM 64-IX). The group also reviewed a proposal for developing a surface observation code (similar to METAR) for automated stations and continued discussions for a standard code format for data being exchanged between operational processing centers. The latter is part of proposals and discussions within the WMO on Gridded Binary (GRIB) and Binary Universal Form (BUFR). The WG/MC is continuing coordination and review of the initial chapters of FMH-12.

Under the proposal to streamline the Federal coordinating structure, the WG/MC will be aligned with the new Committee for Weather Information Systems.

Mobile Meteorological Equipment

ICMSSR tasked the Ad Hoc Group for Mobile Meteorological Equipment (AHG/MME) to provide a forum for coordinating information on mobile observing and forecasting systems within the federal meteorological community. In December 1995, AHG/MME published a revised ***Federal Directory of Mobile Meteorological Equipment and Capabilities*** to catalogue both current mobile systems and capabilities and those programmed to be available in the near future.

In the proposal to streamline the Federal coordinating structure, the AHG/MME will be disestablished. The responsibilities for AHG/MME will be monitored by the newly-formed Committee for Observing Systems.

Monitoring the Stratosphere

In April 1997, the Working Group for Monitoring the Stratosphere (WG/MS) sponsored a meeting of scientists from the public and private sectors as well as the academic community to address ground-based and *in situ* ozone measurements for the upper troposphere and lower stratosphere. A major focus of the meeting was correlative measurements with space-based systems. The Working Group also continues oversight for the implementation of the ***National Plan for Stratospheric Monitoring, 1988-1997 (July 1989)***, which includes monitoring for ozone, trace gases, and water vapor. Updating the National Plan is expected to begin in late 1997.

Under the proposal to streamline the Federal coordinating structure, the WG/MS will be aligned with the new Committee for Observing Systems.

Operational Environmental Satellites

Within the proposal to streamline the Federal coordinating structure, the Committee for Operational Environmental Satellites was redesignated as the Working Group for Operational Environmental Satellites (WG/OES). WG/OES will be aligned under the Committee for Observing Systems.

Operational Processing Centers

The principals of the OFCM-sponsored Committee for Operational Processing Centers (COPC) and the Shared Processing Program Operations Steering Committee (SPOSC) meet twice a year to discuss data issues, modeling activities and algorithm development, and other cooperative efforts. During FY 1997, the two committees met consecutively, followed by a joint executive session. The October 1996 meeting was hosted by the Naval Oceanographic Office (NAVOCEANO) in New Orleans, Louisiana, and the May 1997 meeting was hosted by the Fleet Numerical Meteorology and Oceanography Center (FNMOC) in Monterey, California. Progress continues on linking the centers together using Asynchronous Transfer Mode (ATM) communications, which significantly upgrades the landline and satellite communications that the OPCs currently use. The first ATM link between FNMOC and Air Force Global Weather Center was operational in February 1996; the ATM network will be fully operational in early FY 1998. The COPC also received updates on the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) and the North American Atmospheric Observing System (NAOS). The Director of the National Centers for Environmental Prediction serves as chairman of the NAOS Program Council--the goal of NAOS is to redesign the composite meteorological observing system to enhance North American weather forecasting for better weather services and greater cost efficiency.

The Ad Hoc Group for Observations (AHG/OBS), which was formed by the COPC in 1996 to address the issues of declining numbers of observations and the variability of data types and counts in the databases of the OPCs, was very active during FY 1997. The Chairman, AHG/OBS, provided an update on the group's activities at both meetings.

Post-Storm Data Acquisition

A Working Group for Post-Storm Data Acquisition (WG/PSDA) was established by ICMSSR to prepare an interagency plan for scientific and engineering data acquisition, especially highly perishable data, after coastal storms, tornadoes, tsunamis, and lake storms. The following agencies actively participate: the U.S. Army Corps of Engineers, NWS, FEMA, USGS, NOAA Coastal Oceans Program, National Institute for Standards and Technology (NIST), and the USDA's Natural Resources Conservation Service.

In 1997, the WG/PSDA completed a memorandum of understanding with the Civil Air Patrol (CAP) to provide cost-effective aerial post-storm survey flights on an "as available" basis. To the extent possible, CAP will provide the needed airborne support to meet the WG/PSDA's requirements within 6 hours of a request from an authorized OFCM authority. The ***National Post-Storm Data Acquisition Plan*** is in the final stages of completion.

Under the proposal to streamline the Federal coordinating structure, the WG/PSDA will be aligned with the new Committee for Observing Systems.

Profiler Systems

The Working Group for Profiler Systems (WG/PS) met in the spring of 1997 in conjunction with a Profiler Systems Signal Processing Workshop. The use of profilers has proven valuable in many operational applications such as severe weather forecasting, pollution monitoring and space launch support; however, a limiting factor is in the signal processing. Current signal processing techniques affect real-time applications where there is little time to validate data accuracy. Many of the signal processing problems are well understood and can be solved by implementing state-of-the-art techniques. The WG/PS is drafting a review paper that covers the state-of-the-technology and outlines future profiler enhancements. The draft review paper is planned to be complete in the first quarter FY 1998.

During FY 1998, the working group will be working on an action plan to achieve quality and reliability improvements in profiler products.

Under the proposal to streamline the Federal coordinating structure, the WG/PS will be aligned with the new Committee for Observing Systems.

Radar Meteorological Observations

Under the proposal to streamline the Federal coordinating structure, the WG/RMO will be disestablished. The responsibilities for WG/RMO will be monitored by the Working Group for Doppler Radar Meteorological Observations.

Satellite Telemetry

The Satellite Telemetry Interagency Working Group (STIWG) is co-chartered by the Federal Coordinator for Meteorology and the Chief, Office of Water Data Coordination. The STIWG reports to the coordinators through the Committee for Basic Services and the Hydrology Subcommittee in their respective coordinating infrastructures. The STIWG agencies collect data from remote Data Collection Platforms (DCP) through the GOES Data Collection System (DCS). DCPs owned by the user agencies sense and collect a variety of data at remotely located positions. Among those types of data are rainfall, stream flow, water levels in lakes and reservoirs, seismic stress and vibration, wind direction and speed, atmospheric pressure, soil moisture, air/soil temperature, sea surface temperatures, and relative humidity.

A major concern of the STIWG and NESDIS has been the growing numbers of DCPs and the possibility of system saturation. Several international users are coming on-line with a growing number of DCPs. In response to this growing concern, NESDIS has taken steps to increase the efficiency of bandwidth use in the satellite and to increase the throughput at the ground processing system at the Command and Data Acquisition Station. The STIWG member agencies have funded additional demodulators for the ground receiving system and a domestic communications satellite channel to disseminate the collected data to users. They have also funded studies to evaluate the advantages and impacts of higher baud-rate equipment. Based on these results, STIWG agencies have jointly funded the development of 300 and 1200 baud transmitters, demodulators, and test sets.

The STIWG met three times in FY 1997 to discuss the operations of the GOES DCS. The working group members discussed the joint funding of GOES DCS enhancements and, in particular, the contract for higher baud rate transmitters, demodulators, and test sets which were being developed under a contract managed by NESDIS. NESDIS awarded the contract in September 1995 with delivery of prototypes scheduled for fiscal year 1997.

During a special meeting in July, the members discussed further developments in the high baud rate contract and the need for funding for a DOMSAT (domestic satellite) channel in 1997 and beyond. STIWG member agencies currently use direct read-out receivers to acquire the data they remotely sense and transmit to GOES DCS. Those data are streamed to the earth station at Wallops Island, Virginia, which retransmits the data to the DOMSAT for broadcast. This system configuration was programmed to be replaced by the NOAAPORT system. NOAAPORT will operate in a different frequency band than the DOMSAT broadcast, thus, requiring some modifications to the direct read-out receivers and antennae.

The STIWG completed its review and approved the ***National GOES DCS Operations Plan*** for publication. The plan will be available for distribution in August 1997. The STIWG has reduced the number of regular meetings from 4 to 2 per year, but will meet as needed for funding and contract business.

In the proposal to streamline the Federal coordinating structure, the STWIG will be aligned under the new Committee for Weather Information Systems.

Severe Local Storms Operations

The Working Group for Severe Local Storms Operations (WG/SLSO) completed its work on the ***National Severe Local Storms Operations Plan*** and the plan was published in March 1997.

Within the proposal to streamline the Federal coordinating structure, the WG/SLSO will be aligned under the Committee for Weather Operations and Services.

Surface Observations

With the publication of FMH-1, the Working Group for Surface Observations (WG/SO) recommended the disestablishment of the Ad Hoc Group for FMH-1 and assumed the responsibilities for maintenance of the publication. The group plans to revisit the topic of a common interagency observing handbook. In addition, the group is examining the need to broaden the working group's focus from an aviation-oriented perspective to one that balances the needs of all surface observation users.

Under the proposal to streamline the Federal coordinating structure, the WG/SO will be aligned with the new Committee for Observing Systems.

Tropical Cyclone Research and Reconnaissance

In January 1997, the Working Group for Tropical Cyclone Research published the ***National Plan for Tropical Cyclone Research and Reconnaissance (1997-2002)***--the third in the series dating back to December 1990. The plan details a program for tropical cyclone/hurricane research and reconnaissance that provides an improving level of service to adequately protect the citizens of the coastal areas of the United States. It defines the challenges that the forecast centers face and divides them into four focus areas: observations/analysis, forecasting, communications/ dissemination, and verification/documentation. Within each focus area, a series of objectives (14 total) are defined. These objectives closely correlate with the highest priority challenges identified by the forecast centers and are designed to focus the cooperative efforts among the various research groups, both within and outside of government. The goals of the program, over the next 5 years, are: (1) to validate the data and product requirements, together with the supporting research, needed to provide for long-term improvements in tropical cyclone forecasting and warning services and (2) to determine the optimum mix of complementary and cost-effective remote and *in-situ* systems to satisfy those requirements. Progress on achieving the goals and objectives of the program will be reviewed at the annual Interdepartmental Hurricane Conferences, hosted by the OFCM, as well as in updates to the plan.

In the proposal to streamline the Federal coordinating structure, the Task Group for Tropical Cyclone Research (TG/TCR) will be disestablished. The responsibilities for the TG/TCR will be absorbed by the renamed Working Group for Hurricane and Winter Storms Operations and Research (WG/HWSOR).

Upper Air Observations

The Working Group for Upper Air Observations (WG/UAO) met in the Spring to review DOD's research and development efforts on GPS-based upper air observation systems and to further define agency requirements. In May, the Ad Hoc Group for Federal Meteorological Handbook No. 3 (AHG/FMH-3) completed the revisions of the handbook and received WG/UAO approval for publication and distribution. ***FMH-3, Rawinsonde and Pibal Observations*** was distributed in May 1997. With the completion of this task, the WG/UAO recommended and received CBS concurrence to disestablish the ad hoc group.

Under a proposal to streamline the Federal coordinating structure, the WG/UAO will be aligned within the Committee for Observing Systems.

Volcanic Ash Reporting and Warning

At the request of the federal agencies in 1993, the ICMSSR established the Ad Hoc Group for Volcanic Ash (AHG/VA) to develop a national plan for Volcanic Ash Reporting and Warning. The plan will identify responsibilities of the federal agencies to report and collect data on volcanic disturbances and eruptions, and to develop forecasts and warnings of locations and movement of ash plumes or clouds.

The AHG/VA continues its work on the national plan. The document has undergone numerous changes during the course of its development including a name change. The new title is "***A National Framework for Volcanic Ash Hazards to Aviation***." The final draft is being reviewed by members and publication is projected for early 1998.

During 1997, the AHG/VA also discussed the utility that the World Area Forecast System (WAFS) will bring to the Volcanic Ash Warning System. The United States supports the ICAO Volcanic Ash Warning System and will have two Volcanic Ash Alerting Centers (VAACs)--one in Anchorage, Alaska, and another in Washington, DC. The group also addressed an interagency effort to place seismic sensors on more Alaskan volcanoes to promote safety along the North Pacific air routes. During the summer 1996, the Coast Guard and the University of Alaska assumed responsibility for installation of additional instruments on four volcanoes. The FAA provided funds for the additional sensors in 1997 as well.

Interdepartmental Hurricane Conference

The Office of the Federal Coordinator for Meteorology hosted the 51st Interdepartmental Hurricane Conference (IHC) during March 25-28,1997 in Miami, Florida. The conference agenda consisted of: a review of the 1996 tropical cyclone season in the Atlantic Ocean, Gulf of Mexico, Caribbean Sea, and the Pacific Ocean; the current tropical cyclone research

and requirements for the 1997 tropical cyclone season; a review of the military weather reconnaissance mission; and the revision to the ***National Hurricane Operations Plan*** (NHOP). The featured, guest speaker was Dr. Gregory Holland, Australian Bureau of Meteorology, whose presentation described the results of "pioneering adventures" in tropical cyclone reconnaissance including the performance of unmanned aerial vehicles. Further testing of this capability is planned in FY 1998 at the Joint Typhoon Warning Center in Guam.

The Working Group for Hurricane and Winter Storms Operations met in conjunction with the IHC to update the NHOP. The 1997 edition of the NHOP was published in May. The 52nd Interdepartmental Hurricane Conference is scheduled for January 26-30, 1998 in Clearwater Beach, Florida.

In the OFCM's streamlining proposal, the WG/HWSO will absorb the responsibilities of the TG/TCR and be renamed the Working Group for Hurricane and Winter Storms Operations and Research (WG/HWSOR).

Committee and Working Group Structure

A schematic of the current federal committee and working group structure for meteorological coordination is found on the back inside cover of this plan.

Federal Meteorological Handbooks

At the direction of the ICMSSR, the OFCM maintains a continuing program to revitalize the Federal Meteorological Handbooks (FMH). Responsibility for review and revisions, if necessary, of each handbook is assigned to the appropriate committee and/or working group within the existing interdepartmental coordinating infrastructure. The FMH series includes observing and reporting practices for surface, upper air, radar, and meteorological rocket observations. The titles of nine existing handbooks are: ***Surface Weather Observations and Reports***, ***Surface Synoptic Codes***, ***Rawinsonde and Pibal Observations***, ***Weather Radar Observations***, ***Meteorological Rocket Observations***, and ***Doppler Radar Meteorological Observations***.

To date, revisions have been completed for the ***Surface Weather Observations and Reports*** (FMH-1), ***Surface Synoptic Codes*** (FMH-2), ***Rawinsonde and Pibal Observations*** (FMH-3), ***Meteorological Rocket Observations*** (FMH-10), and ***Doppler Radar Meteorological Observations*** (FMH-11) handbooks. In May 1997, the Ad Hoc Group for FMH-3 finalized and published the third edition of FMH-3. This edition is a compilation of standards and procedures for taking, processing, encoding, communicating, and archiving rawinsonde and pibal observations. Previously, this information was described in FMH's 3 through 6. Federal agencies are continuing to develop the ***Manual on Codes--U.S. Supplement*** (FMH-12). This new handbook will include, along with other codes to be determined, the Pilot Report (PIREP) code form that had been included in earlier versions of FMH-1.

New versions of all handbooks are available to private-sector users through the Customer Services at the National Climatic Data Center, Asheville, North Carolina. Federal agencies may request copies from the OFCM.

Meteorological Publications of OFCM

The preparation of federal plans is a major responsibility of the Federal Coordinator and requires extensive planning and coordination. Generally, federal plans are prepared for each of the specialized meteorological services and for meteorological programs common to two or more agencies. The federal coordinating committees and working groups compile information from the involved agencies and propose a unified plan for consideration. Current publications of the Federal Coordinator for Meteorology are listed in Table 2.1. With the exception of FMH's, copies of OFCM publications are available upon request.

## RELATED FEDERAL METEOROLOGICAL COORDINATION

The focus of OFCM and of this report is on federal operational meteorological programs and supporting research that directly supports the operational programs. Brief descriptions are given below of federal coordination activities that are not specifically a part of OFCM activities.

### Surface Transportation - Road/Weather Information System

Throughout FY 1997, the OFCM participated in several meetings and workshops to assist the DOT's Federal Highway Administration (FHWA) with on-going activities related to the Intelligent Transportation System (ITS). OFCM provided technical assistance in meteorology and advice on meteorological codes related to the development of the National Transportation Communications for ITS Protocol (NTCIP). The primary objective of the NTCIP is to provide a communications standard that ensures the interoperability and interchangeability of traffic control and ITS devices (including meteorological sensors). In addition, staff members provided technical advise and shared information on similar remote sensing efforts being conducted in other federal agencies.

OFCM staff and agency members participated in other meteorology-related, interagency programs which were not run by OFCM. These programs were under the auspices of the Committee for the Environment and National Resources and the Subcommittee for National Disaster Reduction. OFCM staff also participated in NOAA's North American Atmospheric Observing System (NAOS) activities. The goal of NAOS is to meet evolving NOAA requirements for North American atmospheric observations needed to support the assessment and prediction for weather and climate.

### World Weather Program

Some federal agencies participate in international activities relating to meteorological services and data exchange. These activities are carried out under the World Weather Program of the World Meteorological Organization, which is a specialized agency of the United Nations. The World Weather Program is described in Appendix E.

Table 2.1 Current OFCM Publications

| Publication Title | Date | Number |
|---|---|---|
| Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 1997 | June 1996 | FCM-P1-1996 |
| National Plan for Space Environment Services and Supporting Research: 1993-1997 | August 1993 | FCM-P10-1993 |
| National Severe Local Storms Operations Plan | February 1997 | FCM-P11-1997 |
| National Hurricane Operations Plan | May 1997 | FCM-P12-1997 |
| National Winter Storms Operations Plan | September 1996 | FCM-P13-1996 |
| Federal Plan for Cooperative Support and Backup Among Operational Processing Centers | May 1996 | FCM-P14-1996 |
| National Plan for Stratospheric Monitoring, 1988-1997 | July 1989 | FCM-P17-1989 |
| National Aircraft Icing Technology Plan | April 1986 | FCM-P20-1986 |
| National Plan to Improve Aircraft Icing Forecasts | July 1986 | FCM-P21-1986 |
| Federal Plan for the Coordination of Automated Weather Information System Programs | May 1988 | FCM-P23-1988 |
| Federal Plan for Meteorological Information Management | July 1991 | FCM-P24-1991 |
| National Plan for Tropical Cyclone Research and Reconnaissance (1997-2002) | January 1997 | FCM-P25-1997 |
| National Aviation Weather Program Plan | September 1992 | FCM-P27-1992 |
| Federal Plan for Marine Environmental Services and Supporting Research | June 1996 | FCM-P29-1996 |
| The National Space Weather Program: Strategic Plan | August 1995 | FCM-P30-1995 |
| The National Space Weather Program: Implementation Plan | January 1997 | FCM-P31-1997 |
| National Aviation Weather Strategic Plan | April 1997 | FCM-P32-1997 |
| Federal Meteorological Handbook No. 1 - Surface Weather Observations and Reports | December 1995 | FCM-H1-1995 |
| Federal Meteorological Handbook No. 2 - Surface Synoptic Codes<br>Surface Synoptic Code Tables (Update) | December 1988<br>July 1990 | FCM-H2-1988<br>FCM-T1-1990 |
| Federal Meteorological Handbook No. 3 - Rawinsonde & Pibal Observations | May 1997 | FCM-H3-1997 |
| Federal Meteorological Handbook No. 10 - Rocketsonde Observations | December 1988 | FCM-H10-1988 |
| Federal Meteorological Handbook No. 11 - Doppler Radar Meteorological Observations | | |
| Part A - System Concepts, Responsibilities and Procedures | June 1991 | FCM-H11A-1991 |
| Part B - Doppler Radar Theory and Meteorology | June 1990 | FCM-H11B-1990 |
| Part C - WSR-88D Products and Algorithms | February 1991 | FCM-H11C-1991 |
| Part D - WSR-88D Unit Description and Operational Analysis | April 1992 | FCM-H11D-1992 |
| Directory of Atmospheric Transport and Diffusion Models, Equipment, and Projects | April 1993 | FCM-I3-1993 |
| Federal Directory of Mobile Meteorological Equipment and Capabilities | December 1995 | FCM-I5-1995 |
| A Guide to WMO Code Form FM 94 BUFR | March 1995 | FCM-I6-1995 |
| Tropical Cyclone Studies<br>Tropical Cyclone Studies Supplement | December 1988<br>August 1989 | FCM-R11-1988<br>FCM-R11-1988 S |
| Interdepartmental Meteorological Data Exchange System Report, IMDES (under revision) | July 1991 | FCM-R12-1991 |
| Federal Meteorological Requirements 2000 | October 1990 | FCM-R13-1990 |
| Standard Formats for Weather Data Exchange Among Automated Weather Information Systems | November 1994 | FCM-S2-1994 |
| Standard Telecommunication Procedures for Weather Data Exchange (under revision) | October 1991 | FCM-S3-1991 |
| Federal Standard for Siting Meteorological Sensors at Airports | August 1994 | FCM-S4-1994 |
| 51st Interdepartmental Hurricane Conference (Minutes) | May 1997 | None |

SECTION 3

# RESOURCE INFORMATION AND AGENCY PROGRAM UPDATES

The tables in this section summarize fiscal information of the federal government for Fiscal Years (FY) 1997 and 1998. The funds shown are those used to provide meteorological services and associated supporting research that has as its immediate objective the improvement of these services. Fiscal data are current as of the end of June 1997 and are subject to later changes. The data for FY 1998 do not have legislative approval and do not constitute a commitment by the United States Government. The budget data are prepared in compliance with Section 304 of Public Law 87-843, in which Congress directed that an annual horizontal budget be prepared for meteorological programs conducted by the federal agencies.

## AGENCY OBLIGATIONS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

Table 3.1 contains fiscal information, by agency, for meteorological operations and supporting research. The table shows the funding level for FY 1997 based on Congressional appropriations, the budget request for FY 1998, the percent change, and the individual agencies' percent of the total federal funding for FY 1997 and FY 1998.

### DEPARTMENT OF AGRICULTURE (USDA)

The USDA budget request for FY 1998 is $28.14 million for operations and supporting research and represents a 2.1 percent increase from the requested FY 1997 funding level of $27.57 million. The USDA assists the Department of Commerce in determining farmers' needs for weather information and in disseminating the information to them. Major USDA activities related to weather observations include incremental modernization of the snow telemetry (SNOTEL) system operated by the Natural Resources Conservation Service (NRCS) and the replacement of manual fire rating stations with remote automated weather stations (RAWS) by the Forest Service. The SNOTEL and RAWS networks provide cooperative data for NOAA's river forecast activities, the irrigation water supply estimates, and Bureau of Land Management operations. The modernization of the RAWS completed the testing phase for acceptance in operations.

For supporting research, the USDA requests $15.59 million to focus on the interactions of weather and climate with plant and animal production and water resources management. The goal of supporting research is to develop and disseminate information and techniques to ensure an abundance of high-quality agricultural commodities and products while minimizing the adverse effects of agriculture on the environment. The research budget does not include the coordinated effort with EPA on ultraviolet radiation. The Forest Service supports a research program, initiated in 1988, for a long-term monitoring network to assess potential effects of global climate change and variability on forest health and productivity. Work also continues in forestry ecological systems modeling.

### DEPARTMENT OF COMMERCE (DOC)

All reported DOC meteorological activities are within the National Oceanic and Atmospheric Administration (NOAA). The NOAA FY 1998 total congressional request of $1.21 billion for meteorological programs represents a 1.7 percent increase over the FY 1997 appropriated funds. NOAA's FY 1998 operations and supporting research requests for each of the major line office activities are described below:

Weather Services. Funding levels for FY 1998 will decrease by 305 positions and $10.0 million as part of the transition to the modernized office structure. Operations support funds of $450.8 million (a 2.2 percent decrease over FY 1997) are programmed to operate the Weather Surveillance Radar-1988 Doppler (WSR-88D) or NEXRAD units which significantly improve severe weather warning capabilities; to prepare for the Modernization and Associated Restructuring Demonstration (MARD); to continue Stage II staffing of Weather Forecast Offices (WFO) as the Advanced Weather Interactive Processing Systems (AWIPS) are deployed; and to provide funding in support of the certification requirements of Public Law 102-567.

NOAA continues to modernize the NWS by acquiring technologically advanced systems. This approach is consistent with the goal of providing more timely and accurate warning and forecast services to the public and in support of the Advance Short-Term

## TABLE 3.1 METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH COSTS*, BY AGENCY

(Thousands of Dollars)

| | Operations | | | % of FY98 | Supporting Research | | | % of FY98 | Total | | | % of FY97 | % of FY98 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AGENCY | FY97 | FY98 | %CHG | TOTAL | FY97 | FY98 | %CHG | TOTAL | FY97 | FY98 | %CHG | TOTAL | TOTAL |
| Agriculture | 12105 | 12553 | 3.7 | 0.6 | 15467 | 15591 | 0.8 | 4.5 | 27572 | 28144 | 2.1 | 1.2 | 1.2 |
| Commerce/NOAA | 1101079 | 1132490 | 2.9 | 55.9 | 91002 | 80240 | -11.8 | 22.9 | 1192081 | 1212730 | 1.7 | 51.1 | 51.0 |
| Defense(Subtot) | 420412 | 434746 | 3.4 | 21.4 | 85803 | 78558 | -8.4 | 22.4 | 506215 | 513304 | 1.4 | 21.7 | 21.6 |
| Air Force | 259535 | 265357 | 2.2 | 13.1 | 41961 | 39734 | -5.3 | 11.3 | 301496 | 305091 | 1.2 | 12.9 | 12.8 |
| DMSP** | 42424 | 41973 | -1.1 | 2.1 | 17964 | 14076 | -21.6 | 4.0 | 60388 | 56049 | -7.2 | 2.6 | 2.4 |
| Navy | 96263 | 107633 | 11.8 | 5.3 | 11786 | 11985 | 1.7 | 3.4 | 108049 | 119618 | 10.7 | 4.6 | 5.0 |
| Army | 22190 | 19783 | -10.8 | 1.0 | 14092 | 12763 | -9.4 | 3.6 | 36282 | 32546 | -10.3 | 1.6 | 1.4 |
| Interior/BLM | 800 | 800 | 0.0 | 0.0 | 0 | 0 | 0.0 | 0.0 | 800 | 800 | 0.0 | 0.0 | 0.0 |
| Transportation/CG | 6774 | 6774 | 0.0 | 0.3 | 0 | 0 | 0.0 | 0.0 | 6774 | 6774 | 0.0 | 0.3 | 0.3 |
| Transportation/FAA | 408955 | 434763 | 6.3 | 21.4 | 16627 | 6317 | -62.0 | 1.8 | 425582 | 441080 | 3.6 | 18.2 | 18.6 |
| EPA | 0 | 0 | 0.0 | 0.0 | 5700 | 5700 | 0.0 | 1.6 | 5700 | 5700 | 0.0 | 0.2 | 0.2 |
| NASA | 4903 | 4459 | -9.1 | 0.2 | 162700 | 163750 | 0.6 | 46.8 | 167603 | 168209 | 0.4 | 7.2 | 7.1 |
| NRC | 364 | 298 | -18.1 | 0.0 | 0 | 0 | 0.0 | 0.0 | 364 | 298 | -18.1 | 0.0 | 0.0 |
| TOTAL | 1955392 | 2026883 | 3.7 | 100.0 | 377299 | 350156 | -7.2 | 100.0 | 2332691 | 2377039 | 1.9 | 100.0 | 100.0 |
| % of FY TOTAL | 83.8% | 85.3% | | | 16.2% | 14.7% | | | 100.0% | 100.0% | | | |

*The FY 1997 funding reflects Congressionally appropriated funds; the FY 1998 funding reflects the amount requested in the President's FY 1998 budget submission to Congress.

**DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

Warning and Forecast Services goal of NOAA's Strategic Plan. A net increase of $14.4 million is requested for this sub activity.

Specifically in FY 1998, NWS requests a decrease of $2.2 million for the NEXRAD acquisition program. This decrease reflects near completion of NEXRAD system acquisition. The NEXRAD network will provide nationwide Doppler radar coverage, improve detection of severe weather and floods, reduce false alarm rates, increase warning lead times, and replace the existing obsolete radar network. The FY 1998 funding for the ASOS program decreases by $0.2 million as the full-scale production phase and production improvement activities continue. This decrease represents near completion of ASOS acquisition. Funding is required to operate and maintain the current network of ASOS systems and continue planned product improvements.

The FY 1998 budget request includes an increase of $16.9 million for the AWIPS to continue critical software development activities and proceed with nationwide deployment of the AWIPS system. For the first time, AWIPS will integrate satellite and radar data and provide the local forecaster a capability that will significantly improve forecasts and warnings. In addition to supporting the re-mapping of GOES data, AWIPS will provide the communications capability needed to allow internal and external users access to much of NOAA's real-time environmental data. In addition, NWS request a $0.1 million decrease for the Central Computer Facility budget to reflect a decreased annual payment toward the Cray J-916 systems buyout, the continuing lease and maintenance of the Cray C-90 supercomputer, and the completion of the NWS telecommunications gateway upgrade.

Environmental Satellite, Data, and Information Services. Proposed funding for FY 1998 includes a decrease in the Polar-Orbiting Satellite Program of $41.9 million and an increase in the Geostationary Satellite Program of $66.2 million. These changes allow for continuation of procurements to provide the spacecraft and instruments, launch services, and ground systems necessary to assure continuity of environmental satellite coverage. The FY 1998 budget request will maintain a system of polar-orbiting satellites that obtains global data and a system of geostationary satellites that provides near continuous observations of the Earth's western hemisphere. Funding is included for NOAA's share of the converged NOAA and Department of Defense (DOD) polar-orbiting system that will replace the current NOAA series and the DOD Defense Meteorological Satellite Program (DMSP) in the year 2007.

A reduction of $0.2 million is requested to continue the Ocean Remote Sensing Program which began in FY 1995. During the next several years, NOAA will acquire data from foreign and other non-NOAA satellites that will provide measurement of ocean currents, surface winds and waves, subsurface temperature and salinity profiles, ice thickness and flows, and other marine factors.

Decreases totaling $0.7 million are included to maintain basic mission services, including maintenance and operation of satellite ground facilities, provision of satellite-derived products, and conduct of research to improve the use of satellite data.

An increase of $3.0 million is requested to continue implementation of the NOAA Virtual Data System (NVDS). This system will modernize existing data storage and retrieval systems, and vastly improve, streamline, and simplify customer access to environmental data. A decrease of $4.0 million is requested for the operation of the three NOAA data centers and environmental data management modernization programs. This reductions will be partially offset by increases in data sales.

Weather Research. Requested funding for FY 1998, which includes Solar Terrestrial Services and Research, is $43.5 million--the same level as FY 1997. Covering inflationary cost increases will negatively impact the production of base programs which are described in Appendix A.

DEPARTMENT OF DEFENSE (DOD)

The DOD total budget request for FY 1998 is $513.3 million. This total represents a 1.4 percent increase in the funding level from FY 1997. Specific highlights for each of the military departments are described below:

U.S. Air Force

U.S. Air Force resources for meteorological support fall under four categories: general operations, general supporting research, DMSP operations, and DMSP and National Polar-orbiting Operational Environmental Satellite System (NPOESS) supporting research. The Air Force request (including DMSP) for FY 1998 is $361.1 million.

General Operations. The operations portion of the FY 1998 budget request is $247.3 million and represents a large portion of the environmental support to the DOD. These funds will pay for weather and space environmental support to the USAF (both active duty and reserve components), the U.S. Army, nine unified commands, and other agencies as directed by the Chief of Staff of the Air Force. Over 3,400 people conduct these activities at over 200 worldwide locations. These people include active duty military, Air Force reservists, Air National Guard weather flight personnel, weather communications and computer specialists, and civilians. General operations funds pay the salaries of these people providing weather support, and the day-to-day operations and maintenance costs for the support they provide.

General Supporting Research. The FY 1998 budget request for Air Force supporting research is $39.7 million. The Air Force continues R&D efforts for the Cloud Depiction and Forecast System II (CDFS II) and the Global Theater Weather Analysis and Prediction System (GTWAPS), and begins R&D efforts for the Tactical Weather Radar (TWR). CDFS II will expand the computer processing capability of the current CDFS at AFGWC and will build a high resolution, worldwide cloud database by enabling the ingest and exploitation of all weather satellite and sensor data received at AFGWC. GTWAPS will provide AFGWC and the DOD a theater modeling capability to support the warfighters. A variety of other research efforts will investigate the electrodynamics of the Sun and Earth's magnetosphere, ionospheric dynamics, mesoscale meteorology, visible and infrared properties of the environment, and cloud parameterization and prediction.

DMSP Operations. Though funding for DMSP comes from the Air Force, this system is the major source of space-borne meteorological data for the military services and other high-priority DOD programs. Through the shared processing program, the DOD provides environmental data from DMSP sensors to the NWS via the network hub at the National Environmental Satellite, Data, and Information Service, and to the Navy via the network hubs at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) and the Naval Oceanographic Office (NAVOCEANO).

The operations portion of the FY 1998 budget request is $42 million. The major portion of this funding is for on-orbit operations, tactical terminal procurement, and satellite sensor integration. These funds also pay operations costs for one dedicated command and control facility. DMSP funds for 217 military and civilian personnel associated with the operation of, and to a much smaller extent, the procurement of the DMSP system.

DMSP and NPOESS Supporting Research. The FY 1998 budget for DMSP R&D is $14.1 million. The funds will be used for launch vehicle integration; system integration and testing; and mission sensor calibration, validation, and algorithm development efforts. The FY 1998 DOD R&D budget for NPOESS is $29 million. FY 1998 funds will be used for system architecture studies, independent risk reduction and technology development efforts, and to begin critical sensor and algorithm development. NPOESS is scheduled to be available in 2007 as a backup to the final launch of the NOAA polar-orbiting satellites and DMSP satellites. This system will exploit advanced hardware and software technologies to produce a more reliable, longer-lived spacecraft with greater mission capability.

U.S. Navy

The U. S. Navy FY 1998 budget request for meteorological programs is $120 million. The request includes $108 million for operational programs and $12 million for supporting research.

Operations Support. Operational support for the Navy and Marine Corps includes the day-to-day provision of meteorological and oceanographic (METOC) products and services. Naval METOC support continues to evolve with the shift in United States military operational focus to expeditionary forces support. As Naval operations in the littoral increase, Navy and Marine Corps METOC support is being focused on providing on-scene capabilities for personnel that directly furnish environmental data to sensors and weapons planning and employment systems.

In addition to aviation and marine METOC support, the Navy provides a variety of unique services on demand, such as electro-optical and acoustic propagation models and products, METOC-sensitive tactical decision aids, and global sea ice analyses and forecasts. The primary program direction continues to be improvements in data collection and processing capabilities for on-scene METOC support in the littoral zones.

Systems Acquisition. Major systems undergoing procurement or upgrades include:

- Naval Integrated Tactical Environmental System (NITES) -- a collection of five METOC subsystems:
  --Tactical Environmental Support System (TESS(3)/NC)
  --Joint TESS Remote Workstation (J-TRWS) and Joint METOC Segment (JMS)
  --METOC Integrated Data Display System (MIDDS)
  --Interim Mobile Oceanography Support System (I-MOSS)
  --Allied Environmental Support System (AESS)
- Primary Oceanographic Prediction System (POPS) at FLENUMMETOCCEN
- USMC Meteorological Mobile Facility (Replacement) (METMF(R))

Research and Development (R&D). This area is not generally system-specific; instead, Navy R&D efforts typically have applications to one or more meteorological, oceanographic, or tactical system(s). Navy's tabulation of these data includes R&D funding for exploratory research, demonstration, validation, engineering, and manufacturing development.

Initiatives of the Navy and Marine Corps, under sponsorship of the Oceanographer of the Navy, transition projects from exploratory development to operational Naval systems. Such efforts include advances in the Navy's numerical METOC forecasting capability, expansion in communications and data compression techniques, further development and improvement of models to better predict METOC parameters in littoral regions, and an improved understanding of the impact these parameters have on sensors, weapon systems, and platform performance.

U.S. Army

The U.S. Army is requesting $19.7 million for operational support and $12.7 million in research and development in FY 1998. Operational support decreased by $2.4 million or about 10 percent from FY 1997 funding levels. Operational manning will stay about the same at just over 300 with the majority in artillery support. Operational meteorological support at the test ranges and research and development facilities stays about the same in FY 1998 as in FY 1997. Major decreases in weather support programs and manpower, experienced over the past several years, has leveled off in FY 1998.

The Field Artillery Meteorological Hydrogen Generator (MHG) program was completed in FY 1997. The Meteorological Measuring System (MMS) was also completed in FY 1997 but will under go modifications in FY 1998 to be able to use Global Positioning System (GPS) radiosondes. Cost to modify systems within the Training and Doctrine Command (TRADOC) will be $0.9 million. The Integrated Meteorological System (IMETS) continued fielding in FY 1997 with Block II systems scheduled for fielding in FY 1998 at a cost of $1.4 million. Upgrades of previously fielded Block I IMETS to Block II capabilities and other product improvements will follow after FY 1998. The Army Authorized Objective is one IMETS for each Army echelon with an assigned Air Force Weather Team, but is resource constrained at this time. The Communications and Electronics Command (CECOM), Intelligence and Electronic Warfare (IEW) Directorate supports the CECOM Level II manager and the Project Director, IMETS with technical management of programs under their control. The funding for IEW Directorate internal support in FY 98 is $0.5 million.

TRADOC support costs in FY 1998 include the services and repairs for computerized training devices in upper air artillery training programs. These costs were not previously included. TRADOC expenditures across the command were down from $3.8 million in FY 1997 to $2.7 million in FY 1998 with a reduction in costs associated with the completion of the MMS program. U.S. Army Pacific Command (USARPAC) will have a small increase in costs associated with new, direct Staff Weather Officer (SWO) support to U.S. Army, Japan starting in FY 1998. U.S. Army Europe (USAREUR) and Seventh Army will have a small increase in funding primarily to lease weather satellite receivers.

In operational support for Research, Development Test and Evaluation (RDTE), Army Matériel Command funding for the Test and Evaluation Command (TECOM) Meteorological Teams (MET) in FY 1997 was $6.7 million for basic operations supporting 10 Army test ranges and R&D sites, with one site closing during the year. FY 1998 funding is $6.8 million. TECOM MET Teams now operate on a 60/40 percent consumer reimbursable/direct funding basis. Meteorological instrumentation for TECOM MET Teams operations will be acquired through other Army technical development resources or through direct funding from RDTE projects for test specific or unique requirements rather than from mission funds.

In meteorological R&D, the Army Research Laboratory (ARL), Battlefield Environment (BE) Division moved its basic meteorological research from White Sands Missile Range, New Mexico to the ARL Laboratory Center, Adelphi, Maryland in FY 1997. Basic research stays about constant from FY 1997 to 1998 at $3.6 million. Applied research associated with Weather Exploitation and Artillery Meteorology branches at White Sands Missile Range decreases from $6.1 million in FY 1997 to $5.5 million in FY 1998.

Other meteorological research at the Army Research Office (ARO), Corps of Engineers laboratories and centers, and the U.S. Army Research Institute of Environmental Medicine remain small programs with only minor changes in funding from FY 1997 to 1998.

DEPARTMENT OF THE INTERIOR (DOI)

The DOI funding request for FY 1998 is $800,000. This figure is for meteorological operations and support of the Bureau of Land Management (BLM) remote sensing requirements for Remote Automatic Weather Station (RAWS) and Lightning Detection Programs. Normal operations and maintenance of the restructured RAWS program is approximately $600,000 beginning this year. (This includes personnel, vehicles per diem, normal procurement and facilities).

The BLM downsizing effort in RAWS will continue in FY 1998. Total reduction in station numbers will be by one-fourth. Continue optimization will take place over the next few years. Subsequent cost savings in operations costs will be used to replace aging equipment and upgrade sensors packages. Proposed changes in Lightning Detection operations will further reduce the out-year expenditures in this program. Coordination between DOI agencies and the USDA Forest Service regarding combined meteorological requirements for the National Wildfire support functions is ongoing. During the coming downsizing efforts, interagency RAWS replacement coordination will continue to maximize National Fire Danger Rating System (NFDRS) sampling points and minimize the total number of systems required in the West.

DEPARTMENT OF TRANSPORTATION (DOT)

The meteorological programs for the United States Coast Guard and the Federal Aviation Administration for FY 1997 and FY 1998 are described below.

U.S. Coast Guard (USCG)

All of USCG's funding for meteorological programs is for operations support. In FY 1998, the requested funding level is $6.77 million. Among the Coast Guard's activities are the collection and dissemination of meteorological and iceberg warning information for the benefit of the marine community. The Coast Guard provides coastal and marine weather observations to NOAA's NWS, radio transmission of NWS weather warnings to marine users, the use of buoy tender facilities to support the activities of the National Data Buoy Center, and the management and operation of the International Ice Patrol that provides warnings to mariners of the presence of icebergs in the North Atlantic shipping lanes.

Federal Aviation Administration (FAA)

The total FAA request for aviation weather in FY 1998 is $441.1 million for both operations and supporting research; the FAA funding for FY 1997 for aviation weather was $425.6 million. The increase in the budget is principally in operations which will rise from the appropriated $409.0 million to the requested $434.8 million. Funding for supporting research in FY 1998 will decrease about 62 percent to $6.3 million.

The FAA is principally concerned with aviation weather. The FAA role is limited to the observation and dissemination of aviation weather information and to short-range automated warnings and forecasts. FAA's aviation weather programs are directed at improving the timeliness and accuracy of weather information to the aviation user when and where it is needed. The FAA also supports research in those areas that involve improvements to the observation, data dissemination, and forecasting of aviation weather. The end users of the resulting products include pilots, dispatchers, and air traffic controllers.

The FY 1998 increases in Systems Acquisition are 4.5 percent to $103.7 million. Acquisition programs with significant increases are the Weather and Radar Processor (WARP), the Integrated Terminal Weather System (ITWS), and Automated Surface Observing System (ASOS). Lesser acquisition increases are in the Low Level Windshear Advisory System, Digital Altimeter Setting Instrument, and Next Generation Runway Visual Range. Decreases to acquisition programs are associated with completion or near completion of the programs. Appendix C contains descriptions for these systems.

Individual system acquisition and operational programs with changes greater than $2 million are listed below:

| Program | Change ($ Millions) |
|---|---|
| Systems Acquisition: | |
| Automated Surface Observing System | 9.7 |
| Weather and Radar Processor | 2.6 |
| Terminal Doppler Weather Radar | - 2.5 |
| Integrated Terminal Weather System | 5.9 |
| Wind Shear Processor | 5.6 |
| Operations Support: | |
| Flight Service Stations Operations | 4.7 |
| ASOS Back-up | 10.1 |

The FY 1998 funding request for operational support increases by $25.3 million (6.9 percent) to $327.1 million, which reflects modest increases for leased communications, contract weather observations and certain maintenance functions; and significant increases in Flight Service Station operations and ASOS backup. The large increase in operations support are associated with FAA's broadened role and responsibility for surface observations, ASOS observer augmentation, and staffing for the Aviation Weather Division.

Supporting research funding decreases from $16.6 million in FY 1997 to $6.3 million in FY 1998. The number of personnel expected to be engaged in FAA's aviation weather program is at 3434, nearly level.

## ENVIRONMENTAL PROTECTION AGENCY (EPA)

All of the EPA'S funding of meteorological programs is for supporting research. The anticipated funding level in FY 1998 for directed meteorological research is $5.7 million which is approximately the same as the FY 1997 funding level.

However, to promote excellence in environmental science and engineering, the EPA has established a new national fellowship program and substantially increased its support for investigator-initiated research grants. The increase in funding for grants (with reliance on quality science and peer review) and for graduate fellowships (to support the education and careers of future scientists) will provide for a more balanced, long-term capital investment in improved environmental research and development.

The funding for the grants program increased from $80 million in FY 1996 to $100 million in FY 1997, and will remain at this level in FY 1998. The augmented grants program will fund research in areas including ecological assessment, air quality, environmental fate and treatment of toxic and hazardous wastes, and exploratory research. The portion of these grants that will be awarded for meteorological research during FY 1998 cannot be foreseen, but it is probable that the grant awards will increase the base amount of $5.7 million listed above for directed meteorological research.

The EPA is continuing its development and validation of air quality dispersion models for air pollutants on all temporal and spatial scales as mandated by the Clean Air Act, as amended. Research will focus on indoor, urban, mesoscale, and regional models which will be used to develop air pollution control strategies, and human and ecosystem exposure assessments. There will be increased emphasis placed on meteorological research into regional and urban formation and transport of ozone and particulate pollution in support of the proposed revisions to the National Ambient Air Quality Standards. Increased efficiency of computation and interpretation of results are being made possible by means of high performance computing and scientific visualization techniques.

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Nearly all of NASA's funding in meteorology is for supporting research. The requested funding for supporting research in FY 1998 is $163.75 million, which is virtually unchanged from the FY 1997 funding level. These funding levels are composed of the estimated meteorology share of the supporting research and analysis programs as well as Earth Observing System (EOS) and Earth Probe instruments, EOS science and EOS Data and Information Systems. The FY 1998 level reflects a near 16 percent increase in the EOS and a 4 percent decrease in the EOSDIS funding from the corresponding FY 1997 levels. The Earth Probes line for FY 1998 is nearly 29 percent lower than the FY 1997 level. This line reflects reductions due to the anticipated launch of the TRMM satellite in November 1997. This reduction is offset by a slight increase in funding for the Earth System Science Pathfinders (ESSP) program. An increase of nearly 12 percent is requested for the research and analysis programs as we approach launch activities in the EOS program.

## NUCLEAR REGULATORY COMMISSION (NRC)

The NRC requested funding is for meteorological operations. The FY 1998 request is essentially unchanged from the FY 1997 request.

The meteorological support program in the United States Nuclear Regulatory Commission is focused solely on obtaining and analyzing meteorological data and information to be utilized in atmospheric transport and dispersion models used in dose projections, plume pathway characterizations, and concentration estimates related to the safe operation of nuclear facilities and the protection of public health and safety and the environment. Obtaining current, accurate, and relevant meteorological information on a real-time basis for use during emergencies is the primary consideration. The NRC budget in this area reflects this priority.

## AGENCY FUNDING BY BUDGET CATEGORY

Table 3.2 depicts how the agencies plan to obligate their funds for meteorological operations broken down by "budget category." The two major categories are "Operations Support" and "Systems Acquisition." To a large degree, these categories correspond to non-hardware costs (Operations Support) and hardware costs (Systems Acquisition). For agency convenience in identifying small components that do not fit into these two major categories, a third category is added called "Special Programs." Programs that provide support to several government agencies such as the Air Force's DMSP are listed on a separate line.

Table 3.3 describes how the agencies plan to obligate their funds for meteorological supporting research according to budget categories. The agencies' supporting research budgets are subdivided along similar lines--Research and Development (non-hardware), Systems Development (hardware), and Special Programs (for those items that do not easily fit into the two major categories).

## AGENCY FUNDING BY SERVICE CATEGORY

Table 3.4 summarizes how the agencies plan to obligate operational funds for basic and specialized meteorological services; Table 3.5 is a similar breakout for supporting research funds. Table 3.4 reveals that "basic" services require approximately 54 percent of the total operational costs while aviation services require about 38 percent. The remaining 8 percent is distributed among the other specialized services. The definitions of specialized and basic services are described below.

### Basic Services

Basic services provide products that meet the common needs of all users and include the products needed by the general public in their everyday activities and for the protection of lives and property. "Basic" services include the programs and activities that do not fall under one of the specialized services.

### Specialized Meteorological Services

Aviation Services. Those services and facilities established to meet the requirements of general, commercial, and military aviation.

Marine Services. Those services and facilities established to meet the requirements of the DOC, DOD, and DOT on the high seas, on coastal and inland waters, and for boating activities in coastal and inland waters. The civil programs which are directly related to services solely for marine uses and military programs supporting fleet, amphibious, and sea-borne units (including carrier-based aviation and fleet missile systems) are included.

Agriculture and Forestry Services. Those services and facilities established to meet the requirements of the agricultural industries and federal, state, and local agencies charged with the protection and maintenance of the Nation's forests.

General Military Services. Those services and facilities established to meet the requirements of military user commands and their component elements. Programs and services which are part of basic, aviation, marine, or other specialized services are not included.

Other Specialized Services. Those services and facilities established to meet meteorological requirements that cannot be classified under one of the preceding categories; such as, space operations, urban air pollution, global climate change, and water management.

## TABLE 3.2 AGENCY OPERATIONAL COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

| AGENCY | Operations Support FY97 | Operations Support FY98 | Systems Acquisition FY97 | Systems Acquisition FY98 | Special Programs FY97 | Special Programs FY98 | Total FY97 | Total FY98 | Total %CHG | % of FY98 TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture | 12105 | 12553 | 0 | 0 | 0 | 0 | 12105 | 12553 | 3.7 | 0.6 |
| Commerce/NOAA | 558048 | 546313 | 524981 | 563704 | 18050 | 22473 | 1101079 | 1132490 | 2.9 | 55.9 |
| Defense(Subtot) | 381554 | 400152 | 38739 | 34465 | 119 | 129 | 420412 | 434746 | 3.4 | 21.4 |
| Air Force | 242896 | 247344 | 16639 | 18013 | 0 | 0 | 259535 | 265357 | 2.2 | 13.1 |
| DMSP* | 26682 | 28528 | 15742 | 13445 | 0 | 0 | 42424 | 41973 | -1.1 | 2.1 |
| Navy | 95606 | 106963 | 657 | 670 | 0 | 0 | 96263 | 107633 | 11.8 | 5.3 |
| Army | 16370 | 17317 | 5701 | 2337 | 119 | 129 | 22190 | 19783 | -10.8 | 1.0 |
| Interior/BLM | 600 | 600 | 200 | 200 | 0 | 0 | 800 | 800 | 0.0 | 0.0 |
| Transportation/CG | 6774 | 6774 | 0 | 0 | 0 | 0 | 6774 | 6774 | 0.0 | 0.3 |
| Transportation/FAA | 305945 | 327078 | 99199 | 103676 | 3811 | 4009 | 408955 | 434763 | 6.3 | 21.4 |
| EPA | ------ Not Applicable ------ | | | | | | | | | |
| NASA | 2185 | 2294 | 1066 | 550 | 1652 | 1615 | 4903 | 4459 | -9.1 | 0.2 |
| NRC | 364 | 298 | 0 | 0 | 0 | 0 | 364 | 298 | -18.1 | 0.0 |
| TOTAL | 1267575 | 1296062 | 664185 | 702595 | 23632 | 28226 | 1955392 | 2026883 | 3.7 | 100.0 |
| % of FY TOTAL | 64.8% | 63.9% | 34.0% | 34.7% | 1.2% | 1.4% | 100.0% | 100.0% | | |

*DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

## TABLE 3.3 AGENCY SUPPORTING RESEARCH COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

| AGENCY | Research & Development | | Systems Development | | Special Programs | | Total | | | % of FY98 |
|---|---|---|---|---|---|---|---|---|---|---|
| | FY97 | FY98 | FY97 | FY98 | FY97 | FY98 | FY97 | FY98 | %CHG | TOTAL |
| Agriculture | 15467 | 15591 | 0 | 0 | 0 | 0 | 15467 | 15591 | 0.8 | 4.5 |
| Commerce/NOAA | 61888 | 61326 | 23870 | 13670 | 5244 | 5244 | 91002 | 80240 | -11.8 | 22.9 |
| Defense(Subtot) | 84144 | 77708 | 400 | 550 | 1259 | 300 | 85803 | 78558 | -8.4 | 22.4 |
| Air Force | 41961 | 39734 | 0 | 0 | 0 | 0 | 41961 | 39734 | -5.3 | 11.3 |
| DMSP* | 17964 | 14076 | 0 | 0 | 0 | 0 | 17964 | 14076 | -21.6 | 4.0 |
| Navy | 11786 | 11985 | 0 | 0 | 0 | 0 | 11786 | 11985 | 1.7 | 3.4 |
| Army | 12433 | 11913 | 400 | 550 | 1259 | 300 | 14092 | 12763 | -9.4 | 3.6 |
| Interior/BLM | | | | | ------ Not Applicable ------ | | | | | |
| Transportation/CG | | | | | ------ Not Applicable ------ | | | | | |
| Transportation/FAA | 15339 | 5672 | 1288 | 645 | 0 | 0 | 16627 | 6317 | -62.0 | 1.8 |
| EPA | 5700 | 5700 | 0 | 0 | 0 | 0 | 5700 | 5700 | 0.0 | 1.6 |
| NASA | 112750 | 11660 | 49950 | 47150 | 0 | 0 | 162700 | 163750 | 0.6 | 46.8 |
| NRC | | | | | ------ Not Applicable ------ | | | | | |
| TOTAL | 295288 | 177657 | 75508 | 62015 | 6503 | 5544 | 377299 | 350156 | -7.2 | 100.0 |
| % of FY TOTAL | 78.3% | 50.7% | 20.0% | 17.7% | 1.7% | 1.6% | 100.0% | 100.0% | | |

*DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

## TABLE 3.4 AGENCY OPERATIONAL COSTS, BY SERVICE

(Thousands of Dollars)

| AGENCY | Basic Meteorology | | Aviation | | Marine | | Agriculture & Forestry | | General Military | | Other | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FY97 | FY98 | FY97 | FY98 | FY97 | FY98 | FY97 | FY98 | FY97 | FY98 | FY97 | FY98 | FY97 | FY98 |
| Agriculture | 0 | 0 | 0 | 0 | 0 | 0 | 12105 | 12553 | 0 | 0 | 0 | 0 | 12105 | 12553 |
| Commerce/NOAA | 1043983 | 1075394 | 35596 | 35596 | 19000 | 19000 | 0 | 0 | 0 | 0 | 2500 | 2500 | 1101079 | 1132490 |
| Defense(Subtot) | 16716 | 18298 | 288202 | 299189 | 27444 | 29933 | 0 | 0 | 81391 | 80604 | 6659 | 6722 | 420412 | 434746 |
| Air Force | 0 | 0 | 259535 | 265357 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 259535 | 265357 |
| DMSP* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42424 | 41973 | 0 | 0 | 42424 | 41973 |
| Navy | 16716 | 18298 | 28233 | 33366 | 27444 | 29933 | 0 | 0 | 18255 | 20364 | 5615 | 5672 | 96263 | 107633 |
| Army | 0 | 0 | 434 | 466 | 0 | 0 | 0 | 0 | 20712 | 18267 | 1044 | 1050 | 22190 | 19783 |
| Interior/BLM | 0 | 0 | 0 | 0 | 0 | 0 | 800 | 800 | 0 | 0 | 0 | 0 | 800 | 800 |
| Transportation/CG | 5730 | 5730 | 0 | 0 | 1044 | 1044 | 0 | 0 | 0 | 0 | 0 | 0 | 6774 | 6774 |
| Transportation/FAA | 0 | 0 | 408955 | 434763 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 408955 | 434763 |
| EPA | ------ Not Applicable ------ | | | | | | | | | | | | | |
| NASA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4903 | 4459 | 4903 | 4459 |
| NRC | 274 | 208 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 90 | 90 | 364 | 298 |
| TOTAL | 1066703 | 1099630 | 732753 | 769548 | 47488 | 49977 | 12905 | 13353 | 81391 | 80604 | 14152 | 13771 | 1955392 | 2026883 |
| % of FY TOTAL | 54.6% | 54.3% | 37.5% | 38.0% | 2.4% | 2.5% | 0.7% | 0.7% | 4.2% | 4.0% | 0.7% | 0.7% | 100.0% | 100.0% |

*DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

## TABLE 3.5 AGENCY SUPPORTING RESEARCH COSTS, BY SERVICE

(Thousands of Dollars)

| AGENCY | Basic Meteorology FY97 | Basic Meteorology FY98 | Aviation FY97 | Aviation FY98 | Marine FY97 | Marine FY98 | Agriculture & Forestry FY97 | Agriculture & Forestry FY98 | General Military FY97 | General Military FY98 | Other FY97 | Other FY98 | Total FY97 | Total FY98 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture | 0 | 0 | 0 | 0 | 0 | 0 | 15467 | 15591 | 0 | 0 | 0 | 0 | 15467 | 15591 |
| Commerce/NOAA | 89377 | 78615 | 1625 | 1625 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 91002 | 80240 |
| Defense(Subtot) | 5564 | 4787 | 41961 | 39734 | 11786 | 11985 | 0 | 0 | 26492 | 22052 | 0 | 0 | 85803 | 78558 |
| Air Force | 0 | 0 | 41961 | 39734 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 41961 | 39734 |
| DMSP* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17964 | 14076 | 0 | 0 | 17964 | 14076 |
| Navy | 0 | 0 | 0 | 0 | 11786 | 11985 | 0 | 0 | 0 | 0 | 0 | 0 | 11786 | 11985 |
| Army | 5564 | 4787 | 0 | 0 | 0 | 0 | 0 | 0 | 8528 | 7976 | 0 | 0 | 14092 | 12763 |
| Interior/BLM | | | | | | | ------ Not Applicable ------ | | | | | | | |
| Transportation/CG | | | | | | | ------ Not Applicable ------ | | | | | | | |
| Transportation/FAA | 0 | 0 | 16627 | 6317 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16627 | 6317 |
| EPA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5700 | 5700 | 5700 | 5700 |
| NASA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 162700 | 163750 | 162700 | 163750 |
| NRC | | | | | | | ------ Not Applicable ------ | | | | | | | |
| TOTAL | 94941 | 83402 | 60213 | 47676 | 11786 | 11985 | 15467 | 15591 | 26492 | 22052 | 168400 | 169450 | 377299 | 350156 |
| % of FY TOTAL | 25.2% | 23.8% | 16.0% | 13.6% | 3.1% | 3.4% | 4.1% | 4.5% | 7.0% | 6.3% | 44.6% | 48.4% | 100.0% | 100.0% |

*DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

## PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS

Table 3.6 depicts agency staff resources in meteorological operations. The total agency staff resources requested for FY 1998 is 20,833. This total represents a decrease of 3.7 percent from FY 1997.

## INTERAGENCY FUND TRANSFERS

Table 3.7 summarizes the reimbursement of funds from one agency to another during FY 1997. Agencies routinely enter into reimbursable agreements when they determine that one agency can provide the service more efficiently and effectively than the other. While specific amounts may vary from year-to-year, the pattern shown is essentially stable and reflects a significant level of interagency cooperation.

Department of Commerce. The NWS will reimburse DOT $25.0 million for Alaska housing utilities and technological advances. NASA will receive $60,000 for stratospheric studies and a total of $276.3 million for satellite acquisition and launching--polar orbiting ($63.1 million) and geostationary ($213.2 million).

Department of Defense. The Air Force will reimburse DOC a total of $4.2 million for WSR-88D Operational Support Facility support ($3.4 million), COMET participation ($5,000), OFCM support ($140,000), Share Processing Network ($139,000), and supporting research ($565,000). The Navy will reimburse DOC $100,000 for climatological analysis and forecasting. The Army reimbursements to DOC include $650,000 to maintain precipitation reporting stations and $40,000 for basic supporting research at NOAA's Environmental Technology Laboratory. The Army will also reimburse the United States Geological Survey $410,000 for operations and maintenance of hydrologic and precipitation reporting stations. Additionally, the Army will reimburse NASA's Goddard Space Flight Center $71,000 for basic supporting research. NASA will also reimburse the National Center for Atmospheric Research (NCAR) $12,000 to conduct basic supporting research.

Department of Transportation. The FAA will reimburse NOAA $14.0 million in FY 1998 for procurement of WSR-88D and ASOS systems. Additionally, NOAA will receive $17.4 million for operational support--$7 million for WSR-88D and ASOS maintenance, $7.7 million for aviation weather observations, $7.6 million for the Center Weather Service Units at all Air Route Traffic Control Centers, $1.4 million to establish the World Area Forecast System, $360,000 for meteorological instructors at the FAA Academy, and $300,000 for studies and dissemination.

The FAA will reimburse the National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA) a total of $14.3 million for supporting research. The NSF will receive $13.0 million and NASA will receive $1.28 million for aeronautical hazards.

National Aeronautics and Space Administration (NASA). The Air Force will receive reimbursement of $1.1 million for observations and forecasts. NOAA's National Weather Service will receive $1.05 million for spaceflight weather support; National Data Buoy Center will receive reimbursements of $105,000 for operations of data buoys.

Environmental Protection Agency (EPA). NOAA's Air Resources Laboratory (ARL) will be reimbursed $5.1 million for development, evaluation, and application of air quality dispersion models, and for providing meteorological expertise and guidance for EPA policy development activities.

Department of Energy (DOE). The NOAA/OAR will be reimbursed $4 million to support the Nuclear Support Office at the Nevada Nuclear Test Site.

Nuclear Regulatory Commission (NRC). The NRC will reimburse NOAA's ARL ($90,000) and DOE ($64,000) for technical assistance.

## FACILITIES/LOCATIONS for TAKING METEOROLOGICAL OBSERVATIONS

Table 3.8 indicates the number of facilities or platforms at which the federal agencies carry out (or supervise) the various types of weather observations.

TABLE 3.6 PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS
(Units are Full Time Equivalent Staff Years)*

| AGENCY | FY 1997 | FY 1998 | %CHG | % of FY 1998 TOTAL |
|---|---|---|---|---|
| Agriculture | 98 | 102 | 4.1 | 0.5 |
| Commerce/NOAA | 6,184 | 5,876 | -5.0 | 28.2 |
| Reimbursed** | 210 | 200 | -4.8 | 1.0 |
| Defense(Subtotal) | 5,794 | 5,585 | -3.6 | 26.8 |
| Air Force | 3,701 | 3,424 | -7.5 | 16.4 |
| DMSP* | 283 | 217 | -23.5 | 1.0 |
| Navy | 1,504 | 1,574 | 4.7 | 7.6 |
| Army | 306 | 304 | -0.7 | 1.5 |
| Interior/BLM | 12 | 6 | -5.0 | 0.0 |
| Reimbursed** | 6 | 4 | -33.3 | 0.0 |
| Transportation/CG | 106 | 106 | 0.0 | 0.5 |
| Transportation/FAA | 3,433 | 3,434 | 0.0 | 16.5 |
| EPA | 0 | 0 | 0.0 | 0.0 |
| NASA | 0 | 0 | 0.0 | 0.0 |
| NRC | 1 | 1 | 0.0 | 0.0 |
| TOTAL | 21,638 | 20,833 | -3.7 | 100.0 |

* Numbers of personnel are rounded to nearest whole number.
** "Reimbursed" are personnel funded by other agencies.
**********

TABLE 3.7 INTERAGENCY FUND TRANSFERS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

| Agency Funds Transferred from: | Agency Funds Transferred to: | FY 1997 Funds ($K) Estimated or Planned | |
|---|---|---|---|
| | | Operations | Supporting Research |
| Commerce/NOAA | DOT/USCG | 2500 | |
| | NASA Studies | 60 | |
| | NASA (Procurement) | 305,202 | |
| Defense/Air Force | DOC | 3,634 | 565 |
| Defense/Navy | DOC/NOAA/NCDC | 100 | |
| Defense/Army | DOC/NOAA/NWS | 650 | |
| | DOC/NOAA/ETL | | 40 |
| | DOI/USGS | 410 | |
| | NASA/GSFC/GISS | | 48 |
| | NASA/GSFC | | 23 |
| | NSF/NCAR | | 12 |
| Transportation/FAA | DOC/NOAA | 17,352 | |
| | DOC/NOAA (Procurement) | 13,995 | |
| | NSF | | 13,000 |
| | NASA | | 1,284 |
| NASA | DOD/USAF | 1,100 | |
| | DOD/NOAA/NWS | 1,050 | |
| | DOC/NOAA/NDBC | 105 | |
| EPA | DOC/NOAA/ARL | | 5,100 |
| DOE | DOC/NOAA/OAR | 4,000 | |
| NRC | DOC/NOAA/ARL | 90 | |
| | DOE | 64 | |

TABLE 3.8 FACILITIES/LOCATIONS for TAKING METEOROLOGICAL OBSERVATIONS

| TYPE OF OBSERVATION/AGENCY | No. of Locations (FY 1997) |
|---|---|
| **Surface, land** | |
| Commerce (all types) | 748 |
| Air Force (U.S. & Overseas) | 137 |
| Navy (U.S. & Overseas) | 43 |
| Army (U.S. & Overseas) | 13 |
| Marine Corps (U.S. & Overseas) | 13 |
| Transportation (Flight Service Stn) | 61 |
| Transportation (Lim Aviation Wx Rptg Stn) | 114 |
| Transportation (Contract Wx Observing Stn) | 124 |
| Transportation (Auto Wx Observing Stn) | 175 |
| Transportation (Auto Sfc Obs Sys, fielded) | 318 |
| Transportation (USCG Coastal) | 124 |
| Interior | 470 |
| Agriculture | 1080 |
| NASA | 3 |
| **Surface, marine** | |
| Commerce (SEAS-equipped ships) | 140 |
| Commerce (Coastal-Marine Autom Network) | 65 |
| Commerce (NOAA/NOS/PORTS) | 4 |
| Commerce (Buoys--moored) | 64 |
| Commerce (Buoys--drifting) | 21 |
| Commerce (Buoys--large navigation) | 10 |
| Commerce (Water-level gauges) | 189 |
| Navy (Ships with met personnel) | 27 |
| Navy (Ships without met personnel) | 325 |
| Transportation (USCG Ships) | 72 |
| NASA | 2 |
| **Upper air, balloon** | |
| Commerce (U.S.) | 86 |
| Commerce (Foreign, cooperative) | 22 |
| Air Force, Fixed (U.S. & Overseas) | 16 |
| Air Force, Mobile | 6 |
| Army, Fixed (U.S. & Overseas) | 15 |
| Army, Mobile | 52 |
| Navy, Fixed (U.S. & Overseas) | 18 |
| Navy, Mobile | 39 |
| Navy, Ships | 27 |
| Marine Corps, Fixed (U.S. & Overseas) | 1 |
| Marine Corps, Mobile | 11 |
| NASA (U.S.) | 2 |
| **Atmospheric Profilers** | |
| Army | 6 |

| TYPE OF OBSERVATION/AGENCY | No. of Locations (FY 1997) |
|---|---|
| **Upper air, rocket** | |
| NASA | 2 |
| Air Force | 2 |
| Navy | 1 |
| Army (U.S. & Overseas) | 5 |
| **Doppler weather radar (WSR-88D) sites** | |
| Commerce (NWS) | 120 |
| Air Force | 28 |
| Army | 2 |
| Transportation | 12 |
| **Off-site WSR-88D Processors (PUPs)** | |
| Commerce (NWS) | 63 |
| Air Force | 102 |
| Navy | 32 |
| Army | 3 |
| Marine Corps | 8 |
| Transportation | 25 |
| **Airport terminal Doppler weather radars** | |
| Transportation (Commissioned) | 3 |
| Army (not airfield--Test Range) | 1 |
| **Conventional radar (non-Doppler) sites** | |
| Commerce (NWS) | 31 |
| Commerce (at FAA sites) | 27 |
| Air Force, Fixed (U.S. & Overseas) | 17 |
| Air Force, Remote Displays | 4 |
| Air Force, Mobile Units | 3 |
| Army (Overseas) | 1 |
| Navy, Fixed (U.S. & Overseas) | 6 |
| Navy, Remote displays/RADIDS | 6 |
| Marine Corps, Fixed (U.S. & Overseas) | 2 |
| Marine Corps, Mobile units | 15 |
| **Weather reconnaissance** (No. of aircraft) | |
| Commerce (NOAA) | 3 |
| Air Force Reserve (AFRES) | 10 |
| **Geostationary meteorological satellites** (No. operating) | |
| Commerce (planned config of 2) | 2 |
| **Polar meteorological satellites** (No. operating) | |
| Commerce (planned config of 2) | 2 |
| Air Force (planned config of 2) | 2 |

SECTION 4

# "OWNING THE WEATHER--AN ARMY FORCE MULTIPLIER"*

## INTRODUCTION

*"Everyone talks about the weather - now we're going to do something about it. We're going to give the war-fighter the information he needs to fight under all weather conditions."... General Jimmy D. Ross, 1994*

Although we cannot change the weather, Army decision makers have the opportunity to do something about the weather. In much the same way that night vision equipment made it possible for late-20th century soldiers to own the night, U.S. Army planners hope to give early-21st century warriors advanced technology and capabilities that will enable them to own the weather.

Almost 200 years ago, it was the U.S. Army that first began to develop our Nation's weather collection and forecast capability. Weather is critical to Army tactical operations and strategic planning; weather affects virtually every operation, piece of equipment, and person on the battlefield. All weapons systems are affected in some way, directly or indirectly, by some form and degree of adverse weather. *Owning the Weather* is about understanding, anticipating and exploiting the impacts of weather to gain a war-fighting edge over enemy forces.

### Army Weather Doctrine

Around 500 BC, Sun Tzu wrote in *The Art of War:*

*"Know the enemy, know yourself; your victory will never be endangered. Know the ground, know the weather; your victory will then be total."*

U. S. Army Field Manual 100-5 (FM 100-5) *Operations* in highlighting the importance of weather to the war-fighter states:

"...attacking forces exploit weather conditions that affect mobility, concealment, and air support whenever possible. Commanders and staffs demand tactical weather forecasts that will affect ground operations and operations by Army aviation in the ground environment, in addition to the more general theater weather patterns."

The commander who can best measure and take advantage of weather and terrain has a decided advantage over his opponent. By understanding the effects of weather, seeing the opportunities the effects offer, and anticipating when they will come into play, the commander can set the terms for battle. In so doing, the commander is able to maximize his advantages and exploit any limitations on opposing forces caused by the weather.

### Historical Perspective

History documents the effects of weather on wars, war-fighters, and weapons. The outcome of many famous battles; such as, Waterloo, Trenton, Operation Overlord, and the Battle of the Bulge, all were impacted by weather. Prior to the D-Day invasion of Europe in June 1944, German weather forecasters advised that an Allied invasion was impossible because of stormy weather. However, Allied forecasters predicted 36 hours of clearing and their forces successfully attacked while the German defenses were down.

During the first 2 days of Operation Desert Storm, over 50 percent of the F-117 sorties were aborted over their targets due to weather. Similarly, only 37 percent of the scheduled A-10 close air support missions were completed due to low cloud cover. During the initial deployment in support of the Bosnian peace operation, a significant number of the air sorties into Tuzla aborted due to poor weather. The Army also encountered major difficulties in crossing the flooded Sava River. In each of these instances, weather had a favorable and unfavorable impact on the battlefield and operations, in general.

## OWNING THE WEATHER

*Owning the Weather* (OTW) will soon provide the Army with an effective all-weather mission capability by giving war-fighters the information they need to fight and operate smart weapons under all weather conditions. A near all-weather operational capability

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* This section was prepared by Mr. Richard J. Szymber, a meteorologist at the U.S. Army Research Laboratory, Battlefield Environment Division, U.S. Army Intelligence Center, Fort Huachuca, Arizona. Mr. Szymber holds a bachelor's degree in Geography from Arizona State University and a master's degree in Atmospheric Sciences from the University of Arizona. He is involved in satellite meteorology research in addition to developing and promoting "*Owning the Weather*" concepts and programs. He previously worked in the former U.S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, New Mexico, and has served as a professional meteorologist for the U.S. Air Force and Navy.

can be achieved through the selection of the appropriate mix of battlefield sensors, weapon systems, and tactics. This mix provides friendly forces with the ability to see, maneuver, fight, and win in all types of weather. OTW enables field commanders to anticipate the differential impacts of weather conditions on both sides; OTW will allow commanders to exploit these "weather windows of opportunity."

Definition and Process

OTW is the use of advance knowledge of battlefield environmental conditions and their effects on friendly as well as enemy soldiers, systems, operations, and tactics to gain a decisive advantage. It involves exploiting and improving weather-related technological advantages of our battlefield systems over hostile systems and, thereby, makes adverse weather a force multiplier. OTW enables the commander to quickly assess the impacts of weather on friendly and enemy capabilities by helping them to recognize and seize the military advantage. OTW technology can also be incorporated into training, combat simulations, weapons development, and system testing and evaluation.

OTW is a strategy for exploiting the battlefield environment in force projection operations, stability and support operations, and major regional conflicts. OTW is a four step process (See Figure 4.1):

- Battlespace sensing/data collection.
- Processing, analysis, forecasting, data/product generation, and dissemination.
- Battlefield visualization and tactical decisions.
- Combat weather exploitation and information operations.

The OTW process begins with observations of the weather and environmental conditions for the area of operations, including critical data-denied target areas. These conditions are observed and collected in real time from a variety of battlefield sensing systems. Next, these meteorological data are processed and analyzed by numerical weather prediction/forecast models prior to being disseminated to users. Finally, the observations, forecasts, and their resulting effects are transformed into weather intelligence. This weather intelligence takes the form of easily understood automated weather-effects decision aids and battlefield weather visualization products that are incorporated into tactical operations.

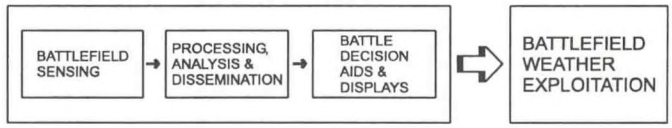


Figure 4-1. The *Own the Weather* Operational Process

No single-sensing system can supply all the essential observations. Rather, a suite of complementary sensing systems--space-based, airborne, and ground-based--is necessary to provide observations at the required accuracies, resolutions, and areal coverage.

The Integrated Meteorological System (IMETS) is a tactical system mounted on a High Mobility Multi-Purpose Wheeled Vehicle (HMMWV). IMETS uses existing Army common hardware/software, standard integrated command post shelters, tactical communications, and specialized software and weather products to provide a complete battlefield weather system. IMETS is a component of an Intelligence and Electronic Warfare (IEW) system of the Army Battle Command System (ABCS). IMETS is staffed and operated by U.S. Air Force weather teams assigned to various Army organizational levels--echelons above corps, corps, division, separate brigade, aviation brigade, armored cavalry regiment, and special forces ranger regiment. IMETS is now in production with fielding and upgrades to be completed by calendar year 2000. (Figure 4.2 shows an IMETS tactical configuration.)

IMETS will receive, process, analyze, generate, and distribute mission-specific observations, forecasts, advisories/warnings, and other weather intelligence products. As a mobile, automated weather information processing, and communications system, IMETS is designed to provide timely weather and environmental effects forecasts, observations, and decision aid information to appropriate command elements. It will collect data from various sources and distribute timely battle-scale weather information to multiple command elements via the ABCS. This information will be used in tactical decision aids (TDA) resident on other Army battlefield automated Command & Control ($C^2$) systems. These $C^2$ systems provide war-fighters with real time and predicted environmental effects on missions and systems. (Figure 4.3 Integrated Meteorological System)

Figure 4.2 IMETS tactical configuration.

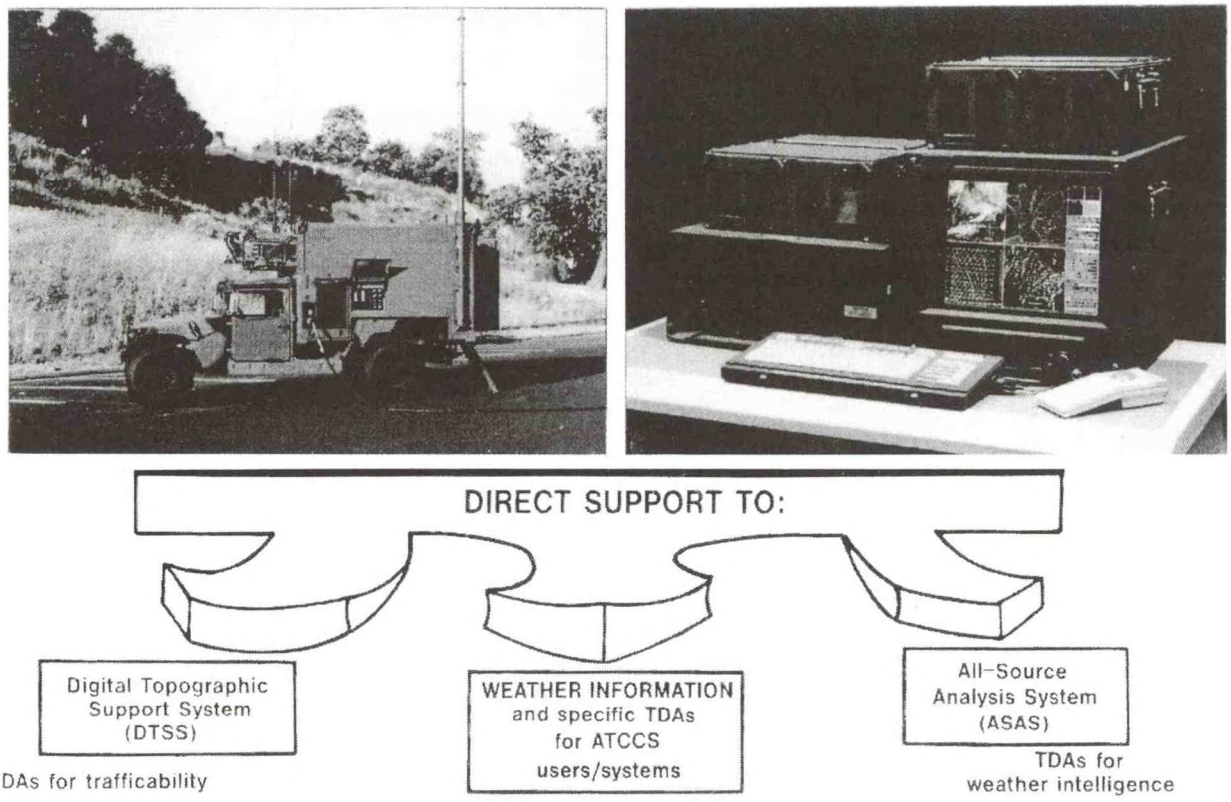


Figure 4.3 Integrated Meteorological System

IMETS will also provide weather forecasts tailored to the specific operational and tactical environment by using battle-scale or mesoscale meteorological models. These numerical weather models produce forecasts for a more limited region than those provided by the usual large-scale forecasts and include effects of complex terrain on atmospheric conditions.

The rapid generation of weather effects information for planning tactical operations and for making combat decisions is critical. This military decision-making process ranges from Intelligence Preparation of the Battlefield (IPB) to mission execution. IPB, TDAs, and war-gaming are all means by which commanders can quickly and accurately determine the weather effects on impending operations and, thereby, be provided with the opportunity to change or modify actions accordingly. TDAs not only provide information about weather effects on combat systems and terrain, but also show the commander if and when weather conditions give him an advantage over the enemy.

Weather-support TDAs also enable commanders to manipulate current and predicted weather effects information using "what-if" scenarios. This "what-if" war-gaming capability can lead to the development of alternative courses of action in anticipation of changes in the weather. The Integrated Weather Effects Decision Aid (IWEDA) is a sophisticated expert system that provides these capabilities. IWEDA automatically identifies and presents favorable, marginal, and unfavorable weather impacts based on operating limitations of friendly and enemy weapons systems with respect to time and area of operation. IWEDA is tailored to specific tactical operations and missions, and provides detailed weather impacts information in terms of what operations and equipment are affected, as well as when, where, and why they are affected.

Weather as a Force Multiplier

> *"An Army able to mount a coordinated attack night or day in any weather multiplies the force exchange ratio somewhere between 15- and 20-to-1."*
>
> Lieutenant General Jay Garner (1994)

The atmosphere affects nearly all Army systems. For example, haze and fog can severely degrade target recognition and acquisition devices; dense fog could render them useless. Precipitation is a primary concern for trafficability, but precipitation also

degrades optical and infrared devices. Precipitation can even incapacitate radar systems. Wind, turbulence, and temperature can move and disperse chemical agents, smoke, and other obscurants. Wind is also a major factor affecting artillery accuracy--as the range of the artillery weapon increases, so do the effects of atmospheric conditions on the projectiles. Advance knowledge of the weather and its impact on friendly and enemy matériel and operations provides an advantage and a combat multiplier.

## FUTURE TRENDS

### Training and Simulations

Realistic training and simulations can mitigate the detrimental effects of weather and contribute to increased overall combat readiness. For example, consider a case of reduced visibility and its impact on the outcome of a tank battle. Suppose, two opposing tanks are separated by 4 kilometers (km). One tank is equipped with infrared sights while the other tank has only visible, direct-view optics. If the visibility is 4 km, both tanks can see one another about equally well. When visibility drops to 2 km, the tank with the direct-view optical system can no longer fix its sights on the other tank. However, the other tank "can see" with its infrared sensor and has a clear advantage. A similar type of situation occurred in the Battle of 73 Easting during Operation Desert Storm (Figure 4.4).

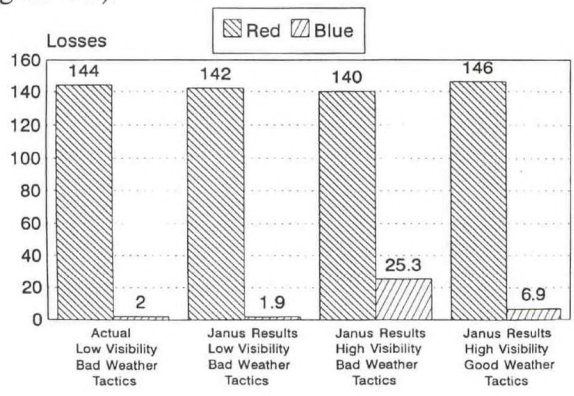


Figure 4.4 Janus Results of the Effects of Weather and Tactics on the Battle of 73 Easting

### Battlespace Sensing Systems

OTW requires high quality measurements of atmospheric variables combined with appropriate models to obtain a detailed picture of current and future environmental conditions over the entire battlefield. Several sensing systems are planned to provide this capability. Figure 4.5 is a conceptual depiction of long-range OTW sensing systems for battlefield data collection.

Direct-readout observations from meteorological satellites provide the best areal coverage, globally, and in theater. IMETS will receive and process:

- Low and high resolution imagery (visible, infrared, and microwave) and atmospheric soundings from polar orbiting Defense Meteorological Satellite Program (DMSP) and National Oceanic and Atmospheric Administration (NOAA)/TIROS* satellites.
- High temporal resolution imagery from geostationary satellites.

Airborne meteorological observations will be provided by an automatic meteorological sensor on-board unmanned aerial vehicles (UAV). The UAVs will also have the capability to deliver dropsondes over critical target areas. In addition to atmospheric profiles and flight-path measurements, the UAVs will carry visible and infrared video cameras to return imagery of clouds, precipitation, and present weather, such as obstructions to vision. IMETS will also receive airborne observations, target weather information, and pilot reports from the Air Force and Army aviation units.

Army Artillery Meteorological (ARTYMET) sections, located near artillery units, will provide upper air observations over forward areas. Currently, these ARTYMET sections utilize the Meteorological Measuring System (MMS) along with radiosondes and the Computer Assisted Artillery Meteorology (CAAM) models and software to collect and process these upper air data. Eventually, tactical atmospheric profilers will provide upper air measurements with extremely rapid refresh rates. IMETS will also receive upper air profiles for rear areas taken at fixed airfields by Air Force weather teams.

Remote, automatic sensing systems will provide IMETS with surface weather and ground state observations from several areas on the extended battlefield. These unattended sensing systems will be selectively deployed throughout the depth of the

*DMSP and NOAA/TIROS satellites will be replaced by the converged National Polar-Orbiting Operational Environmental Satellite System (NPOESS) by 2010.

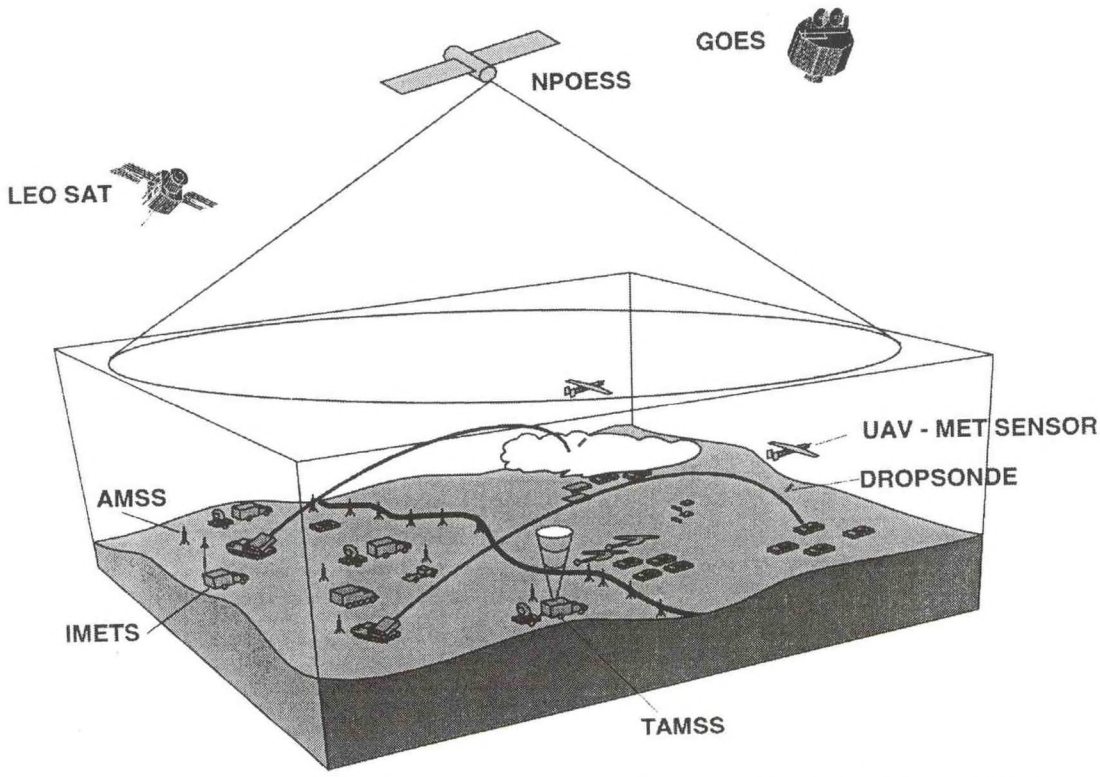


Figure 4.5 Generalized View of the Long-Range (2010) OTW Data Collection Concept

battlefield and tied into an automated communications system. The hand-emplaced or vehicle-mounted Automatic Meteorological Sensor System (AMSS) will provide surface observations at key terrain points. The Improved Remotely Monitored Battlefield Sensor System (IREMBASS) with AMSS (IRAMSS) will provide surface observations in forward flanking and close battle areas along likely enemy avenues of approach. The IRAMSS can be hand-emplaced or air delivered to areas deep behind enemy lines. Surface observations will also be taken by the ARTYMET sections equipped with MMS and Semi-Automatic Meteorological Station (SMS). Surface observations for deep areas will be received by IMETS via satellite link from the Remote Miniature Weather Sensor (RMWS) deployed by special operations forces. In addition to automated reports, manual surface observations will serve as another source of data for IMETS. These observations will be taken by long-range ground reconnaissance and surveillance elements, engineer units, air traffic controllers, and Air Force observers at airfields and IMETS locations.

Battlefield Visualization and Information Operations

Battlefield visualization of weather and its effects is an essential element of battle command and is necessary for gaining information dominance. Information dominance is achieved through the execution of information operations. Information operations, in turn, maximizes the capability to exploit the weather and, thereby, utilize future weather conditions as a force multiplier.

OTW information operations has three objectives (outlined in Figure 4.6). These objectives are accomplished by protecting access and use of weather information systems while exploiting and attacking the enemy's weather information assets. Exploiting and attacking involves intercepting, altering or denying, and influencing the enemy's picture of the weather. Weather information and information operations combined with knowledge of the limitations on war-fighting capabilities makes a powerful information warfare weapon.

| WEATHER (WX) COMMAND AND CONTROL WARFARE (C2W) COMPONENTS | | |
|---|---|---|
| WX C2W PROTECT | * | Protect and secure our weather support INFOSYS (system, databases, computers and communications, and personnel) |
| WX C2W EXPLOIT | * | Understand enemy weather INFOSYS |
| | * | Steal and utilize enemy weather data |
| WX C2W ATTACK | * | Deny enemy weather information |
| | * | Modify enemy weather data |
| | * | Influence enemy weather picture |

Figure 4.6 Weather Information Command and Control Warfare $C^2W$ Components

Other Operations and Applications

Although war remains the baseline objective for OTW support to the Army, many other missions are now likely. A major regional conflict is one of many new contingencies for which the Army requires weather support. Other mission areas are noncombat operations; such as, evacuation of civilians, peacekeeping, nation building, disaster relief, etc. These new missions require more flexible and mobile forces to respond to a wider range of unpredictable threats and situations. Tailored weather information is vital to the success of these noncombat operations.

Additional applications of noncombat operations in which OTW technologies and products can be utilized include air and noise pollution control, environmental cleanup, global climate change programs and experiments, transportation safety, forestry fire control, and agriculture.

## CONCLUSION

OTW, the United States Army concept for future battlefield weather operations, will assist the Army in more effectively achieving its objectives through the use of advanced information age technology. It encompasses providing battlefield weather information never before available to commanders and soldiers, and assessing weather impacts on friendly and enemy equipment, operations, and tactics. Armed with this information, commanders can ascertain the critical time, place, and manner a decisive advantage can be gained to increase the likelihood of victory.

OTW will provide a digitized, common picture of the battlespace environment for mission planning and rehearsal, situational awareness, synchronized battle management, and advanced decision and execution support. OTW provides a "capability" solution to Army modernization which leverages and maximizes the capabilities of existing and programmed systems and equipment. It builds on over 25 years of shared Army effort and investment in meteorological research and development, and presents a low-cost, low-risk, high-payoff opportunity with a large battlefield return on investment.

APPENDIX A

# DEPARTMENT OF COMMERCE WEATHER PROGRAMS

# NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The National Oceanic and Atmospheric Administration (NOAA) is the principal meteorological agency of the federal government. By law, NOAA is responsible for reporting the weather of the United States, providing weather and flood warnings and forecasts to the general public, developing and furnishing applied weather services, and recording the climate of the United States. This mission is carried out within NOAA by the National Weather Service (NWS); the National Environmental Satellite, Data, and Information Service (NESDIS); the Office of Oceanic and Atmospheric Research (OAR); the National 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 ($\mu$) and 12.0$\mu$ 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 2½ hours after the full disk scan may be a mixture of 15 minute interval (routine weather) or 7½ 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, .55$\mu$ to .75$\mu$)--1 km.
- Channel 2 (Infrared, 3.8$\mu$ to 4.0$\mu$)--4 km.
- Channel 3 (Water Vapor, 6.5$\mu$ to 7.0$\mu$)--8 km.
- Channel 4 (Infrared, 10.2$\mu$ to 11.2$\mu$)--4 km.
- Channel 5 (Infrared, 11.5$\mu$ to 12.5$\mu$)--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-$\mu$m 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 $\mu$m, 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 $183\pm1$, $183\pm3$, and $183\pm7$ 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° (48 km on surface at nadir) and AMSU-B a field of view of 1.1° (16 km on surface at nadir). AMSU-A (AMSU-B) samples 30 (90) Earth views, covering $\pm48.95°$ 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 recommendations 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.

APPENDIX B

# DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates a military environmental service system to provide specialized worldwide meteorological, space environmental and oceanographic analysis and prediction services in support of military forces. This system directly supports all phases of military operations, from strategic planning to tactical operations. While the Army and Marine Corps each have a small specialized weather support capability, the Naval Meteorology and Oceanography Command and Air Force Weather are the primary sources of military weather products. The military weather services contribute to the national and international weather observing capability by taking conventional observations on land and at sea where there are no other conventional weather observing capabilities and where the observations are most needed to meet military requirements. In addition, DOD maintains specialized observing capabilities, such as the Defense Meteorological Satellite and Global Weather Intercept Programs, to meet unique military requirements. Observational data are sent by military communications networks to military and civil facilities in the United States and overseas.

## UNITED STATES AIR FORCE

### METEOROLOGICAL SERVICES

The Air Force functional manager for meteorological and space environmental services is the Director of Weather (HQ USAF/XOW), within the HQ USAF, Deputy Chief of Staff for Air and Space Operations. HQ USAF/XOW oversees the development and implementation of weather support concepts, doctrine, policies, plans, and programs to ensure effective weather support for the Air Force, Army, and other agencies as directed by the Chief of Staff, USAF. The Air Force also provides support to DOD Joint operations as directed by the Joint Chiefs of Staff under the Unified Action Armed Forces (JCS Publication 0-2) document. HQ USAF/XOW also interfaces with other military departments, federal agencies, and international organizations concerning coordination, cooperation, standardization, and interoperability of weather services.

Air Weather Service (AWS), a field operating agency (FOA) reporting to HQ USAF/XOW, provides centralized weather support to designated users through two centralized support organizations: Air Force Global Weather Center (AFGWC) and the Air Force Combat Climatology Center (AFCCC). Air Force Space Command provides space environmental support through the 55th Space Weather Squadron (55 SWS), formerly the Air Force Space Forecast Center.

Observations. Meteorological observations are classified as surface, upper air, radar, or satellite observations. Observation and sensing of the space environment are discussed in the Space Environmental Services section.

Surface observations are taken by Air Force personnel to support military operations and for weather analysis and forecasting. Observations from both Air Force and Army locations (fixed and tactical) are made available to local users and are transmitted to AFGWC and to other military and civil locations throughout the world.

Upper air observations provide a major input for numerical analysis and forecasting. Most of this information comes from United States and foreign rawinsonde sources and military and civilian satellite-derived data. Additional upper air information is obtained from military and civilian pilot reports.

Weather radar is a principal source of information for providing warnings of severe weather. Many of the radars are part of the United States basic weather radar network or are used to support the National Hurricane Operations Plan. The tactical weather radars are used to support contingency operations. The Air Force is evaluating concepts for a tactical doppler weather radar which could operate in both mobile and fixed locations.

The Air Force manages the Defense Meteorological Satellite Program (DMSP), which provides a large volume of cloud, upper air, and space environmental data, and is the most important single

source of global weather data used for combat support. On-board sensors provide AFGWC and the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) with visible, infrared, and microwave imagery of the entire globe, temperature and moisture sounding data, auroral electron counts, and other specialized space environment data. DMSP also supplies direct, real-time readout of regional image and mission-sensor data to DOD land-based and shipborne terminals located worldwide.

The present DMSP satellite series (Block 5D-2) uses an operational linescan system. The visible detectors were selected to optimize distinction among clouds, ground, snow, and water. It uses both stellar and inertial references, together with on-board processors, to maintain stability and pointing accuracy. The DMSP also flies a microwave temperature and humidity sounder (SSM/T, SSM/T-2) which provides vertical temperature moisture and height profiles of the atmosphere. The microwave imager (SSM/I) observes rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data.

Communications. The utility of meteorological information depends on an effective communications network. The current automated weather network provides for the collection of meteorological data from multiple, worldwide sources, delivers these data to weather centrals and forecast facilities, and distributes products to the field. The Air Force communications system consists of conventional alphanumeric networks, high-speed automated digital facilities, long-haul, point-to-point data circuits, facsimile networks, and high-frequency intercept facilities.

The Air Force-operated Automated Weather Network (AWN) is the backbone of military weather communications to deliver foreign and domestic weather data to designated users. Weather intercept sites in key overseas areas obtain World Meteorological Organization (WMO) weather broadcasts, as well as non-WMO broadcasts, for AWN delivery to AFGWC. The AWN also delivers these data to the Navy and to the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Prediction (NCEP).

Overseas collection and dissemination networks deliver data to, and exchange data with, the AWN Automatic Digital Weather Switch (ADWS) at Hickam AFB, Hawaii, and RAF Croughton, United Kingdom. In the CONUS, the ADWS at Tinker AFB, Oklahoma, provides alpha numeric products to the Automated Weather Distribution System (AWDS), the CONUS Meteorological Data System (COMEDS), and other special teletype systems, and provides direct support to AWDS in the collection and dissemination of weather information. These circuits also collect and disseminate military Notice to Airman (NOTAM) message traffic to all DOD CONUS users.

The Communications Front-End Processor (CFEP) at Offutt AFB, Nebraska, is the hub of all communications at AFGWC. It provides weather facsimile charts on dedicated circuits for graphic data to worldwide military users. CFEP also interfaces with the AWN and drives separate graphics networks serving the CONUS, Alaska, Europe, Central America, and the Pacific.

Preparation of Analyses and Forecasts. The primary center for providing weather analyses and forecasts for Air Force and Army operations is AFGWC at Offutt AFB, Nebraska. AFGWC uses a networked computer system and an interactive graphics and imagery system to implement a "build-and-apply" concept. Worldwide weather data are relayed to AFGWC and blended with civil and military meteorological satellite data to construct a real-time, integrated environmental database. Computer programs further digest the data to construct models of the atmosphere and to forecast its future behavior. Manual tailoring of the data is critical for application to the specific needs of the warfighters. The interaction between forecaster and machine is accomplished with the Satellite Data Handling System (SDHS). SDHS consists of interactive workstations capable of high-speed interaction with satellite and conventional meteorological data to prepare forecasts and other environmental products. AFGWC also provides backup for the National Weather Service (NWS) facsimile network, the NWS Automation of Field Operations and Services (AFOS) products, and the National Severe Storms Forecast Center.

In support of DOD combat operations, Air Force Weather operates centralized units consisting of AFGWC, AFCCC, 55 SWS, fixed theater Forecast Units (FU), fixed Weather Support Units (WSU), and provides personnel to deployed Joint Meteorological/Oceanographic (METOC) Operations Center (JMOC). (Note: Air Force Weather is currently undergoing reengineering. Among the other organizational changes, the Air Force Weather Agency

(AFWA) will be formed at Offutt AFB combining AFGWC and HQ Air Weather Service. Support descriptions in this and subsequent paragraphs will change under this new agency.) Normally weather support is a mix of centrally and locally produced meteorological products. AFGWC has shifted to a regional emphasis with special cells designed for major world regions. These regional cells provide large scale analyses, forecasts and guidance for local meteorologists who apply the information to specific missions. Theater forecast units are specifically named units; e.g., the Korean Forecast Unit, designated to provide forecast services and products from a fixed location for a specific geographical area, tactical operation, or exercise. A JMOC provides the same services as a theater forecast unit; however, it is deployed to support a specific combat operation or exercise which is not or cannot be supported by theater forecast unit. AFGWC directly supports Air Force, Army, and Joint forces when the theater forecast unit lacks support capabilities and when a JMOC is not established.

Dissemination of Forecasts and Warnings. The Air Force and Army require worldwide meteorological services for specific operational and planning activities. Military users require meteorological information directed to the needs of weapon systems being developed or used, command and control systems, Army firing units, research, development and evaluation, testing, training and deployment of military forces, and contingency operations.

Air Force Weather enhances the unique global capability of military aviation while indirectly assisting civil aviation. Air Force personnel provide flight weather briefings, air/ground radio services, and tailored observations, forecasts, watches, and warnings for military operations.

A special aspect of the military weather mission is the need to provide decision assistance to commanders and resource managers. To fulfill this requirement, designated Air Force weather personnel serve as part of the working staff of operational Air Force, Army, and Joint force units. In this capacity, Air Force weather personnel identify all weather-sensitive areas of the operation, monitor the weather service provided in these areas, and provide expert advice to mitigate weather impacts on training or combat operations. This effort helps ensure that Air Force, Army, and Joint force units fulfill their missions regardless of the weather and results in efficient use of weather resources by gearing them to mission needs.

Deployed weather teams are the basic units providing weather support in a combat theater. These teams provide surface and upper air observations, staff weather officer services, and forecasts. The tactical forecast system, tactical weather radar, tactical meteorological satellite direct readout terminals, and tactical communications terminals provide the means to acquire vital meteorological data within a theater. A high frequency radio broadcast (HFRB) system is used to augment transmission of alphanumeric and facsimile products to the theater weather force. The HFRB system consists of regional broadcast stations at Andersen AFB, Guam, Elkhorn, Nebraska, and Roosevelt Roads, Puerto Rico.

Specialized Support. AFCCC, Scott AFB, Illinois, provides environmental data and specialized studies to support the Air Force, Army, and other government agencies. (Note: AFCCC will be moving to Asheville, North Carolina, and become collocated with the National Climatic Data Center. Support descriptions in this and subsequent paragraphs will change following this relocations.) Typical support satisfies requirements for assessments of natural environmental effects on military plans, weapon systems, facilities, and intelligence activities. AFCCC collects environmental data from AFGWC and then sorts, checks, stores, and employs these data to produce tailored products. AFCCC also operates a facility, collocated with the National Climatic Data Center in Asheville, North Carolina, to facilitate cooperation and data exchange. AFCCC typically collects, quality assures, and applies worldwide surface and upper air observations, a three-dimensional (3-D) cloud analysis extracted from meteorological satellite imagery (Real-time Neph-analysis), a global analysis of snow cover, solar, geomagnetic, and space observations and indices, and many other specialized environmental data sets.

The Air Force also supports an array of Air Force and Army specialized requirements. Some of these are described below.

The Army weather support mission is completely integrated into the Air Force's overall mission concept. The Army trains and educates Air Force personnel about Army organizations, concepts of operations, and the weather sensitivities of Army operations and equipment. Air Force weather units are aligned and

integrated with the Army intelligence organization. Weather products are tailored to be directly usable and understandable by Army personnel and are integrated into Army communications systems. Mobile and fixed meteorological equipment is programmed by the Air Force. In a tactical environment, weather personnel serve with echelon-above-corps, corps, divisions, separate brigades, regiments, aviation brigades, armored cavalry regiments, ranger regiments, and special forces groups (as well as subordinate battalions deployed at forward operating bases). The Air Force provides observer support to all command levels identified above. The Army Forward Area Limited Observing Program (FALOP) and the Army artillery meteorology (ARTYMET) program augment the Air Force observations in the tactical environment.

The Air Force provides meteorological products to the Nation's space and missile programs. This includes a wide range of weather observing services at the Air Force Eastern Range and the Kennedy Space Center. The Air Force also provides launch forecasting service for NASA's manned and unmanned launches and for commercial launches from the Kennedy Space Center. The Air Force also provides specialized meteorological services for the Air Force Western Range at Vandenberg AFB, California, and the Pacific Missile Range which includes Point Mugu and San Nicholas Island, California, and Barking Sands, Hawaii. In addition, the Air Force supports the White Sands Missile Range, New Mexico, the Kwajalein Missile Range, and other DOD research and test facilities.

The Air Force and Navy operate the Joint Typhoon Warning Center (JTWC) on Guam under the Naval Pacific Meteorology and Oceanography Center West, Guam. JTWC provides tropical cyclone warning services to DOD units and other United States subscribers in the area west of 180 degrees to the east coast of Africa in both hemispheres.

The Air Force directly supports DOD Special Strategic Programs, the National Command Authority, the National Military Command System, and the National Security Agency. Tailored environmental support products are disseminated to these customers worldwide.

The Air Force and NOAA operate the Joint USAF/NOAA Space Environment Services Center at Boulder, Colorado. The center provides space environmental data, products, services, and solar forecasts to a wide variety of customers.

The Air Force also provides Agrometeorological output to the USDA's Foreign Agricultural Service and other national customers. The output provided includes diagnostic soil hydrology and other meteorological output pertinent to crop growth and yield estimation.

DOD Modeling and Simulation Executive Agent for the Air and Space Natural Environment. The Air Force was confirmed in 1995 by the Executive Council for Modeling and Simulation (EXCIMS), representing the Office of the Under Secretary of Defense for Acquisition and Technology as the Executive Agent. The Executive Agent is responsible for ensuring authoritative air and space environment models, algorithms, and data intended for cross-agency/cross-Service laboratories in air and space natural environmental boundaries.. As of 1996, the Executive Agent will reside at AFCCC. It will be structured as a multi-service Modeling and Simulation division.

Air National Guard (ANG). There are two distinct functions within the ANG weather program. The traditional program consists of 33 weather flights, ranging in size from 13 to 25 personnel. The flights meet monthly to train for their wartime missions and support both Army National Guard (ARNG) and U.S. Army Reserve (USAR) units as well as ANG flying units. A Weather Readiness Center operates at Camp Blanding, Starke, Florida, to provide Army tactical skills training that is not available elsewhere in the Air Force. The ANG is also responsible for peacetime weather operations at locations where the ANG is responsible for airfield operations.

Planned Enhancements. Air Force, Army, and joint force operational requirements for environmental support are the basis for all Air Force actions to improve existing or acquire new capabilities. The Air Force assesses these requirements and attempts to satisfy them through either hardware acquisitions or technique development. AWS and the Naval Meteorology and Oceanography Command are working on initiatives to improve environmental support to joint, interservice, and service operations. They focus on the strengths of each of the services and build on existing cooperative efforts.

The Air Force is modernizing and improving its base-level weather systems. This includes the Automated Weather Distribution System (AWDS) Pre-Planned Product Improvements (P3I) and Next Generation Weather Radar (NEXRAD--WSR-88D) programs.

The WSR-88D is being procured under the auspices of the NEXRAD Joint System Program Office. It is an automated, digitized, S-band Doppler system that was jointly developed and procured. It is operated and maintained by DOD, NOAA, and FAA within the CONUS and by the Air Force and Navy overseas. The system incorporates the latest technological advances in Doppler radar, data processing, communications, and display. The CONUS WSR-88D network will satisfy weather radar requirements in support of the general public, the military, and the aviation community.

The Centralized Data Management System (CDMS) transition is a related series of distinct acquisition, development, and integration efforts to transition AFGWC from a database-dependent applications environment to a centralized database management system. Under the CDMS transition, AFGWC centralized the management of a number of key databases on one computer for both unclassified and classified production. This acquisition will be integrated with improved AFGWC hardware/software systems and will transition to the centralized database management environment under planned programmed steps. CDMS transition reached initial operational capability in 1992 with operational support to the Global Applications Database. Full operational capability is currently scheduled for FY 2002 in conjunction with the AFGWC SDHS replacement.

The Cloud Depiction and Forecasting System (CDFS) II will make major software and hardware modifications at AFGWC to upgrade the weather satellite data processing, cloud depiction and forecasting, and classified weather support functions to meet customer-stated support requirements. CDFS II will also incorporate weather satellite data, cloud depiction and forecast data, and supporting databases into the AFGWC CDMS.

The MARK IVB Direct Readout program has procured new satellite receiver terminals to replace the aging MARK IIIs. In addition to providing high resolution satellite imagery from polar and geosynchronous weather satellites, the MARK IVB terminals accepts and uses data from the DMSP microwave imager and sounders and the TIROS microwave sounding units A and B. The MARK IVB produces both uniform gridded data fields and traditional meteorological products.

The Small Tactical Terminal (STT) is a small, lightweight, ruggedized, modularized, interoperable, first-in satellite receive terminal that receives data transmitted by geostationary and polar orbiting meteorological satellites. There are three configurations of the STT. The basic STTs receive low resolution DMSP and civil polar (TIROS, METEOR, etc.) data as well as WEFAX transmissions from geostationary satellites. The Enhanced STT adds the capability to receive and display high resolution DMSP and TIROS real-time broadcasts. Finally, the Joint Task Force Satellite Terminal add the capability to receive high resolution, geostationary data.

STTs are being fielded at the lowest level of tactical weather operations (i.e., support to USAF flying squadrons and Army divisions). Furthermore, all STTs can be networked through battlefield communication internets to create comprehensive satellite imagery distribution systems. Future developments in the STT program build on these initial capabilities to further reduce the size and weight of equipment and maximize use of the communication links on the battlefield.

## SPACE ENVIRONMENTAL SERVICES

55th Space Weather Squadron (55 SWS) is the Air Force focal point for operational space environmental support. 55 SWS also participates with NOAA in the joint operation of the Space Environment Center (SEC) in Boulder, Colorado. Under existing agreements, SEC and 55 SWS provide limited backup for each other during contingencies. Many DOD systems operate in, or are affected by, conditions above 50 kilometers. The space environment includes the thermosphere, ionosphere, and magnetosphere, as well as the regions that influence them, such as the sun and interplanetary space. 55 SWS provides basic and specialized space environmental support to military electromagnetic communications, surveillance, and warning systems which operate in this environment. Space environment forecast products and/or specialized services are provided for the following:

- Ionospheric conditions.
- Energetic particle fluxes at satellite orbits.
- Solar flare, solar particle, and geomagnetic storm events.

- Upper-atmospheric density variations by providing geomagnetic and solar indices.
- High frequency (HF) radio wave propagation.
- Detailed post-analysis studies of operational system problems to determine if the space environment was a contributing factor.

The effects of the space environment on DOD systems are many and varied. The magnetosphere affects satellite operations through such phenomena as single event upsets (SEU) and spacecraft charging. Manned spaceflights are vulnerable to intense radiation from large solar flares and geomagnetic storms, particularly for high inclination orbits. Ionospheric conditions have a profound effect on the propagation of radio waves and radar signals, leading to communications blackouts and erroneous radar returns. Variations in the neutral atmosphere affect satellites orbiting at relatively low altitudes.

Sources of Space Environmental Data. To obtain solar data, the 55 SWS operates a network of solar optical and radio telescopes. Solar Electro-Optical Network (SEON) observatories are located at Sagamore Hill, Massachusetts, Ramey, Puerto Rico, Holloman AFB, New Mexico, Palehua, Hawaii, San Vito, Italy, and Learmonth, Australia. The 55 SWS also receives real-time solar X-ray and energetic particle data from the Geostationary Operational Environmental Satellites (GOES); DMSP, NOAA, and other DOD geostationary satellites provide additional energetic particle data in low-Earth and geosynchronous orbits.

A world-wide (primarily northern hemisphere) network of ionosondes and polarimeters provides ionospheric data. AWS is currently deploying the automated Digital Ionospheric Sounding System (DISS) to replace older instruments and provide improved ionospheric coverage.

The 55 SWS monitors variations of the geomagnetic field using ground-based magnetometers through a cooperative agreement with the USGS, computes a real-time geomagnetic index, and transmits the derived index to users.

Warning and Forecast Services. In near-real-time, 55 SWS provides operators advance warning of conditions that could degrade performance of their systems. Notifications include:

- Solar X-ray events which can disrupt HF communications on sunlit paths.
- Solar radio bursts which can disrupt communications systems and interfere with radar systems.
- Solar proton events which can produce radiation hazards to spacecraft and absorption of transpolar HF radio waves.
- Ionospheric disturbances which can degrade HF and satellite communications systems.
- Geomagnetic disturbances which can affect the orbital parameters of low altitude satellites, cause spacecraft charging and/or physical damage, disrupt HF radio wave propagation, or interfere with radar systems.

Future Improvements in 55 SWS Support. 55 SWS is enhancing its ability to observe the space environment, analyze data, and model the near-Earth environment.

The Ionospheric Measuring System (IMS) is a planned replacement for the current polarimeter network. IMS, using signals from Global Positioning System (GPS) satellites, will measure total electron content. The initial purchase and deployment of five IMS units is in progress.

The SEON Solar Maximum Modification will improve the capabilities of the SEON observatories. There continues to be efforts to upgrade obsolete and non-supportable equipment and to improve and automate current capabilities. Efforts to upgrade obsolete and non-supportable equipment to maintain current capability continue.

A series of Solar X-Ray Imager (SXI) will be flown beginning on the next GOES satellite launched. The SXI will monitor solar emissions in the extreme ultraviolet (EUV) and X-ray portions of the solar spectrum. These data will be downlinked to the SEC and transmitted to 55 SWS in real-time.

The Solar Wind Interplanetary Measurements (SWIM) is an Air Force Phillips Laboratory investigation using data from NASA's WIND research satellite launched on 1 November 1994. SWIM provides two hours of real-time interplanetary solar wind data to 55 SWS each day. Additionally, there will be two campaigns a year during which real-time data will be provided 8 hours a day. The expected life of SWIM/WIND is 5 to 7 years. Efforts to expand the availability of real-time data are continuing.

Solar Radio Burst Locator (SRBL). This new ground-based system is projected to be operational in 1999. SRBL radio mappings of active regions on the solar disk will augment the present optical observations of these phenomena which are limited by clouds and other atmospheric obscurants. Precise location of active regions on the solar disk is crucial to accurate forecasting of solar flare impacts on the near-earth environment.

The Space Environmental Technology Transition (SETT) program transitions state-of-the-art space environmental models to operational use at 55 SWS. These models will specify and forecast the space environment from the Sun to the Earth's upper atmosphere. The output of these models will drive specific application programs tailored to customer needs. The transition of the SETT models to the 55 SWS will be complete by 1999. Follow-on model development will focus on improving model accuracies and will replace surrogate parameters (as model inputs) with direct measurements wherever possible.

- Magnetospheric Models. The Magnetospheric Specification Model (MSM) provides specification of magnetospheric particle fluxes at geostationary altitudes and precipitating particle fluxes in the auroral zone. An upgrade to this model, the Magnetospheric Specification and Forecast Model, will provide forecast capability and increase the MSM coverage area. One application of MSM output will be as input for satellite anomaly programs. The MSM became operational at the 55 SWS in FY 1995.
- Ionospheric Models. The Parameterized Real-Time Ionospheric Specification Model specifies global electron density using near-real-time satellite and ground-based data. It becomes operational in late FY 1996. A second ionospheric model, the Ionospheric Forecast Model (IFM) will be based on a model developed by Utah State University. When completed, IFM will provide an ionospheric forecasting capability; it is currently undergoing validation. Ionospheric model output will be used as input for space track radar correction and HF radio wave propagation programs. Another variant of ionospheric models, the Wide-Band Model, will provide estimates of ionospheric scintillation severity between two endpoints. The specification accuracy of this model has recently been improved by the inclusion of equatorial and high latitude climatological data.
- The Interplanetary Shock Propagation Model is designed to predict the time of arrival and the dynamic pressure pulse associated with solar flares. This will provide a 1-3 day warning of geomagnetic storms resulting from solar activity.
- The Integrated Space Environmental Model is a coupling model and executive system being developed to integrate the SETT models into a single system sharing input and output data. It will provide a single framework to coordinate and facilitate the execution of all SETT models using scientific expertise and decision-making ability within the program, which will increase consistency of the outputs, optimize run times, and decrease forecaster workload.

## SUPPORTING RESEARCH

The objective of the Air Force meteorological research program is to provide comprehensive knowledge of the atmosphere, how it works, how it limits system performance, and how it can be exploited to the advantage of the Air Force as a force multiplier. Improved measurement and prediction techniques, together with an early evaluation of weather effects on new systems, can make a significant difference and bring the Air Force, Army, and joint forces closer to their goal of conducting operations in all kinds of weather. Requirements for research and technology in meteorology are expressed in Mission Area Assessments and Mission Need Analyses. In addition, the AWS provides guidance in the form of documented Technology Needs.

Within the Air Force, the Phillips Laboratory, Geophysics Directorate (PL/GP) at Hanscom AFB, Massachusetts, is responsible for conducting both in-house and contractual basic research, exploratory development, and advanced technology development in the environmental sciences, including meteorology and space weather. Its exploratory development program in meteorology emphasizes moisture and cloud numerical weather prediction, satellite remote sensing, climatological studies, weather simulation, atmospheric density measurement and prediction, battlefield weather observing and forecasting, and tactical weather decision aids. Research and development (R&D) for DMSP, the Strategic Environmental Research and Development

Program (SERDP), and the Defense Modeling and Simulation Office (DMSO) are also conducted. The entire Air Force atmospheric sciences R & D program is being carefully coordinated with similar efforts in the Army and Navy.

Weather Prediction. Research in weather prediction techniques and models is focused on mesoscale or battlefield domains. Particular emphasis is placed on cloud processes in the atmospheric boundary layer and studies of their formation, evolution, and dissipation. Procedures to better account in numerical models for surface exchange processes and for representing surface characteristics in model data bases will be stressed. These include: soil type, vegetation type and growth stage, soil moisture and temperature, and snow cover and depth. On-going studies of the sensitivity of boundary layer processes to the representation of surface characteristics will be translated into model algorithms for test and evaluation. Mesoscale model data impact studies will focus on both ground-based (profiler and surface sensors) and satellite (imagery and sounding) sources. Tactical wartime data denial experiments will also be conducted as part of these studies. Theater-scale analysis and forecasting models will be developed for use in a workstation environment.

Research to support the increasing needs for a global cloud prediction capability at AFGWC will take two approaches. Multivariate diagnostic algorithms from global and regional-scale numerical models will be evaluated to infer cloud characteristics (total cloud and layered amounts, bases, tops) for prediction intervals beyond 12 hours. Short-range cloud prediction (0-12 hr) techniques will seek to exploit new global cloud analysis capabilities to be available at AFGWC through the CDFS II hardware/software upgrade. Here imagery extrapolation methods will be augmented by simple physical models to account for short-term cloud growth and decay and by highly resolved (in space and time) cloud climatology statistics. In addition, diagnostic algorithms to provide surface and hazard predictions for Theater Battle Management are being sought.

Research to improve hazardous weather warning capabilities at air bases from WSR-88D Doppler weather radars will be focusing on better tornado, hail, and severe storm structure algorithms due to the use of a new mesocyclone detection model which was developed in FY 1994. The development of algorithms to define fine line features (such as gust fronts and synoptic-scale frontal boundaries) will be completed by FY 1996. Studies to identify lightning precursors in WSR-88D data for air mass thunderstorms will be initiated. Studies of the atmospheric electric field distribution aloft and its relationship to aerospace vehicle-triggered lightning will continue. These studies will focus on measurements taken with electric field sounding rockets in field programs to be conducted in FY 1996.

Satellite Remote Sensing. To enhance Air Force, Army, and joint force operations, a major effort is directed toward using satellites to determine temperature and water vapor vertical profiles and horizontal fields. Research efforts also include effectiveness studies for active satellite sensors, such as satellite-borne lidars and radars, for determining the profiles of wind and other weather variables with very high vertical resolution for initialization and assimilation into weather prediction models.

Techniques will be developed to incorporate microwave imagery and geosynchronous satellite data into the cloud analysis programs at AFGWC. The present level of support will continue for this research to develop new analytical methods in satellite meteorology. The ultimate goal is to more accurately specify cloud characteristics; e.g., cloud height, cloud physical thickness, optical depth, particle size, cloud phase, and rain areas. The design of satellite sensors in terms of wavelength, resolution, and bandwidth and the calibration of deployed satellite measurement systems, such as the DMSP SSM/T-2 water vapor sounder, will continue primarily in support of DMSP. Research on integration of the environmental information from a number of satellite measurement platforms and sensors is underway.

Characterization of cloudiness on the operational theater scale, based on direct readout of satellite weather data, is being implemented in support of tactical operations. A package of satellite cloud analysis algorithms, called TACNEPH, has been developed and will be implemented in the DMSP STT.

Climatology Studies. Support of Environmental Requirements Cloud Analysis and Archive (SERCAA) is the new global cloud analysis program for use in determining the radiative and hydrological effects of clouds on climate and global change. SERCAA is the prototype of the next-generation, real-time automated cloud analysis model. The first phase of SERCAA directly supports the CDFS II. An archive of these

quality cloud products, which will be useful in environmental monitoring and climate change research, is planned.

In climatological technique development, weather simulation models are being developed to replicate numerically typical weather sequences for operational applications. Research in modeling clouds and visibility is being expanded to include additional atmospheric elements, specifically a mesoscale environmental simulation package to provide a realistic sequence of weather events at any given location. This model will allow environmental factors to be considered in the design stage of weapon systems and for application to war games.

Research into specifying the probability of simultaneous cloud-free viewing from multiple sites under various cloud conditions is ongoing. Simulation of time evolution of 3-D scenes of weather elements will initially concentrate on cloud scenes. Whole-sky imagery data and concomitant satellite imagery will provide the basis for developing algorithms for ground-based and satellite (or aircraft)-based viewing scenarios. Weather simulation computer models for conceptual design and studies and analysis applications will continue.

The first of two DMSO projects focuses on developing techniques for simulating Environmental Effects for Distributed Interactive Simulation (E2DIS) and to conduct related requirements and capabilities surveys. The second is to implement into E2DIS format the 3-D cloud scene model developed in the first project.

Two programs are in progress to develop a more complete understanding of atmospheric effects on laser propagation. The first of these programs supports the Airborne Laser Program and is evaluating the effects of atmospheric phenomena near the tropopause on laser propagation. Modeling and measurements in support of a more complete understanding of turbulence, aerosols, and cirrus clouds on such propagation are the focus. In the second of these programs, investigations are underway to evaluate the ability to measure winds with a Doppler Lidar in support of weapons targeting (the so-called ballistic wind problem). Actual measurements are being conducted together with supporting meteorological observations and analyses.

The Climatological and Historical Analysis of Clouds for Environmental Simulations (CHANCES) program was initiated in 1994 and will continue into 1996 to expand the climatological analysis to include the tops and bottoms of layered clouds. The program is developing a very high resolution, global cloud climatology from conventional and meteorological satellite observations for planners of satellite and high-altitude aircraft surveillance operations.

Atmospheric Density. The objective of the atmospheric density work is to develop very accurate methods to measure and predict the density of the neutral atmosphere in the altitude range of 90 to 1500 kilometers. Current density models do not achieve the levels of accuracy required by the Air Force so new measurements of density will be made using recently developed, well-calibrated, and highly accurate instruments. These new measurements will be the basis for an upper atmospheric global circulation model that incorporates the current physical understanding of the processes that drive the upper atmosphere. Models will be used to calculate accurate trajectories of satellites, reentry vehicles, and space debris.

Battlefield Weather Observing and Forecasting. The electro-optical tactical decision aid (EOTDA) system software is hosted on microcomputers in the base weather stations and host command and control computer systems and uses an AFGWC-provided data base. This automated forecasting aid is used to predict acquisition and lock-on ranges for precision-guided weapons and target acquisition systems used by the Air Force, Navy, and Army.

The Air Combat Targeting/Electro-Optical Simulation effort in the Weather Impact Decision Aids (WIDA) program has developed a prototype scene simulation capability for mission planning systems used by tactical aircraft pilots. This prototype combines global terrain and features, target structure, meteorological and operational planning data, target infrared contrast and EO sensor performance models to provide commanders and aircrews complete in-theater environmental situational awareness. Another WIDA program is developing Night Vision Goggle (NVG) Operations Weather Software (NOWS) for predicting the impact of weather on operations which depend on NVGs for their success. The primary NOWS user is the Air Force Special Operations Command. Coordination to incorporate Navy requirements into NOWS is underway.

**Program Overview**

The U.S. Navy, operating in the atmosphere, oceans, and the interface between the two, has the unique requirement to integrate meteorological and oceanographic support globally. Sponsored by the Chief of Naval Operations, Office of the Oceanographer of the Navy, the Navy provides meteorological support for Navy and joint forces, meteorological products to the USMC, and oceanographic support to all elements of DOD. Research and development is conducted under the sponsorship of the Chief of Naval Research and the Oceanographer of the Navy by warfare centers, laboratories, and systems commands, primarily the Naval Research Laboratory (NRL) and the Space and Naval Warfare Systems Command (SPAWARS), as well as various universities and organizations under Navy contract. Operational support to ships, units, and shore stations is provided by elements of the Naval Meteorology and Oceanography Command (NAVMETOCCOM). Direct support to staffs, ships, and units afloat and ashore is provided by officer and enlisted meteorology and oceanography (METOC) personnel assigned to these activities. Shore activities within the NAVMETOCCOM include the Fleet Numerical Meteorology and Oceanography Center, the U.S. Naval Oceanographic Office, the Naval Ice Center, four theater NAVMETOCCOM Centers (Atlantic, European, Pacific, and Western Pacific), five NAVMETOCCOM Facilities, and 37 NAVMETOCCOM Detachments.

Fleet Numerical Meteorology and Oceanography Center (FLENUMMETOCCEN) in Monterey, California, is NAVMETOCCOM's processing center dedicated to running automated, state-of-the-art, operational global and high resolution regional/theater-scale atmospheric and oceanographic analysis and forecast models. FLENUMMETOCCEN is also designated as the primary DOD numerical METOC prediction center per Navy-Air Force cooperative agreement. The center acquires environmental data globally through links with DOD and NOAA conventional and remotely sensed data distribution systems. Numerically-generated products are distributed on Navy and Joint command and control, communications, computers, and intelligence (C4I) systems either directly or via the Navy theater METOC centers. These centers then develop value-added products and services tailored to specific operational requirements. In addition to its standard product suite, FLENUMMETOCCEN is uniquely capable of providing high resolution meteorological and oceanographic products on short notice for any location in support of global contingency military and humanitarian operations. Other FLENUMMETOCCEN products include atmospheric and oceanographic observations, data extracts, and input data for tactical decision aids. In addition to being the primary DOD global numerical weather prediction center, FLENUMMETOCCEN is the designated national Center for Expertise for remotely-sensed microwave products by the Air Force/Navy/NOAA shared satellite processing agreement.

The Navy's program in meteorology is closely linked with oceanography, the focus of two other major Navy METOC centers. The Naval Oceanographic Office (NAVOCEANO), at Stennis Space Center, Mississippi, is responsible for collecting, processing, and distributing oceanographic, hydrographic, and other geophysical data and products. It is the Navy's primary processing facility for NOAA TIROS data and has been designated the national Center of Expertise for satellite-derived sea surface temperature measurements. NAVOCEANO's Warfighting Support Center (WSC) provides near real-time, tailored oceanographic products to support operational Navy and joint commands. Such products include global ocean front and eddy analyses, preprocessed multichannel sea-surface temperature (MCSST) analyses from polar-orbiting satellites, satellite altimetry and scatterometry data from ERS and TOPEX satellites, high-resolution ocean model output, and Special Operation Forces support. Furthermore, as NAVOCEANO is both an operational processing center and a DOD Major Shared Resource Center, research and development programs, using the latest in scalable supercomputing architecture, can be readily transitioned to operational use in Navy METOC models.

Tailored ice forecasts and analyses are provided to DOD by the Naval Ice Center (NAVICECEN), located in Suitland, Maryland. The Navy, through NAVICECEN, NOAA, and the U.S. Coast Guard,

jointly operate the National Ice Center (NIC). The NIC provides sea and lake ice analyses and forecasts for the Arctic and Antarctic regions, coastal United States waters, and the Great Lakes to civil as well as military activities.

Four theater NAVMETOCCOM centers provide broad geographical METOC services within their areas of responsibility. Aligned with specific Naval Component Commanders of the Unified Commanders-in-Chiefs (CINCs) and focused on operations within theater, these METOC centers manage and prioritize the dissemination of tactical numerical METOC products from FLENUMMETOCCEN and NAVOCEANO and add tailored services specifically to support theater requirements. They are hubs for data and product dissemination, providing full spectrum meteorological and oceanographic services to forces operating within their respective areas of responsibility and special METOC products as needed to meet situational requirements of the Joint Force Commander. The Naval Pacific Meteorology and Oceanography Center (NAVPACMETOCCEN), Pearl Harbor, Hawaii, assisted by NAVPACMETOCCEN West, Guam, is responsible for the Pacific and Indian Oceans, Red Sea, and Arabian Gulf areas. Additionally, NAVPACMETOCCEN West operates the Joint Typhoon Warning Center with the U.S. Air Force to provide tropical cyclone advisories to DOD and United States interests in the Western Pacific and Indian Oceans. NAVPACMETOCCEN also issues tropical cyclone advisories, for the eastern and central South Pacific. The Naval Atlantic Meteorology and Oceanography Center (NAVLANTMETOCCEN), Norfolk, Virginia, is responsible for providing METOC services in the Atlantic Ocean and the Greenland, Norwegian, and Barents Seas. The Naval European Meteorology and Oceanography Center (NAVEURMETOCCEN), Rota, Spain, provides METOC support to Joint and Naval forces operating in the Mediterranean, Black, and Baltic Seas. The Atlantic and Pacific NAVMETOCCOM centers share non-ice related METOC product and service support for the Arctic and Antarctic regions. Because of their in-theater presence and focus, NAVMETOCCOM centers are ideally suited to serve as Joint METOC Forecast Units (JMFU) or Coordinating METOC Forecast Centers (CMFC) in support of theater joint operations.

The five NAVMETOCCOM facilities at Jacksonville, Florida; San Diego, California; Pensacola, Florida; Bahrain; and Yokosuka, Japan; provide operations area (OA), local and aviation forecast services, as well as services to aircraft, ship, and submarine staffs. Meteorological and oceanographic forecast guidance from the theater NAVMETOCCOM centers and FLENUMMETOCCEN is used by all facilities.

There are 37 NAVMETOCCOM detachments worldwide. Primarily situated at Naval Air Stations, several are located at Naval Stations in support of sea-going units. They provide METOC forecasting and warning services to DOD and allied units within their local and functional areas of responsibility. Detachments within the continental United States use numerical products from both FLENUMMETOCCEN and NOAA's NCEP. Overseas detachments use the now widely available FLENUMMETOCCEN numerical products, in addition to USAF and foreign products. Two detachments provide specific technical services: one, at the National Climatic Data Center, Asheville, North Carolina, coordinates the Navy's climatological program as its part of the Federal Climate Complex; another, at Tinker AFB, Oklahoma, manages Naval data requirements for the USAF Automated Weather Network (AWN).

**On-Scene Support**

The primary sources of on-scene Navy METOC support for forces afloat and those in-theater ashore are provided by permanently embarked Navy METOC personnel and deployable assets (Mobile Environmental Teams). METOC products and services provided to the operating forces are tailored to requirements of the Fleet and/or Joint Force Commanders and Fleet units. This support consists primarily of tactical METOC information and forecasts for operations, weapon and sensor system employment and tactical decision making, and climatological information for long-range planning. Products are made available to the operating forces via joint and Navy C4I systems, AUTODIN, the High Speed Fleet Broadcast, high frequency facsimile broadcasts, military networks (including military versions of the Internet), commercial systems, and center-maintained Bulletin Board Systems (BBSs) and WEB Home Pages.

The Navy's permanent afloat METOC organic assets are their OA Divisions, embarked aboard major aviation-capable combatants and command ships. Their primary objectives are safety, optimum tactical support to warfare commanders, and tailored on-scene products and services to the assigned task force/group and allied units in joint, combined, or coalition military and humanitarian operations. The centerpiece of the OA Division's suite of METOC equipment is the Tactical Environmental Support System (TESS(3)), an interactive METOC data fusion system which receives, stores, processes, displays, and disseminates meteorological and oceanographic data. TESS(3) receives data from four major sources: global and theater METOC data fields from FLENUMMETOCCEN and NAVOCEANO via the Navy's theater centers; remotely sensed satellite data and imagery from the onboard AN/SMQ-11 satellite data receiver/recorder; alphanumeric data via the High Speed Fleet Broadcast; and local observational data from the Shipboard Meteorological and Oceanographic Observing System (SMOOS). The TESS(3) data base and applications software is provided from the Oceanographic and Atmospheric Master Library (OAML) and the Geophysical Fleet Mission Program Library (GFMPL). The AN/SMQ-11 acquires geostationary satellite weather facsimile (WEFAX) broadcasts and high resolution DMSP and NOAA/TIROS satellite imagery. Local upper air sounding information is made available from the permanently installed AN/UMQ-12 Miniature Rawinsonde System (MRS). The division is also equipped with a PC-based high-frequency facsimile system (PCGRAFAX). Standard CD-ROM based climatology products, the Naval Oceanographic Data Distribution System (NODDS), the Internet-based Joint METOC Viewer (JMV) and the PC Imaging Communications Systems (PICS) software programs are also part of the OA Division inventory.

The Mobile Environmental Teams (MET), based at the theater NAVMETOCCOM centers in Norfolk, Hawaii, and Rota, and at their facilities in Bahrain, Jacksonville, San Diego, and Yokosuka, are the Navy's deployable METOC assets. These teams provide short-term, on-scene services to units and activities without organic METOC personnel within the DOD, other government agencies, and elements of the armed forces of allied nations during combined exercises or operations. The MET have their own portable sensing and display equipment, the heart of which is the Mobile Oceanography Support System (MOSS). MOSS contains modules for tactical meteorological and oceanographic forecasting, polar-orbiting satellite ingest and processing, alphanumeric and facsimile data receipt and display, and *in situ* data collection via the MRS and expendable bathythermograph probes. METs may also deploy with a portable MRS and Alden Marine Facsimile Recorder. If required, they have the capability to install remote Navy Automated Meteorological Observing Systems (AMOS), to sense temperature, humidity, pressure, and winds and provide direct readout and/or telemetry of data via satellite.

Marine Corps (USMC). Marine environmental forecasts are vital to the operation of the USMC. The Deputy Chief of Staff for Aviation, Headquarters, U.S. Marine Corps (Code ASL-44) is the cognizant office for Marine Corps Meteorological and Oceanographic Support and Requirements. The Marine Corps weather organization consists of two operational chains of command, one for garrison aviation weather units and the other for the Fleet Marine Force (FMF).

Garrison aviation weather units at Marine Corps Air Stations and Facilities are manned by USMC METOC personnel and provide direct aviation weather support to host and tenant units. Integral to Marine Corps aviation activities, these weather units provide services to assigned activities and organizations, which include nine major air stations in the continental United States, one in Hawaii, and two in Japan.

Marine Corps METOC support activities are assigned to the FMF in the Aviation Combat Element (ACE) of the Marine Air Ground Task Force (MAGTF). ACE METOC support is derived from the Marine Wing Support Squadron (MWSS) within the parent Marine Aircraft Wing. The existing 10 MWSS METOC activities are equipped to provide support at a bare-based or expeditionary airfield by deploying the Meteorological Mobile Facility METMF. Additionally, Meteorological Support Teams (MSTs) from the ACE MWSSs can be assigned in direct support of the Command Element, Ground Combat Element, and Combat Service Support Element of the MAGTF.

**Battlespace Management Systems**

The Navy's METOC program remains focused on improving data collection, processing, and dissemination capabilities to support operations in the

littoral and to ensure interoperability among the services. A key aspect of this design is a unifying fully-integrated C4I architecture allowing METOC activities to operate in unison with other service elements. Efforts in FY 1998 include:

- Tactical Environmental Support System (TESS(3)/NC). TESS(3) is a modular support system designed to provide Navy decision-makers on major combatant ships with METOC assessments and forecasts and to integrate this data with sensor and weapon platform parameters for system performance assessments. The primary suppliers of these data are the theater METOC centers, which provide value-added products to fleet units in addition to the numerical prediction guidance generated by FLENUMMETOCCEN. The planned TESS(3)/NC will be fully integrated with the next-generation Navy and DOD C4I client-server architecture and will conform to a new vision for information technology systems within the Navy. This new vision focuses on seamless sea-shore transitions, the integration of tactical and non-tactical functions, maximum use of commercial off-the-shelf applications and commonality with industry, and use of a desktop PC as the user interface. TESS(3)/NC will be delivered to the fleet in late 1998, but prototypes are operating now aboard some $2_{nd}$ and $3_{rd}$ Fleet ships.

- Navy Joint TESS Remote Workstation (J-TRWS). Through J-TRWS, METOC data and products are made available to Navy and Marine Corps activities afloat and ashore via the Joint Maritime Command Information System (JMCIS) network. A modular data management and distribution subset of TESS(3) and a segment on the Navy C4I network, the J-TRWS uses TESS(3) data and products to feed real-time tactical decision aids resident within JMCIS. The open system design provides interoperability with other DOD, Federal, and Allied command and control systems. J-TRWS is the basis for the Navy/Air Force Joint METOC Segment of the new Global Command and Control System (GCCS)V3.0. These C4I networks are rapidly migrating to a Windows-NT, client-server architecture.

- Mobile Oceanography Support System (MOSS) upgrade. MOSS is presently undergoing a migration towards a modular, interoperable system -- a NITES variant. It has been upgraded to include a lightweight and portable notebook computer with a docking station. This migratory version, known as Interim MOSS (IMOSS), operates at 100 MHz and has the additional capability to ingest real-time observational data collected by AMOS. The follow-on system, MOSS-Next, will be a modular data management and distribution system operating in a portable environment and incorporating some J-TRWS functionality.

- Meteorological and Oceanographic (METOC) Integrated Data Display System (MIDDS). MIDDS consolidates the numerous METOC functions performed within a shore-based weather station into a client-server architecture which manages the ingestion, processing, display and dissemination of METOC data. Data ingest includes satellite imagery received via GOES-Tap or live WEFAX, digital and analog facsimile, alphanumeric, raster graphic products, Optimum Path Aircraft Routing System (OPARS) products, radar information, lightning, and live Automated Surface Observing System (ASOS) inputs. A system was designed which offered multi-tasking and multi-user capabilities to handle the simultaneous ingest of various products. Hardware was selected to avoid proprietary components and to optimize state-of-the-art processors and display devices available from commercial-off-the-shelf (COTS) vendors. The design was centered around three primary functions. The first was to establish a workstation where the weather forecaster or observer could retrieve, process, and display the various weather products necessary to gain a complete understanding of the atmosphere and how it changed in time. The second was to provide a briefing station with high quality graphics and enhancement features to brief pilots and other base customers on the impact of weather on their operations. The third MIDDS function was to develop a capability to distribute METOC products locally using either dial-in remote access services or Local Area Network (LAN) architectures. MIDDS has been fielded at most Navy and Marine Corps aviation sites.

- Primary Oceanographic Prediction System (POPS). The POPS program was initiated to

provide the computational capability necessary to run massive oceanographic and atmospheric models at both global, theater, and tactical scales. Cray C-90s at NAVOCEANO (POPS-I) and FLENUMMETOCCEN (POPS-II) were installed as part of the Navy's and Federal Government's emphasis on high performance computing. POPS-I has been designated a DOD Major Shared Resource Center, with as much as 85 percent of the computer time on the C-90 devoted to supporting DOD R&D efforts which can then be transitioned to operational use. POPS-II is the numerical engine used by FLENUMMETOCCEN in its role as the primary DOD Numerical Weather Prediction Center. Two subsidiary information systems support POPS at FLENUMMETOCCEN -- the Oceanographic and Atmospheric Support and Information System (OASIS) and the Distributed Processing System (DPS). DPS receives incoming data and distributes final products to external users, while OASIS processes incoming data for POPS and packages POPS output for specific customers. DPS is now being integrated into the OASIS program. Output from Navy's numerical models is made available to NOAA through memoranda of agreement.

**Operational Products and Services**

The Optimum Track Ship Routing (OTSR) is a ship advisory service designed to minimize the risk of damage from extra-tropical and tropical storms, high seas, and sea ice. OTSR also assists port authorities and ships import in the path of tropical cyclones by issuing recommendations for departure time and a sortie location to the Senior Officer Present Afloat. To maximize fuel economy, OTSR provides recommendations for ocean current assistance and avoidance routes in the vicinity of strong ocean currents. OTSR advice considers individual ship characteristics, cargo limitations, and planned operations.

Optimum Path Aircraft Routing System (OPARS) at FLENUMMETOCCEN is a flight planning system to provide tailored routing information to meet individual mission requirements. Among its many options, OPARS can calculate the fuel load needed to arrive with a specific reserve, maximum cargo for a particular flight, in-flight refueling requirements, maximum time on-station, mandatory over water reporting positions, and fuel usage for specific routes and/or altitudes. In preparation for a flight brief, electronic route requests are sent to FLENUMMETOCCEN by the servicing NAVMETOCCOM detachment. To determine optimal aircraft routing, three data bases are incorporated in OPARS: environmental, air route structure, and aircraft performance characteristics. Flight plan information is returned to the originator within minutes for subsequent manipulation and display on a local PC for pilot briefing.

The Navy Oceanographic Data Distribution System (NODDS) is a PC-based software package originally developed in 1982 to make FLENUMMETOCCEN numerical products available to front line DOD users. Products from FLENUMMETOCCEN's global data bases can be selected for user-defined regions and, using an off-the-shelf licensed communications software package, are downloaded as a series of compacted ASCII files to a local PC. All standard meteorological and oceanographic fields and synoptic observations available from FLENUMMETOCCEN can be displayed along with a wide number of oceanographic boundary line products generated at the regional center. Basic satellite imagery (DMSP) is also available. NODDS can overlay up to three different fields, display individual sequence loops, zoom for more detail, display satellite imagery, and produce hard-copy output. NODDS is available to non-DOD Federal agencies and others in the civilian community through an agreement between Navy and NOAA. This version, referred to as NOAA-NODDS to distinguish it from the Navy version, makes available to NOAA unclassified real-time weather and ocean data and products from FLENUMMETOCCEN for access by civilian users.

The Joint METOC Viewer (JMV) is a new capability which will be integrated into NITES and eventually replace NODDS. Building on the incredible global response to the World Wide Web (WWW) and the successful user interface design of NODDS, JMV provides an intuitive Graphical User Interface for retrieving, viewing and annotating METOC information. JMV uses Web technology to allow access to FLENUMMETOCCEN METOC data from nearly anywhere in the world. Authorized DOD and Government users with WWW access now have a simple, cost-efficient way to process weather and ocean information on several computer platforms and operating systems. JMV is now operational at several

hundred DOD sites, including underway ships with WWW capability.

**Supporting Research**

The Navy administers a diverse research and development (R&D) program, ranging from software development to the engineering of sensors, interfaces, processing, display, and distribution devices. Application of R&D activities of the other services and Federal agencies is always considered, and use of existing government and commercial off-the-shelf items is made.

The Navy is a world leader in the field of numerical weather prediction for marine environmental services. Transitioning fundamental scientific research, through additional development, into the operational meteorological and oceanographic models is a key to a successful numerical prediction program. This is an ongoing process at the Naval Research Laboratory's (NRL) Marine Meteorological Division, collocated with FLENUMMETOCCEN, to keep the Navy Operational Global Atmospheric Prediction System (NOGAPS) and its companion Regional Atmospheric Prediction System (NORAPS) at the leading edge of technology. Continued upgrades to the NOGAPS model are planned, incorporating asynoptic and remotely-sensed data in the model initialization process. The relocatable, high-resolution (15-45 km) nested NORAPS model is now used routinely for operational contingency support.

In the future NORAPS will be replaced with the Coupled Oceanographic and Atmospheric Mesoscale Prediction System (COAMPS) model. The atmospheric component of COAMPS will feature triple-nested grids to resolutions of a few kilometers, non-hydrostatic physics, explicit moisture physics and aerosols, and improved data assimilation. The underlying and fully coupled oceanographic component of COAMPS will combine the capabilities of the Optimum Thermal Interpolation System (OTIS), the Wave Model (WAM), and the Princeton Ocean Model (POM) to provide for fully interactive two-way coupling between ocean and atmosphere. With lateral boundary conditions provided by FLENUMMETOCCEN global models, COAMPS will provide the high-resolution, relocatable, and fully-integrated meteorological and oceanographic prediction capability required to support joint littoral operations.

The principal focus of the Navy R&D program in remote sensing is the development of techniques to extract tactically significant information in the littoral regions of the world. Sensors aboard existing satellites are being exploited to the greatest extent possible, and plans are in place to incorporate new capabilities as they are introduced. Because many satellite processing algorithms are designed for use with tactical systems such as TESS(3), expert or rule-based scheme representations are employed wherever possible to reduce manpower-intensive interpretation procedures.

Development of upgraded data assimilation, quality control, and data management techniques in support of these models is also underway. A major thrust has been initiated in the area of numerical weather prediction to develop a shipboard tactical atmospheric forecast capability. This model, intended for use in TESS(3)/NC, will deliver high resolution (5 km), limited area (100s of km), short range (12-24 hr) atmospheric predictions and will assimilate locally acquired data in real time.

ONR is continuing to explore techniques for assimilating environmental data through non-traditional sensors. One such effort in progress is exploring the content and utility of a weather signal tap from the AEGIS AN/SPY-1 air search radar system, a potential candidate for a small-scale shipboard tactical weather radar.

**Sensor Development**

The Shipboard Meteorological and Oceanographic Observing System (SMOOS), currently being fielded, was developed as part of the Navy R&D program in sensor development. As a follow-on to SMOOS, advanced engineering and development of new sensors and related technologies is underway. Some of these include:

- Autonomous drifting buoys for surface and subsurface data.
- Autonomous sensor suites for all Navy ships.
- Aerosol measurement sensors.
- METOC data compression techniques to facilitate communications.

The AN/WSQ-6 series expendable drifting buoys will measure and report air and sea surface temperatures, barometric pressure, subsurface ocean temperature versus depth to 300 meters, omni-directional ambient noise, wind speed and direction,

directional wave spectra, optical parameters, and other properties of the near-surface air/sea environment. The buoys sample and report hourly observations via Service ARGOS; as other communications networks such as Low Earth Orbiting satellites become available, they will be utilized. Near real-time data reception is available via Local User Terminals and TESS(3). As funding and testing permit new sensors will be added to the buoy platform. Multi-parameter, long life, expendable instruments such as the AN/WSQ-6 buoys are vital to the success of the U.S. Navy's contribution to a global ocean observing capability.

The AN/UMQ-12 Mini-Rawinsonde (MRS) consists of a surface receiver, processor, and lightweight balloon-borne expendable sensor package to measure pressure, temperature, humidity, and wind speed and direction. The Navy will be transitioning to a GPS-based mini-rawinsonde system.

Development efforts undertaken by NOAA/NWS have been leveraged in Navy's selection of the NWS' Automated Surface Observing System (ASOS) for Navy and Marine Corps use ashore. Acquisition and installation of ASOS systems continue at Navy and Marine Corps stations worldwide in support of aviation and local area forecasting requirements to replace equipment that has been operated beyond its maintenance life cycles. ASOS will assist Meteorological Technicians in assimilating field meteorological parameters and improving efficient entry of surface aviation observations and synoptic weather reports into the Automated Weather Network (AWN).

Principal User Processors (PUPs) associated with the Next Generation Weather Radar (NEXRAD) are providing significant improvements in radar analysis of meteorological features and severe weather over the United States. The Navy and Marine Corps are participating in the NEXRAD program and will utilize these radars to satisfy their requirements for radar coverage, where possible. On-site NEXRAD PUPs will display imagery from NEXRAD systems covering areas of routine military operations and training.

The Navy will be procuring Supplemental Weather Radars to provide radar coverage at selected Navy and USMC sites, mostly overseas, not scheduled to receive a NEXRAD PUP. This system will replace the obsolete AN/FPS-106 weather radars now in use.

The Marine Corps Meteorological Mobile Facility Replacement (METMF(R)) is a transportable system for providing meteorological support to the Marine Air Ground Task Force (MAGTF). A cost and operational effectiveness analysis of a replacement METMF has been completed, and the system is nearing the demonstration and validation phases of the acquisition process. Housed in a 20 x 20 foot standard Marine Corps van and transportable by a C-130 aircraft, this system will provide a fully functioning weather office for Marine Corps expeditionary airfields for 30 days without resupply. It will include sub-systems for data collection (MRS for upper air and a variety of local and remote sensors), data processing (modified TESS(3)), satellite image ingest and display, Doppler radar display (via the supplemental weather radar), communications, briefing support, and support for remote forces. The METMF(R) will be interoperable with the Marine Corps C4I systems and METOC systems of the other services via the Global Command and Control System (GCCS).

**Interagency Cooperation**

To maximize efficiency and benefit for Navy and NOAA cooperative activities, an Umbrella Memorandum of Agreement (MOA) was signed in 1993. Both agencies continue to review present agreements for conversion into annexes to this MOA and identify new areas of cooperation. Specific areas include:

- Cooperative endeavors in operational numerical modeling, data exchange, and mutual backup between FLENUMMETOCCEN and NCEP.
- Navy/NOAA/Coast Guard operation of the National Ice Center.
- AWS/Navy/NOAA agreement on shared processing of satellite data.
- Navy/NOAA agreement on ASOS procurement, installation, maintenance, and operation.
- Distribution of unclassified Navy METOC products to the civil sector via NOAA.
- Provision of meteorological services to Guam, the Commonwealth of the Northern Marianas Islands, and Micronesia.
- Satellite altimetry data processing.
- Training cooperation through Cooperative Program for Operational Meteorology Education and Training (COMET).

MOAs also exist between the DOC, DOD, and DOT concerning the production and operation of the

NEXRAD system. Additionally, Navy is a DOD participant in the development of the DOC/DOD/NASA converged National Polar-orbiting Operational Environmental Satellite System (NPOESS).

## UNITED STATES ARMY

### ARMY OPERATIONAL SUPPORT

#### Overview of Operational Equipment and Support Missions

U.S. Army weather support is a mix of Army and USAF personnel and equipment under Law and according to Army-Air Force (AF) agreement. Army Regulation (AR) 115-10/Air Force Joint Instruction (AFJI) 15-157, Weather Support for the U.S. Army, 30 June 1996 describes the Service responsibilities and those of Major Army Commands (MACOMs) within the Army providing weather support. The U.S. Army provides direct weather support to two Army missions: upper air observations for Field Artillery fire support, and limited surface weather observations to support Army weapon systems forward of Division tactical operations centers. The Air Force Major Commands (MAJCOMs) provide operational weather services to warfighting MACOMs in combat, contingencies, and peacetime training. U.S. Army Forces Command (FORSCOM), U.S. Army Europe (USAREUR), U.S. Army Pacific (USARPAC), U.S. Army, South (USARSO), U.S. Army Special Operations Command (USASOC), Eighth U.S. Army (EUSA), and U.S. Army Training and Doctrine Command (TRADOC) have Air Force Weather personnel providing daily installation and tactical weather support. Army Artillery Meteorological (ARTYMET) Crews provide direct upper air observation support to artillery units in the same MACOMs. During peacetime training and activation the Air National Guard (ANG) provides AF operational weather support to the Army Reserve and Army National Guard (ARNG), collectively designated the Reserve Component (RC). In addition, during exercises and contingencies the ANG may augment the active Army Weather Teams (WETMs). The ANG acts like an Air Force MAJCOM in providing support to the Army RC.

The Army also provides the operational weather support to Army Research Development, Test and Evaluation (RDTE) ranges, centers, and other research facilities using the Test and Evaluation Command (TECOM) Meteorological Teams (MET Teams) and U.S. Army Space and Strategic Defense Command (SSDC) contractors. TECOM operational support is described under Army Materiel Command in the RDTE section. SSDC provides weather support to Kwajalein Missile Range (KMR) through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field equipment and communications equipment to USAF WETMs for tactical operations. MACOMs have purchased off-the-shelf non-developmental items (NDI) to provide interim Army tactical equipment until the Integrated Meteorological System (IMETS) is fully fielded. IMETS is an automated mobile weather support and communications system. The Project Director (PD) for IMETS is under the direction of Program Manager, Intelligence Fusion. The Communications and Electronics Command (CECOM) and Army Research Laboratory (ARL) provide fielding and technical support to PD, IMETS and to Field Artillery Meteorological programs. IMETS will continue fielding in FY 1998.

The FORSCOM GOLDWING System is a non-developmental item (NDI), providing operational support until IMETS is fielded or other modern tactical communications systems become available in the MACOMs and RC. GOLDWING will be used in conjunction with IMETS for active or RC forces, which are not scheduled to get IMETS because of funding constraints. IMETS communicates with GOLDWING over HF radio.

ARTYMET Crews are assigned to Artillery units at Division level, to Field Artillery Brigades, and to Separate Brigades with a direct support Artillery Battalion. Army soldiers regularly take tactical upper air observations to support Field Artillery units during tactical training exercises, at permanent Army Artillery Ranges, or during the full range of combat missions. ARTYMET Crews also take limited surface observations at tactical locations on an "as needed" basis to support artillery operational requirements.

ARTYMET Crews in the Active Component (AC) and some RC sections currently use the Meteorological Measuring Set (MMS), AN/TMQ-41, to take upper air observations during tactical operations. It is a mobile, upper air sounding system mounted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV). The MMS provides upper air data to the Field Artillery Tactical

Data System for use in adjusting artillery fire, to USAF WETMs, and to the Chemical Officer for use in smoke and in Nuclear, Biological and Chemical (NBC) defense operations. The CECOM section provides a complete description of MMS. The Meteorological Data System (MDS), AN/TMQ-31, replaced by the MMS, has been reissued to eleven Army National Guard (ARNG) and will be used as long as still supportable. The rest of the ARNG units will be upgraded to the MMS and future Profiler systems as they become available. The U.S. Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, develops the requirements documents and is the combat and training developer for meteorological equipment used for Field Artillery support.

The Army provides supplemental, limited surface observations when required in tactical situations to support Army operations. These observations are taken by Intelligence personnel in the forward combat areas when directed by the Intelligence Officer (S2).

Headquarters, Department of the Army, Office of the Deputy Chief of Staff for Intelligence (ODCSINT) is responsible for Army weather support policy. Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS) is responsible for validating and prioritizing weather support requirements and programs to meet Army requirements. The Army Staff also has a full-time active duty User Liaison assigned to the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office.

Army Operational Support Provided by the Air Force

Under AR 115-10/AFJI 15-157, the Air Force is responsible for providing the Army with the necessary manpower and unique tactical and fixed weather equipment to meet Army tactical and garrison AC/RC support requirements. Army support manpower requirements are resourced from Air Force active, reserve, and ANG weather units. While direct support of the Field Artillery remains an Army responsibility and is supported by Army ARTYMET teams, Air Force WETMs provide supplemental information to artillery crews in contingencies for areas beyond direct ARTYMET observation capabilities. The Air Force assigns AF weather personnel to the warfighting MACOMs at theater, corps, division, armored cavalry regiments, aviation brigades, separate brigades, and special forces groups/ranger regiment to provide direct, on site weather support. AF weather squadrons and flights provide garrison and tactical weather warning, observing, forecasting, special support, and staff weather officer (SWO) services to Combat, Combat Support, and Combat Service Support units throughout the peacetime/war continuum. Peacetime garrison activities include supporting flying operations at Army Airfields and severe weather watch, warning, and advisory services for aircraft and post resource protection. The Air Force is responsible for installation, operation, and maintenance of standard Air Force meteorological and observing equipment at Army Air Field Weather Stations. Tactically, the Army is responsible for vehicles, tactical communications, and weather effects criteria. The Army Integrated Meteorological System (IMETS) is fielded for these purposes and is operated by Air Force WETMs. The Army also maintains IMETS hardware and software, with the Air Force maintaining AF software that performs meteorological functions within IMETS. IMETS uses AF meteorological software, but IMETS is built on an Army vehicle, uses Army tactical communications and Army weather effects software. The Army provides other tactical equipment to Air Force WETMs through an Army Table of Organizations and Equipment (TOE).

U.S. Army Space and Strategic Defense Command (USASSDC)

Army Space Command (ARSPACE), a subcommand of USASSDC, provides Army Space Support Teams to deploying Army units. One element of this support is a high resolution weather satellite receiver, which can be readily transported, and which directly acquires and processes the full telemetry stream of civilian and military weather satellites. Imagery and data are used by the staff weather officer in preparation of tailored products and forecasts for use on the battlefield. This equipment is used in contingencies and training exercises, and provides an interim capability pending delivery of IMETS, Block II and associated AF weather satellite equipment. ARSPACE participated in Task Force XXI in FY 1997 through the Tactical Weather (TacWx) initiative. TacWx represents a teaming with the Army Research Laboratory's Battlefield Environment Division, the AF Combat Weather Center, PD IMETS, and the III Corps WETMs to provide the Task Force XXI commander with near real time, state-of-the-art weather information and products. The system consists of ARSPACE Deployable Weather Satellite Workstation, ARL

Battlescale Forecast Model, and the AF Tactical Forecast System, which runs on IMETS hardware. Lessons learned will be used in the IMETS program as product improvements. ARSPACE will also participate in a similar way in Division XXI, to follow Task Force XXI, build on brigade weather capabilities, and apply them at the division level, with special attention to battlefield visualization and simulation activities.

The High Energy Laser Systems Test Facility (HELSTF), a subcommand of USASSDC, located on White Sands Missile Range, is designated as the DOD National Test Range for high energy laser test and evaluation. In addition to laser system test and evaluation, extensive use has been made of on-site laser systems to perform damage and vulnerability testing on laser-hardened materials, missile and aircraft components and various battlefield equipment. Part of the research effort is to develop adaptive optics for atmospheric compensation during lasing.

U.S. Army Kwajalein Atoll (USAKA) is a subcommand of USASSDC, which provides operational support to the test facilities at the Kwajalein Missile Range (KMR). The KMR meteorological services support contractor performs meteorological functions in support of missile operations and for synoptic purposes, including surface, upper air, and meteorological satellite observations, and the preparation of daily aviation, marine and special weather observations for the range.

Army Corps of Engineers Civil Operational Activities

The Corps of Engineers (COE) operates a network of about 7700 gages of which 2200 are land-based limited meteorological observing sites. The remainder are hydrologic in nature. The meteorological portion measure precipitation and other data in the United States to provide information for regulating COE dams and other water projects used for flood control, navigation, hydroelectric power, irrigation, water supply, water quality, and recreation. The COE transfers funds to NOAA/NWS to collect and maintain precipitation information from 1160 of these sites.

Similarly, COE transfers funds to the U.S. Geological Survey to maintain precipitation data collection form 500 sites. The remainder are maintained by the COE. Data from many of these sites are automatically telemetered using satellite, microwave, land lines, radio, etc. to provide for real time use of the data. Although the COE finances the network, data are made available to all other federal agencies.

Training and Doctrine Command (TRADOC) Programs

TRADOC manages and develops training programs, writes Army and Joint weather support doctrine (concepts and field manuals), and establishes the weather requirements documents for Army tactical weather support equipment. The U.S. Army Intelligence Center and Fort Huachuca (USAIC&FH), Fort Huachuca, Arizona, is the proponent and user representative for tactical weather support in wartime, contingencies, and peacetime tactical training. The U.S. Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, is the proponent for upper air meteorological support. The Engineer School, Fort Leonard Wood, Missouri, coordinates weather support requirements in Terrain Analysis and Topographic Engineering. TRADOC schools submit requirements for weather support to HQ TRADOC for approval. HQ TRADOC normally submits requirements for USAF support to HQ, Air Combat Command for implementation. Requirements for Army provided communications or tactical equipment is submitted to ODCSOPS to prioritize and program resources.

USAIC&FH is the functional proponent for tactical Army weather support. The Center's Weather Support Team writes tactical weather support concepts and doctrine; identifies deficiencies and baseline requirements; provides weather support training to Intelligence and USAF personnel supporting the Army; and establishes requirements documents for weather support equipment, except in the artillery support area. USAIC&FH sponsors the Joint Army/Air Force tactical weather concept, which embraces the "Owning the Weather" initiatives of the Army Research Laboratory's Battlefield Environment (BE) Division. These TRADOC concepts describe how weather support to the future Army will be provided. They also describe the employment of the Integrated Meteorological System (IMETS), with its capability to integrate surface and upper air information from national and indigenous sources with battlefield weather data collected by the future Automatic Meteorological Sensor System (AMSS), future Unmanned Aerial Vehicles (UAVs) on-board met sensor, weather satellite, and other sources to provide a 3-dimensional display of weather and environmental effects on and above the battlefield.

Two major Army weather support systems for which USAIC&FH have stated requirements are IMETS and AMSS.

IMETS is a mobile, automated system that receives, integrates, models, and processes weather data. It provides near real-time weather observations and tailored forecasts using digital displays to other Army tactical users. It provides tactical decision aids and weather effects information to help Army warfighters become more effective. IMETS integrates Air Force weather processing capabilities with Army Battle Command System hardware and software in a vehicle-mounted, standard shelter able to move with the supported ground force. IMETS will provide tailored weather data fields to the All Source Analysis System, Digital Topographic Support System, and other Army Battlefield Operating Systems to support Army operations. Further description is in the research and development sections.

AMSS is currently unfunded because of budget constraints. It is planned to be a future source of automated, tactical surface observations in the forward areas and to send data to IMETS to support forecasting processes. Alternate sources of funding will be sought for future years.

USAFAS trains all Field Artillery Meteorological (ARTYMET) Crew members with a staff of 30 military and civilian instructors. USAFAS also has the role of developing requirements documents for new upper air observing systems and writing operational support concepts, doctrine, and procedures to be taught in the classroom and executed in the field.

The Aviation Center, Chemical School, and Engineer School (USAES) incorporate weather instruction and procedures into training programs in their mission areas. USAES develops methods of measuring and forecasting state of the ground parameters for terrain analysis and trafficability assessments. This includes identifying, justifying, and documenting requirements to interface meteorological and engineer battlefield systems. It also monitors R&D advances to incorporate these in combat developments initiatives. Weather is taught in the Engineer Officer Advance Course. USAES previously had a full time meteorologist as a subject matter expert to coordinate weather activities. The meteorologist position was lost in FY 1997. The Aviation Center has unique operational requirements for weather observations and USAF forecast support at remote training locations. Fort Rucker operates additional observing and communications equipment to relay all types of USAF-provided weather information to these Army sites.

Headquarters, TRADOC is the TRADOC approval authority for Army-Air Force weather doctrine, Army weather hardware requirements, and weather support policy within TRADOC.

## WEATHER SUPPORT FOR RESEARCH, DEVELOPMENT, TEST, AND EVALUATION (RDTE)

### Army Meteorological Research, Development, Test and Evaluation

Under Army-Air Force agreement, the Army has responsibility for weather support for research, development, test, and evaluation (RDTE) to support Army ground combat missions as specified in AR 115-10/AFJI 15-157. The Corps of Engineers (COE), and the Army Materiel Command (AMC) are the major contributors to weather research. The Medical Research and Development Command does research related to soldiers performance in the range of weather conditions expected to be encountered in all theaters of operations.

### Corps of Engineers (COE)

The Corps of Engineers (COE) is responsible for reviewing all emerging Army systems for environmental effects, as stated in Army Regulation 70-1. The COE also manages the Technology Demonstration (DT-08) program. Tactical Decision Aids (TDAs) are developed for this program by three COE laboratories: Topographic Engineering Center (TEC), Cold Regions Research and Engineering Laboratory (CRREL), and the Waterways Experiment Station (WES). WES develops TDAs supporting terrain analysis. TDAs interpret the impact of weather and terrain conditions on Army systems and operations. They are based on weather and terrain limitations, known as critical values. Critical threshold values are determined from design criteria, operational testing, or other evaluations of Army capabilities in adverse weather. Critical values define system limitations and are used by decision makers to take advantage over opposing forces. Technology Demonstrations are currently being transitioned to terrain and weather systems such as the Integrated Meteorological System (IMETS), the Digital Topographic Support System

(DTSS), the Army Tactical Command and Control System (ATCCS), and Battle Command Decision Support System.

Topographic Engineering Center (TEC)

The COE Topographic Engineering Center (TEC), Fort Belvoir, Virginia, provides basic and applied environmental support to Army R&D programs and coordinates the development of TDAs relating to environmental effects on combat systems, operations, and personnel. This includes the development and integration of environmental effects data bases and models that are relevant to military plans, operations and the acquisition communities. TEC also develops models and techniques to assist in the generation of proxy environmental information (climate and terrain) for data sparse areas and the integration of models to enable the spreading of this information spatially over map backgrounds. TEC is also responsible for developing integrated software modules that are designed to be exploited in the synthetic environment arena and for developing techniques to portray natural and induced battlefield environments, thus enhancing computerized battle simulations. TEC also contributes to the development of policies and procedures for the consideration of realistic natural environmental conditions for application in the materiel acquisition process. As preparer and custodian of AR 70-38, TEC provides special climatological studies and guidance to materiel acquisition activities. TEC also reviews all emerging materiel systems for environmental effects.

Cold Regions Research and Engineering Laboratory (CRREL)

Under the military portion of its civil and military support mission, the Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire, provides weather support to Army weapon systems RDTE, combat, and combat support mission areas, and develops climatological studies on the effects of winter environment on Army operations. CRREL is responsible for modeling in the areas of Cold Regions Surface-Air Boundary Process, Winter Scene Dynamics, and Spatially Distributed Prediction Over Winter Terrain. CRREL develops data bases and models predicting Infrared and millimeter wave (MMW) weapon system performance, and the capability of technology to enhance military operations in cold environments. Under a Memorandum of Understanding (MOU), the U.S. Army Test and Evaluation Command (TECOM) provides operational observing, weather instrumentation, and forecasting services for CRREL's RDTE efforts through a MET Team located at CRREL.

Army Materiel Command (AMC)

The Army Materiel Command (AMC) is responsible for the design, development, test, and evaluation of equipment to satisfy requirements for meteorological support equipment. AMC provides climatological and meteorological support to RDTE projects involving electro-optics and obscurants. It is also responsible for determining weather effects critical threshold values and environmental sensitivities of battlefield systems. AMC has several subcommands and elements carrying out weather research and development responsibilities.

Test and Evaluation Command (TECOM).

TECOM is a subcommand of AMC providing operational support to 10 ranges and test sites with collocated Meteorological (MET) Teams in FY 1998, The Hunter Ligget Range closed in FY 1997 and the MET team was disestablished. Under responsibilities established in AR 115-10/AFJI 15-157, the TECOM MET Teams provide weather support and atmospheric characterization to Army Research, Development, Test, and Evaluation (RDTE).

TECOM MET has taken the following actions to mitigate the effects of the past decade of funding reductions and downsizing. Where there use to be in-house development of unique test instrumentation such as the Small Portable Transmissometer and Global Positioning System (GPS)-based upper air systems, TECOM MET now relies on commercial-off-the-shelf (COTS) instrumentation. New MET systems or MET sensors instrumentation will be acquired through Army technical development resources or through direct funding from RDTE projects for test specific or unique requirements. Where TECOM MET used to have an in-house staff of expertise, MET now partners with outside expertise. For example, TECOM is partnering with the National Center for Atmospheric Research (NCAR) for the integration of all the unique range sensors and systems into a Four Dimensional Weather System (4DWX). 4DWX is a range scale (micro- and meso-scale) three dimensional (with time) display in near-real-time to forecast, "go, no-go" decisions and to replay the forensic analyses of weather effects on a test. Where TECOM MET used to have the ability to

augment/hire federal employees, MET now augments with contractor employees.

The TECOM MET Teams at ranges supporting RDTE now operate on a 60/40 percent customer reimbursable/direct funding basis. With level funding projected for the out-years, TECOM MET is confident that RDTE MET support requirements will be met. Likewise, the projected stable funding for chemical/biological support, modeling and simulations, and test support at Dugway Proving Ground MET will also allow them to meet their requirements.

Army Research Laboratory (ARL)

The ARL Battlefield Environment (BE) Division of the Information Sciences and Technology Directorate is the lead DOD agency for research and development in the portion of the atmosphere unique to the Army warfighter's battlespace--the planetary boundary layer. BE's mission is to "*Own the Weather*" (OTW) by providing atmospheric effects information to decision makers on the battlefield in planning and executing operations. The Army/Air Force OTW initiative will provide advanced knowledge of current and forecast battlefield environment conditions, along with their effects on systems, soldiers, operations, and tactics, which in turn provides a decisive advantage over opponents. (See the feature article in Section 4 for more information on OTW.)

Under the DOD Project Reliance taxonomy, BE is the lead agency for multi-service programs in transport and diffusion modeling and mobile atmospheric profiling, with the latter technology transferring out of BE to engineering development in FY 1999. In addition, BE contributes to tri-service goals in the areas of theater data fusion and predictions, boundary layer processes, and atmospheric effects.

The BE program is driven by the Army's need for boundary layer meteorological information in data sparse areas and at smaller scales than normally used by either the Air Force, Navy, or civilian community. The requirement to host this capability on Army tactical hardware further constrains the research and development programs.

The Atmospheric Effects efforts address: (1) acoustic propagation and background models for predicting environmental effects on acoustic signatures and sources; (2) micrometeorology of urban environments and vegetative canopies; (3) optics and beam propagation in the boundary layer; (4) transport and diffusion of chemical/biological agents and other aerosols released into the atmosphere; and (5) in-situ and remote detection of chemical/biological agents and pollution aerosols.

The Synthetic Environments efforts address: models and simulations of environmental effects on electro-optical systems under realistic battlefield conditions. The Atmospheric Effects and Synthetic Environment branches now reside at ARL's Adelphi Laboratory Center, Adelphi, Maryland.

ARL BE will perform associated boundary layer profiling research, with the FM-CW radar and Sodars, and acoustical field work, including the 56 foot long Mobile acoustical Source, at Blossum Point, Maryland, upon completion of the site preparation and equipment refurbishment in FY 1998.

The Weather Exploitation efforts address: (1) battlescale forecasts of tactical weather; (2) tactical weather radar, (2) tactical weather assimilation and distribution; (3) advanced tactical decisions aids integrated with tactical weather data products; and (4) transitioning advanced weather technology to Battlefield Automated Systems and Battle Laboratories.

The Artillery Meteorological efforts address: (1) integration of tactical weather data and forecasts into Artillery indirect fire and precision strike operations, and (2) remote sensing Profiler technology for artillery upper air soundings, which is planned to transition in FY 1999 to the engineering developer for advanced engineering and fielding with the Army.

Army Research Office (ARO)

The Army Research Office (ARO), Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamics and kinematic processes of the atmospheric boundary layer at scales of interest to the Army (millimeters to 10's of kilometers) through measurements, simulations, and theoretical considerations.

The basic research program is conducted through the peer-reviewed, individual investigator program and several special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer where the Army operates. Objectives of the research are to develop, from first

principles, the physical basis for understanding the boundary layer processes, thereby leading to better understanding of atmospheric effects on soldiers, materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heterogeneous terrain features on air flow, and the development of natural obscurations throughout the diurnal cycle. An essential element of the research is the development of instrumentation to measure the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales.

Other areas of special funding are also managed. The Augmentation Awards for Science and Engineering Research and Training (AASERT) program provides funding for additional graduate and undergraduate students working under existing sponsored research programs. The Defense University Research and Instrumentation Program (DURIP) provides funds for instrumentation needed to support ongoing research activities.

Communications and Electronics Command (CECOM)

The CECOM Intelligence and Electronic Warfare (IEW) Directorate (Dir), Fort Monmouth, New Jersey, assists the CECOM level II manager and other internal organizations in developing and fielding weather support systems; and helps the Program Manager, Intelligence Fusion with technical management of weather programs. Current programs supported are the Meteorological Measuring Set (MMS), the Profiler, and the Integrated Meteorological System (IMETS). A brief description of each of these programs shows IEW's involvement and supplements earlier discussions under the other MACOMs.

The Meteorological Measuring System (MMS), AN/TMQ-41 is currently fielded to the active Army. It is an upper air meteorological data collection, processing and dissemination system that provides data to the field artillery and target acquisition users. The system meets the requirements of roll-on/roll-off capability during assault. The system is NDI. The contractor has built 42 systems for the Army and ARNG, 21 for the Marine Corps, and additional systems for foreign sales. The IEW Dir is currently assisting in upgrading the MMS. The GPS upgrade will act as a Navigational Aid (NAVAID) to determine radiosonde position. GPS will be used when the current primary NAVAIDS (LORAN-C and VLP/OMEGA) are not available. The GPS processor will fit inside of the MMS meteorological processor, currently being updated to accommodate this upgrade. Another upgrade to the MMS is the Surface Meteorological Sensor (SMS). The SMS will be mounted on a tripod outside the MMS shelter and will be connected to the MMS shelter by cable. The SMS underwent first article testing in FY 1997.

The Profiler will provide the current upper air meteorological system with new and enhanced capabilities. It will provide a suite of sensors which will reduce the time staleness of atmospheric data. These sensors will be capable of sensing on an almost continual basis. It also provides a model of local terrain to further improve the accuracy of the data for firing artillery systems.

The Integrated Meteorological System, AN/TMQ 40, is the primary Army weather support system outside artillery support. It is operated by AF WETMs at all levels with direct AF weather support. It collects available observations and central forecast products, analyzes and forecasts on the micro-scale, and disseminates tailored weather products and weather effects decision aids electronically into the Army Battle Command System for direct use in warfighting missions. Satellite imagery is directly received in IMETS and from the Air Force STT. IMETS can merge weather displays with the common relevant picture of the battlefield to help visualize weather impacts on operations and help the commander and staff to use the information more effectively. IMETS has HF radio connectivity to other Army HF weather communications systems and computer to computer electronic interface over the Army Battle Command System at each tactical operation center and connectivity to higher and lower command levels.

Medical Research and Development Command

U.S. Army Research Institute of Environmental Medicine. The U.S. Army Research Institute of Environmental Medicine (USARIEM), Natick, Massachusetts, conducts research on the effects of temperature, altitude, work, and nutrition on the health and performance of individual soldiers or combat crews operating Army systems.

Applied research efforts in thermal physiology and biophysical modeling are directed toward improving soldier performance and minimizing health risks in climatic extremes. The sensitivity of the soldier to

weather parameters (primarily ambient air temperature, dew point temperature, wind speed, and solar radiation) defines an operational envelope for unimpaired human performance. The goals of applied research efforts are to develop methods to assess and extend the boundaries of the envelope in both training and operational settings.

In support of the Army Ranger training facility at Eglin AFB, Florida, Medical Research and Materiel Command and USARIEM are participating in the development of an automated thermal injury risk assessment system. The MERCURY-Ranger test bed system is being developed in partnership with the Army Research Laboratory's Battlefield Environment Division (ARL/BE), the Canadian Defence and Civil Institute of Environmental Medicine (DCIEM), and the USAF's 46th Weather Flight at Eglin AFB. The MERCURY program ingests data from several local surface weather stations and automatically spreads the data across a region of interest using objective and heuristic interpolation methods. The resulting high resolution (1 km) gridded weather data fields are then used as inputs to the thermal strain prediction models for heat stress, cold air exposure, or cold water immersion. Results are displayed as color coded map overlays of thermal injury risk categories or tolerance times. A prototype cold water partial immersion model is being developed and implemented in cooperation with DCIEM. That model uses real-time water temperature and depth measurements along with standard weather parameters at river locations to predict safe exposure times in cold water river fording scenarios. This highly automated test bed system is intended to provide a platform for evaluating methods needed to translate real-time weather information into robust assessments of soldier system health risks and performance limitations.

Army weather and battlefield atmospherics researchers are working closely with MACOM users and other DOD organizations to ensure the highest possible payoff for its research and development dollars.

APPENDIX C

# DEPARTMENT OF TRANSPORTATION WEATHER PROGRAMS

## FEDERAL AVIATION ADMINISTRATION

The FAA has the responsibility to provide national and international leadership in the optimization of aviation weather systems and services. This leadership is manifested through the management of a safe and efficient National Airspace System (NAS) and the encouragement of consensus and cooperation between government agencies, private weather services, research organizations, and user groups involved in aviation weather.

### AVIATION WEATHER MANAGEMENT

NAS Management. For the last few years, the Federal Aviation Administration (FAA) has been focusing on initiatives to prevent accidents and delays attributable to weather. The focus on these initiatives underscored the need for centralized aviation weather program management. Feedback from users and other weather service providers only reinforced the FAA commitment to meet that need.

By necessity, operational aviation weather activities needed to be dispersed among FAA organizations responsible for the day-to-day operational responsibilities. The research and acquisition activities associated with the aviation weather program have already been centralized into the Office of Research and Acquisition. However, the policy and requirements functions for aviation weather were dispersed throughout the offices of Flight Standards Services, Airway Facilities Requirements and Life-Cycle Management, Air Traffic Plans and Requirements, and System Capacity and Requirements. The dispersal of these activities over four different organizations was an obstacle to the development and management of an aviation weather program that would meet the needs of the NAS envisioned for the 21st Century.

In 1995, the Associate Administrators for Air Traffic Services, Regulation and Certification, and Research and Acquisition agreed to centralize FAA aviation weather policy and requirements functions into one multidiscipline organization. The Associate Administrator for Air Traffic Services supported the location of the new organization within the office of Air Traffic Requirements Service. On October 1, 1995, the Aviation Weather Division was established and staffed with personnel from diverse backgrounds, such as flight standards, meteorology, airway facilities, and air traffic. A reorganization that established the Air Traffic Requirements Service in early 1997 elevated Aviation Weather to a Directorate.

Most of the ongoing activities within FAA aviation weather program are well known. First, FAA works in partnership with many other government agencies to integrate aviation weather issues and activities into the overall national weather program. The partnership with the National Weather Service (NWS), that has been in existence for decades, is enjoying a revitalization with the establishment of the new weather division. The new division is working diligently to reaffirm FAA's leadership role in aviation weather and the important role of NWS in meeting aviation weather requirements.

During the next 5 years, FAA will focus on four major areas for aviation weather services:

- Roles/responsibilities.
- Training.
- Technology.
- Investment strategies.

This focus will provide some immediate benefits and, more importantly, will strengthen the foundation for future NAS services.

Roles and Responsibilities. The successful execution of a national aviation weather program is first dependent upon an explicit and mutually understood definition and acceptance of roles and responsibilities both within and outside of the FAA. The execution of these roles and responsibilities have been enhanced by the chartering and complete staffing of the Aviation Weather Division, clarifying FAA lines of business, and completing intra-agency and interagency plans.

Training. Aviation weather information, which is complex and highly perishable, is most useful when customers can successfully plan, act, and respond in ways that avoid accidents and delays. FAA will improve the ability of the aviation community to use weather information through a review and upgrade of airmen training and certification programs. FAA will also develop multimedia training tools to support aviation safety and training initiatives.

*STRATEGIC VIEW FOR AVIATION WEATHER MODERNIZATION*

*Although many of the weather activities described in this Appendix were initiated before the creation of the Aviation Weather Division, the new division will lead the development of a strategic view for a national aviation weather program and further develop the plan for implementing that program. There are four major drivers of this strategic view.*

*First, there is operational urgency. The FAA is committed to the prevention of accidents and delays attributable to weather. From 1989 through 1993, 23 percent of all aviation accidents were attributable to weather. In 1992, 65 percent of all delays were attributable to weather at an estimated cost of over $4 billion. The projected growth of domestic traffic over the next 10 years demands the implementation of programs that increase capacity while continually maintaining mandated safety standards. A "weather-wise" program for the 21st century will anticipate and meet user requirements for both safety and capacity.*

*The next driver is the large and diverse group of stakeholders in the national aviation weather program. The large number of stakeholders increases the competition for limited resources; the diversity of stakeholders frequently results in conflicting objectives and priorities. The ability to integrate the needs and requirements of these stakeholders into the policies, investment strategies, and performance metrics of the national program will be key to its success.*

*The rapid advancement of aviation technologies is the third driver of this strategic view. The plan will redefine and clarify basic assumptions about the nature and delivery of aviation weather services. There will be a renewed emphasis on weather information as opposed to weather data. Aeronautical Data Link will enable simultaneous real-time dissemination of weather information to both the pilot and the air traffic controller. FAA will develop display and decision-making tools that enhance rather than burden decision making. FAA will develop procedures to support the users of this new technology as well as those users who will continue to rely on ground-based information systems. Human factors studies demonstrate the need to find the optimum balance point between technology and human performance. This need will be a key consideration in the design and placement of new equipment; in the training of pilots, dispatchers, and controllers; and in the regulations and procedures applicable in the NAS.*

*The final driver is consideration of the changing role of government and the diminishing funding of government services. Clearly the federal government is obligated to lead the development of a national aviation weather program, and this program should, by definition, consist of standards for and definitions of program requirements and services. However, to what extent should and can the federal government accept the responsibility for funding aviation weather services? Unfortunately, a world of unlimited resources does not exist. The more fundamental question, regardless of resources, is the appropriate role of the federal government. At this point, these questions cannot be answered; but, with a "weather-wise" strategic view, the FAA, along with other stakeholders, may be able to influence the answer.*

Technology. Aviation weather technology includes the ways in which aviation weather information is gathered, disseminated, and displayed. The development of this technology also demands that consideration be given to human factors and the application of decision-making tools. FAA will support the use of technology by improving aviation weather information through integration of federal and non-federal resources; applying human factor considerations to the content, format, and dissemination of weather information; and establishing configuration management criteria for the software and hardware elements of aviation weather systems.

Investment Strategies. Sound investment strategies are characterized by the integration of many activities, primarily those of identifying, planning, and evaluating. Over the next 5 years, FAA will develop a sound investment strategy for a national aviation weather program that:

- Communicates the aviation weather objectives.
- Describes where the FAA wants to be.
- Considers all FAA and non-FAA funding for aviation weather that contributes to NAS performance.
- Develops and uses metrics that provide information on the performance of the national aviation weather program.

## AVIATION WEATHER ACQUISITION AND SERVICES

One of the primary functions of the new organization is the development and management of requirements for the FAA Capital Investment Plan. Recent projects have focused on weather detection and display systems for pilots and air traffic controllers to ensure that aircraft avoid hazardous weather. The following paragraphs describe those projects.

### Terminal Aviation Weather Programs

The Integrated Terminal Weather System (ITWS) will integrate weather data from sensors in the terminal area to provide and display compatible, consistent, real-time products that require no additional interpretation by controllers or pilots--the primary users. ITWS will use data from automated surface observing systems, Doppler weather radars, and low-level windshear alert systems, together with NWS data and products, to forecast aviation impact parameters, such as convection, visibility, icing, and windshear, including downbursts. Initial capabilities will include sensors available now through the late 1990's. The development is now in the demonstration phase at several airports in various climatic regimes. ITWS will operate at about 45 high activity airports that are supported by terminal Doppler weather radars. Full implementation is expected after the turn of the century.

The Terminal Doppler Weather Radar (TDWR) program consists of the procurement and installation of a new terminal weather radar based on Doppler techniques. TDWR units will be located to optimize the detection of microbursts and windshear at selected high activity airports. In addition, it will have the capability to identify areas of precipitation and the locations of thunderstorms.

Microbursts are weather phenomenon that consist of an intense downdraft with strong surface outflows. They are particularly dangerous to aircraft that are landing or departing. TDWR scanning strategy will be optimized for microburst/windshear detection. The radar will be located near the airport operating areas in a way to best scan the runways, and the approach and departure corridors. The displays will be located in the tower cab and Terminal Radar Approach Control (TRACON).

FAA has ordered 45 TDWR systems and 2 support units for training and testing. Deliveries will be completed by the end of calendar year (CY) 1997. A software upgrade has been initiated to integrate TDWR and low level windshear alert system data.

The Low Level Windshear Alert System (LLWAS) provides pilots with information on hazardous windshear conditions that create unsafe conditions for aircraft landings and departures. A total of 110 airports have LLWAS. The basic system consists of a wind sensor located at center field and five sensors near the periphery of the airport. A computer processes the sensor information and displays windshear conditions to air traffic controllers for relay to pilots.

The LLWAS-Network Expansion (LLWAS-NE) is the first step in the FAA's efforts to upgrade the NAS capability to detect windshear. The earlier, six-sensor systems provided adequate protection against microbursts; however, testing at Denver Stapleton Airport and Orlando International Airport have resulted in the development of two more sophisticated windshear detection systems--LLWAS-NE and LLWAS-3. LLWAS-NE will include expanding the network of sensors, improving sensor siting and providing runway-oriented alerts.

The improvement phase, referred to as LLWAS-3, will include expanding the network of sensors, developing improved algorithms for the expanded network, and installing new information/alert displays. The new information/alert displays will enable controllers to provide pilots with head wind gain or loss estimates for specific runways. These improvements will increase the system's windshear detection capability and reduce false alarms. Improvements are also expected to reduce maintenance costs. Initially, 83 airports have been identified to receive LLWAS-3; LLWAS-3 is scheduled to be fully deployed by CY 2001.

In the future, LLWAS-3 and TDWR will work in conjunction with one another and provide a synchronous alarm of windshear to the air traffic controller; in fact, development of a system is underway that will integrate the information from these two systems into a single windshear display. Investigation is also underway on how integrated windshear information can best be communicated or displayed to the pilot. Also, studies will be conducted to evaluate other sensors for the airport approach and departure corridors. These sensors are intended to provide windshear detection out to three miles from the touchdown zone.

The Surface Weather Observing Program. The FAA has taken responsibility for observations at many airports all across the country. To provide the appropriate observational service, FAA will use automated systems, human observers, or a mix of the two. It has been necessary to place airports into four categories according to the number of operations per year, any special designation for the airport, and the frequency at which the airport is impacted by weather.

- Level D service is provided by a stand-alone Automated Weather Observing System (AWOS) or an Automated Surface Observing System (ASOS). In the future, Level D service may be at as many as 400 airports.
- Level C service includes the ASOS/AWOS plus augmentation by tower personnel. Tower personnel will add to the report observations of thunderstorms, tornadoes, hail, tower visibility, volcanic ash, and virga when the tower is in operation. Level C service includes about 250 airports.
- Level B service includes all of the weather parameters in Level C service plus Runway Visual Range (RVR) and the following when observed--freezing drizzle versus freezing rain, ice pellets, snow depth and snow increasing rapidly remarks, thunderstorm/lightning location remarks, and remarks for observed significant weather not at the station. Level B service includes about 57 airports.
- Level A service includes all of the weather parameters in Level B service plus 10-minute averaged RVR for long-line transmission or additional visibility increments of 1/8, 1/16, and 0 miles. Level A service includes about 78 airports.

Automated surface weather observing systems will provide aviation-critical weather data (e.g., wind velocity, temperature, dew point, altimeter setting, cloud height, visibility, and precipitation type, occurrence, and accumulation) through the use of automated sensors. These systems will process data and allow dissemination of output information to a variety of users, including pilots via computer-generated voice.

FAA has deployed Automated Weather Observing Systems (AWOS) at over 200 airports to provide the basic aviation weather products directly to pilots approaching the airport. The majority of these systems were installed at various non-towered airports to enhance aviation safety and the efficiency of flight operations by providing real-time weather data at airports that previously did not have local weather reporting capability. These systems are built to the standards of quality necessary to ensure the safety of flight operations and are available off-the-shelf as a commercial product.

The FAA has negotiated with the National Oceanic and Atmospheric Administration (NOAA) to procure, install, operate, and maintain Automated Surface Observing Systems (ASOS) at the remaining airports where the FAA provides observations and at additional non-towered airports without weather reporting capabilities. A production contract was awarded in February 1991. The FAA will be sponsoring, as part of the reimbursable agreement with NOAA, 537 systems with an option for 228 additional systems. The current buy of FAA-sponsored systems is for 304 of which 292 were installed by August 1997.

The AWOS/ASOS Data Acquisition System (ADAS) will function primarily as a message concentrator and will collect weather messages from AWOS and ASOS equipment located at controlled and non-controlled airports within each air route traffic control center's (ARTCC) area of responsibility. ADAS will distribute minute-by-minute AWOS/ASOS data to the Weather and Radar Processor (WARP) and the Data Link Processor (DLP) within the center in which it is installed. ADAS will also distribute AWOS data to the National Airspace Data Interchange Network (NADIN) which will in turn forward the data to Weather Message Switching Center Replacement (WMSCR) for further distribution. The DLP (via Mode S) will make weather data available, on a timely basis, to pilots and air traffic controllers within the "local" area as well as other users. Field implementation of ADAS has started and will be completed in 1998.

AWOS for Non-Federal Applications. Under the Airport Improvement Program (AIP), state and other local jurisdictions may justify to the FAA their need to enhance their airport facilities. Upon approval, these improvements may be partially funded by the FAA using resources from the Airway Trust Fund. The local airport authority becomes responsible for the remainder of the funding necessary to complete the procurement as well as the funding for the regular

maintenance. The addition of an AWOS is one of the improvements that qualify for AIP funding assistance. Systems that qualify must meet certain standards which are defined in an FAA Advisory Circular on Non-Federal Automated Weather Observing Systems.

There are currently five versions of the non-Federal AWOS. An AWOS-A provides only altimeter setting. The AWOS I system contains sensors to measure wind direction and speed, ambient and dew point temperatures, altimeter setting, and density altitude. The AWOS II contains the AWOS I sensors plus a visibility sensor; AWOS III adds a cloud height sensor to an AWOS II. AWOS IV will include AWOS III capabilities plus the option for precipitation identification, thunderstorm detection, and runway surface condition. Most importantly, all versions are required to have the capability to broadcast a minute-by-minute update of the current weather to the pilot by radio, using a computer-generated voice output. AWOS III also enables the pilot, as part of their preflight activities, to call the AWOS and obtain the current weather observation. In addition, the observation may be transmitted to the database within the national weather network.

There are more than 275 non-Federal AWOS locations. Some of these are capable of reporting through a geostationary communications satellite, and many more will acquire that capability during the year. These observations will be entered into the national network for use in support of the NAS and the national weather network.

The New Generation Runway Visual Range (RVR) program provides for a new generation RVR sub-element of the NAS. The RVR provides runway visual range information to controllers and users in support of precision landing and takeoff operations. The new generation RVR incorporates state-of-the-art sensor technology and imbedded remote maintenance monitoring. FAA plans to procure and install these RVR systems at all new qualifying locations. FAA plans also call for the replacement of many existing RVRs in the NAS inventory.

The RVR provides for near real-time measurement of visibility conditions along a runway (up to three points along the runway can be measured-- touchdown, midpoint, and rollout) and reports these visibility conditions to air traffic controllers and other users. The system automatically collects and formats data from three sensors: a visibility sensor--forward scatter meters will replace the transmissometers currently in use, a runway light intensity monitor for both runway edges and center-line lights, and an ambient light sensor which controls computer calculations using a day or night algorithm. The data processing unit calculates RVR products and distributes the products to controllers and other users.

A total of 528 RVR visibility sensors will be deployed at 264 airport locations. Delivery of the new RVR sensors began in November. Enhancements are planned to interface with the Tower Control Computer Complex and the ASOS by 1998.

Airport Surveillance Radar-9 Weather Modular Enhancement. The Weather Modular Enhancement will be an add-on modification to the existing Airport Surveillance Radar-9 (ASR-9) and will provide air traffic controllers with information on low level windshear associated with microbursts and gust fronts in the vicinity of the airport. Presently, the ASR-9 weather data that are available consist of the six intensity levels as defined by the NWS.

En Route Aviation Weather Programs

The FAA is procuring the Operational and Supportability Implementation System (OASIS) to improve weather products, flight information, aeronautical data collection, analysis, and timeliness of dissemination and, thereby, enhance the safety and efficiency of the NAS. OASIS will replace the Model 1 Full Capacity Flight Service Automation System, which includes the Aviation Weather Processor. OASIS will also integrate the Interim Graphic Weather Display System functions. It will also include several automated flight service data handling capabilities. This configuration will be its initial deployment capability.

Future enhancements leading to the full capability deployment will include: interactive alphanumeric and graphic weather briefings, direct user access terminal (DUAT) service functionality, automated special use airspace, and training support. OASIS will support flight planning, weather briefings, NOTAM service, search and rescue, and pilot access terminal services.

Each OASIS will have interfaces with its host Air Route Traffic Control Center (ARTCC) computer, U.S. Customs Service, Treasury Department, foreign ATC facilities, and WMSCR. WMSCR will relay most of the weather information, data, and pilot reports (PIREP).

The Next Generation Weather Radar (NEXRAD), known operationally as the Weather Surveillance Radar -1988 Doppler (WSR-88D), is a multiagency program that defined, developed, and implemented the new weather radar. Using the principles of the Doppler effect and state-of-the-art software, the WSR-88D is able to detect many properties of the atmosphere that were not heretofore routinely sampled. Departments of Commerce (DOC), Defense (DOD), and Transportation (DOT) jointly fund WSR-88D implementation costs; DOC is responsible for program management. The WSR-88D was developed and acquired under the auspices of the NEXRAD Program Council within the Office of the Federal Coordinator for Meteorology.

Field implementation began in 1990 and was completed in 1996. There are a total of 161 WSR-88D systems deployed within the three agencies. The FAA sponsored 12 systems in Alaska, Hawaii, and the Caribbean. DOC and DOD WSR-88Ds provide coverage over the continental United States.

The FAA emphasized the development of WSR-88D algorithms that take advantage of the improved detection of precipitation, wind velocity, and hazardous storms. The FAA also stressed that these algorithms provide new or improved aviation-oriented products. These improvements in detection of hazardous weather will reduce flight delays and improve flight planning services through aviation weather products related to wind, windshear, thunderstorm detection, storm movement prediction, precipitation, hail, frontal activity, and mesocyclones and tornadoes.

WSR-88D data provided to ATC through the WARP will increase aviation safety and fuel efficiency. In addition to the benefits to be gained in today's system, future automated ATC functions and improved traffic-flow management require reliable and accurate weather data to maximize fuel savings and manpower productivity.

In addition, the three funding agencies support the field sites through the WSR-88D Operational Support Facility (OSF) at Norman, Oklahoma. The OSF provides software maintenance, operational troubleshooting, configuration control, and training. Planned product improvements include a shift to an open architecture and the development of more algorithms associated with specific weather events, such as hurricanes. Field sites continually provide the OSF with suggestions for improvement of existing algorithms and applications of products.

A new Air Route Surveillance Radar (ARSR-4) provides the ARTCCs with accurate multiple weather levels out to 200 nautical miles. The ARSR-4 is the first en route radar with the ability to accurately report targets in weather. The ARSR-4 is used to provide weather information to supplement the WSR-88D in areas such as the Rocky Mountains. The ARSR-4 is a joint FAA/USAF funded project. Forty joint radar sites were installed during the 1992-1995 period.

The Weather Systems Processor (WSP) program will provide an additional radar channel for processing weather returns and de-alias returns from the other weather channel in the ASR-9. The displays of convective weather, microbursts, and other wind shear events will provide information for controllers and pilots to help aircraft avoid those hazards. A prototype has been demonstrated and limited production will commence in the fourth quarter of CY 1997. Full productions deliveries are expected to be completed by 2001.

Aviation Weather Processing Programs

The FAA participates in coordination among federal agencies, concerning Automated Weather Information Systems (AWIS). The OFCM-sponsored Committee for AWIS developed a national plan which integrates requirements, development, and implementation activities associated with AWIS programs and projects of the DOC, DOD, and DOT. Under this plan, the three departments are cooperating in the review, clarification, and allocation of requirements to the various specialized elements of the planned national AWIS. The intent of this activity is to avoid unnecessary duplication of development efforts and to ensure the sharing of information and products in the operational phase. New interface requirements are being defined and plans for product sharing are being developed. Within FAA, new interfaces with elements of the NAS will be developed to support the aviation weather information dissemination function. One interface will enable the DLP to provide WSR-88D mosaics for communication to pilots as well as receive PIREPs from aircraft in-flight.

The Meteorologist's Weather Processor (MWP) is a commercially available, interactive workstation which was procured through a series of 5-year leases. It is used primarily by NWS meteorologists who are

assigned to Center Weather Service Units (CWSU) at each of the ARTCCs. The MWP receives a stream of products and data fields which is controlled by the vendor but originates with the NWS. This system improves the dissemination of aviation weather information throughout the NAS, including pilots, air traffic controllers, flight service specialists, traffic management specialists, and NWS CWSU meteorologists. The MWP provides specialized automated tools to these meteorologists to enhance their ability to summarize hazardous weather information and ensure that the latest and best information is disseminated to all users.

The original deployment of MWP was completed in 1992. The MWP, leased in the second 5-year period, will interface with the WARP, which should become operational in the late 1990s. The MWP also interfaces with NWS offices to permit a rapid flow of weather information to and from each FAA center. Future leases of the MWP will consider the possibility of utilizing services available from the NWS' Advanced Weather Interactive Processing System (AWIPS).

The Weather and Radar Processor (WARP) will automatically create unique regional, WSR-88D-based, mosaic products. WARP will send these products, along with other time-critical weather information, to controllers through the Advanced Automation System (AAS) and to pilots via the aeronautical data link. WARP will greatly enhance the dissemination of aviation weather information throughout the NAS. It will have interfaces with WMSCR through NADIN, ADAS, OASIS, and DLP.

The Direct User Access Terminal (DUAT) system has been operational since February 1990. Through DUAT, pilots are able to access weather and NOTAMs and also file their IFR and/or VFR flight plans from their home or office personal computer. This system will eventually be absorbed into OASIS.

Aviation Weather Communications

It should be noted that FAA communications systems are multipurpose. Weather data, products, and information constitute a large percentage of the traffic, as do NOTAMS, flight plans and other aeronautical data.

The National Airspace Data Interchange Network (NADIN II) packet-switched network was implemented to serve as the primary interfacility data communications resource for a large community of NAS computer subsystems. The network design incorporates state-of-the-art packet-switching technology into a highly connected backbone network, which provides extremely high data flow capacity and efficiency to the network users. NADIN II consists of operational switching nodes at each Area Control Facility and two network control centers (and nodes) at the National Aviation Weather Processing Facilities at Salt Lake City, Utah, and Atlanta, Georgia. It will interface directly to WMSCR, WARP, MWP, ADLP, ADAS, TMS, ACCC, and the Consolidated NOTAM System. NADIN II also may be used as the intra-facility communications system between these (collocated) users during transition to end state.

The Weather Message Switching Center Replacement (WMSCR) replaces the weather message switching center (WMSC) located at FAA's National Communications Center (NATCOM), Kansas City, Missouri, with state-of-the-art technology. It will perform all current alphanumeric weather data handling functions of the WMSC and the storage and distribution of NOTAMs. WMSCR will rely on NADIN for a majority of its communications support. The system will accommodate graphic data and function as the primary FAA gateway to the NWS' National Centers for Environmental Prediction (NCEP)--the principal source of NWS products for the NAS.

To provide for geographic redundancy, the system will have nodes in the NADIN buildings in Atlanta, Georgia, and Salt Lake City, Utah. Each node will support approximately one-half of the United States and will continuously exchange information with the other to ensure that both nodes have identical national databases. In the event of a nodal failure, the surviving one will assume responsibility for dissemination to the entire network.

The Aeronautical Data Link Program (ADLP) will implement the Data Link Processor (DLP) to support weather services for aircraft utilizing the discreetly addressed data link capability of the FAA's Mode Surveillance (MODE S) system. It will receive downlink requests for weather products from aircraft, formulate replies, and return them to the pilot via the data link. This will improve air-ground communication services by expanding the pilot's ability to access desired weather information while operating on the airport surface or in flight. It will also reduce the workload of flight service specialists and air traffic controllers who currently provide the only means of access to these data.

Initially, the data-link services to be implemented will be for automated databases which currently exist or are planned to be operational in the near term. These include alphanumeric products, such as SIGMETs, AIRMETs, surface observations, terminal forecasts, winds aloft, pilot reports, and alphanumeric radar summary information. Installation of this system began in 1991 and is continuing as programmed. The ADLP will be enhanced to support additional weather information (including windshear advisories) and ATC tower applications (including digital ATIS) and to provide expanded data-link communications functions in support of ATC data-link services.

The Worldwide Aeronautical Forecast System (WAFS) is a three geosynchronous satellite-based system for collecting and disseminating aviation weather information and products to/from domestic or international aviation offices as well as in-flight aircraft. The information and products are prepared at designated offices in Washington, D.C., and Bracknell, United Kingdom. The U.S. part of WAFS is a joint project of the FAA and NWS to meet requirements of the member states of the International Civil Aviation Organization (ICAO). FAA funds the satellite communications link, and the NWS provides the information stream.

Two of the three satellites are funded by the United States. The first is located over the western Atlantic with a footprint covering western Africa and Europe, the Atlantic Ocean, South America, and North America (except for the West Coast and Alaska). The second U.S.-funded satellite is positioned over the Pacific and covers the U.S. West Coast and Alaska, the Pacific Ocean, and the Pacific rim of Asia. The third satellite is stationed over the western Indian Ocean and covers the remaining areas of Europe, Asia, and Africa.

The data available via WAFS include flight winds, observations, forecasts, SIGMETs, AIRMETs, and hazards to aviation including volcanic ash clouds.

Aviation Weather Research Program

Working closely with the Integrated Product Team for Surveillance and Weather, the Aviation Weather Division sponsors research on specific aviation weather concerns, such as in-flight icing. This research is performed through collaborative efforts with the National Science Foundation (NSF), the NWS, and the Massachusetts Institute of Technology's Lincoln Laboratory. A primary concern is the effective management of limited research, engineering, and development resources.

The Aviation Gridded Forecast System (AGFS) will capitalize on significant advances in atmospheric sciences and computer technology to develop a four-dimensional database of weather phenomena that is of major importance to aviation. Data inputs from ASOS, radar wind profilers, satellite sensors, ACARS, radiosondes, and ITWS will provide the most accurate current and forecast variables with high spatial and temporal resolution. High technology computers will allow the forecasts to be run more often in a rapid update cycle. AGFS is being designed to generate timely regional and national aviation weather products for immediate use by non-meteorological personnel, such as pilots, air traffic controllers, traffic management personnel, and flight service specialists. The products will be available on the aeronautical data link. AGFS implementation is expected in the late 1990's.

Improved Aircraft Icing Forecasts. The purpose of this initiative is to establish a comprehensive multiyear research and development effort to improve aircraft icing forecasts as recommended in the *National Plan to Improve Aircraft Icing Forecasts.* This plan was jointly developed under the aegis of OFCM by the DOC, DOD, DOT, NSF, and the National Aeronautics and Space Administration to provide the NWS with an improved aircraft icing forecast capability. The objectives of this plan are to develop (1) an icing severity index, (2) icing guidance models, and (3) a better comprehension of synoptic and mesoscale conditions leading to icing. The result of this effort will be an improved icing forecasting capability that provides pilots with more timely and accurate forecasts of actual and expected icing areas by location, altitude, duration, and potential severity.

Convective Weather Forecasting. The purpose of this research effort is to establish more comprehensive knowledge on the conditions that trigger convection and thunderstorms and, in general, the dynamics of a thunderstorm's life cycle. The program will lead to enhanced capability to predict growth, movement, and type of precipitation from thunderstorms. Gaining this forecast capability will allow better use of the airspace and help aircraft avoid areas with hazardous convective conditions.

Model Development and Enhancement. This research is aimed at developing or improving models to better characterize the in-flight environment and, thereby, deliver superior aviation weather products to end users.

Weather Support to Deicing Decision Making. There is a need to develop products that provide forecasts on the intensity of snow and freezing rain, and how or when these phenomena will change in the short term. This information is needed by airport management to determine when an aircraft will require deicing before take-off. The water content of snow is believed to be an important factor.

Other Aviation Weather Research. Other aviation weather research programs that are continuing, but at a lower level of funding, pertain to ceiling and visibility, turbulence detection, and convective weather detection.

## UNITED STATES COAST GUARD

Among the United States Coast Guard's (USCG) activities are: marine and coastal weather observations by ocean-going cutters and at shore stations; collection and transmission of marine weather observations received from ships at sea by Coast Guard communications stations; broadcast of NWS marine weather forecasts, weather warnings, and weather facsimile charts to marine users; monitoring the seasonal iceberg threat to the North Atlantic shipping lanes off the Grand Banks of Newfoundland and the transmission of warning messages defining the iceberg limits; providing facilities and ship support to maintain the National Data Buoy Center (NDBC) network of automated environmental monitoring platforms; and operation of long-range radionavigation systems (OMEGA and LORAN-C), which are used by the meteorological sounding instruments essential to observational networks.

USCG ocean-going cutters and coastal stations provide weather observations to the NWS. Coast Guard communications stations broadcast NWS marine forecasts, weather warnings, and weather facsimile charts and, also, collect weather observations from commercial shipping for the NWS. In addition, Coast Guard groups broadcast NWS marine forecasts and weather warnings to users.

USCG conducts the International Ice Patrol (IIP) which uses radar-equipped aircraft to patrol the area of the Grand Banks off of Newfoundland during the iceberg season. IIP determines the geographic limits of the iceberg hazard and, twice daily, broadcasts iceberg warning bulletins and daily ice facsimile charts which depict the limits of all known ice. These broadcasts are made to the marine community during the period of iceberg danger. IIP operates an Iceberg Drift and Deterioration Model to predict iceberg distribution between IIP reconnaissance flights. IIP annually archives iceberg data reflecting all targets (both known icebergs and unidentified radar targets). The data is forwarded to the National Snow and Ice Data Center. The listing contains iceberg sighting data along with the last model-predicted position.

Various USCG facilities support NOAA's National Data Buoy Center (NDBC). NDBC's automated network of environmental monitoring platforms in the deep ocean and coastal regions provide accurate and reliable data for NWS and other users. Fifteen Coast Guard personnel fill key technical and operating positions within NDBC; the senior Coast Guard officer assigned serves as the NDBC Deputy Director. Coast Guard cutters provide the deployment and retrieval of data buoys and service visits to both buoys and coastal stations, expending up to 280 cutter days annually. Coast Guard aircraft, boat, and shore facilities also provide NDBC support.

USCG operates navigation stations providing OMEGA and LORAN-C radionavigation signals for the aviation and navigation communities. These signals also support the operation of meteorological sounding instruments essential to observation networks. OMEGA will cease operations September 30, 1997.

Coast Guard Marine Science Technicians receive basic training in meteorology as a major part of the training for their specialty.

Meteorological activities are coordinated by the Ice Operations Division of the Office of Navigation Safety

and Waterways Services at Coast Guard Headquarters. The Coast Guard NDBC operation is managed at Coast Guard Headquarters by the Short Range Aids to Navigation Division of the Office of Navigation Safety and Waterways Services. Field management of the meteorological activities is a collateral function of the Coast Guard district and area staffs.

No Coast Guard unit is dedicated solely to meteorology; all facilities perform a variety of missions. No capital investments in meteorological facilities are planned or contemplated.

APPENDIX D

# WEATHER PROGRAMS OF OTHER AGENCIES

## DEPARTMENT OF AGRICULTURE

Weather is the most important factor influencing the Nation's variability in crop yields and related production. The Nation's food and fiber products are a critical resource impacting our domestic and international economic position and have taken on new dimensions in foreign affairs and national security. The recent expansion in export markets has reduced stocks and benefitted our farm sectors as global consumption of total grains has exceeded production in 3 of the last 4 years. The U.S. Department of Agriculture (USDA) conducts supporting research that focuses on understanding the interactions of weather and climate with plants, animals, forests, and forest ecological systems, and assists the Department of Commerce in determining farmers' needs for weather information and in disseminating that information to them.

The World Agricultural Outlook Board (WAOB), in cooperation with National Weather Service's (NWS) Climate Prediction Center, monitors the daily weather patterns around the world. WAOB agricultural meteorologists convert the weather data into information to assess crop development and yield potential of all major commodity crops for the major producing areas of the world. Special weekly briefings are provided to the Secretary of Agriculture and to the economic and commodity analysts of USDA. The Senate and House Agricultural Committees also request periodic briefings on crop-related drought effects as in 1988 and 1989.

Historically, the Forest Service (FS) has collected meteorological data to assist in the control of forest fires and in the management of smoke from prescribed burning. Other activities also need weather data to ensure sound management decisions. Therefore, a national weather program was established to coordinate all FS meteorological activities and to meet the increasing need for diverse weather information. The major objectives of the program are to: (1) improve quality control of weather data, (2) improve the design and operation of data collection from networks, (3) increase data recovery from the weather stations, and (4) upgrade station maintenance. Meteorological data collected from manual weather stations and Remote Automated Weather Stations (RAWS) support research of weather effects on forestry management, forest fires, smoke management, visibility protection in wilderness areas, and atmospheric deposition. A weather information management system and a library to archive all FS weather data are being developed in cooperation with regional climate centers. The FS monitoring network will provide essential data for use in Global Change Research Program (GCRP) work.

The FS currently operates more than 900 RAWS and manual stations, many in the western United States. Air temperature, relative humidity, soil moisture, wind direction and speed, and precipitation are transmitted via NOAA's Geostationary Operational Environmental Satellite (GOES) telemetry. These data are received via a direct-readout ground site in Boise, Idaho, in cooperation with the Bureau of Land Management. The main use of the data is in the calculation of the fire danger rating for the FS and cooperating agencies. These data are also used by other resource managers; such as, road engineers, wildlife biologists, and hydrologists who monitor precipitation; silviculturalists (who are attempting to maximize tree-planting opportunities); and ecologists, soil specialists, and fisheries biologists (who monitor the effects of runoff). The main secondary user of RAWS data is the NWS for fire weather forecasting and flood warnings.

The Natural Resources Conservation Service (NRCS) operates a network of 1,400 manual snow courses and over 550 automated data collection sites in conjunction with the project (SNOTEL) for the western United States and Alaska. The primary objective of the project is to forecast water supplies and streamflow for the coming spring run-off season. These measurements are made in cooperation with other federal, state, and local agencies, power companies, irrigation companies, and the provincial government of British Columbia.

Water-supply forecasts help irrigators make the most effective use of available streamflow for achieving their agricultural production goals. Farmers who collectively irrigate more than 10 million acres of land in the western U.S. benefit from water supply forecasts. Other federal agencies and private organizations also use water supply forecast information to help them carry out their missions. These forecasts also help the federal government in administering international water treaties.

Beginning in FY 1987, NRCS initiated an upgrade to the SNOTEL data collection system at a total cost of $5 million. This effort continues and includes upgrading 510 data collection sites in the existing SNOTEL system with new state-of-the-art equipment and adding about 40 additional sites. The data-collection site upgrade will include replacement of snow pillows, transducers, damaged precipitation gauges, antennas, towers, solar panels, battery temperature sensors, and deteriorated shelter houses.

Supporting Research

The mission of the USDA supporting research program is to develop and disseminate information and techniques to ensure high quality commodities and products while minimizing any adverse effects of agriculture on the environment. As part of the USDA reorganization, the new Undersecretary for Research, Education, and Economics was created. This includes the merger of the Cooperative State Research Service and the Extension Service, and the transfer of the Economic Research Service and the National Agricultural Statistics Service (NASS).

The research efforts of the Agricultural Research Service (ARS) relate directly to the effects of climate on agricultural production and the natural resource base. They are directed toward developing technologies and systems for (1) managing precipitation and solar energy for optimum crop production, (2) improving our understanding of water-plant-atmosphere interactions, (3) optimizing the use of energy, water, and agricultural chemicals, (4) reducing plant and livestock losses from pests and environmental stress, (5) developing improved techniques for irrigation and drainage, and (6) minimizing the adverse effects of climate and weather, including atmospheric contaminants, on the environment.

The Cooperative State Research, Education, and Extensive Service (CSREES) coordinates research programs in the state agricultural experiment stations, the 1890 Land Grant Distributions, and cooperating forestry schools. These institutions conduct a wide variety of research applicable to agriculture and forestry. Meteorological research in these institutions is practically all climatological. A proportion of each state's program is consolidated into broad regional research projects. Animals and plants are subjected to many climatic stresses and, therefore, are the focus of this research. Research on the changes in levels of ultraviolet (UV) radiation as part of the GCRP was significantly expanded through the CSREES competitive grants program in FY 1994. The work is coordinated with EPA's UV radiation program and will support assessment efforts to develop related national policy on the environment.

Investigations by NASS support domestic crop estimating programs for all major commodities. Promising studies are underway to develop models relating weather parameters and associated variables to corn ear weight and wheat head weight. Previous efforts to develop models for short-term forecasting have had only limited success. Research will continue in this area with the expectation that the relationships between weather variables and crop yield will improve as better plant process models become available.

A NASS program explores the use of satellite and weather data for assessing crop conditions is continuing. A preliminary investigation using polar-orbiting meteorological satellite data showed a good relationship between crop conditions and reflectance data as determined by the agreement between measured and forecast final corn and soybean yields. The crop conditions assessment procedures, based on meteorological satellite data, are being automated and near real-time applications are being explored.

FS research includes efforts to: (1) understand and control forest fire initiation by lightning, (2) improve the translation of mid-range forecast elements to describe forestry conditions, (3) incorporate drought information into management decision-making, and (4) better describe how regional climatic variability affects the use of daily weather information by foresters. The FS long-term monitoring network will provide critical data for use in the GCRP work.

## DEPARTMENT OF THE INTERIOR

The Department of the Interior's (DOI) atmospheric science activities are primarily research and historically had been reported through the National Science Foundation-sponsored Subcommittee for Atmospheric Research; however, budgetary information for the Bureau of Land Management's operational wildfire data collection system is reported in this Federal Plan. The narrative below describes the full range of DOI's meteorological activities.

Bureau of Land Management (BLM)

BLM is one of five Federal Land Management agencies which have centralized wildfire weather operations in the National Interagency Fire Center (NIFC) at Boise, Idaho. BLM's Initial Attack Management System (IAMS) was designed to provide real time data access and modeling for the fire management organization. The IAMS required a considerable dedicated telecommunications network for data distribution. In an effort to reduce these inherent telecommunications costs, the BLM is moving toward a "file server" environment for the IAMS capabilities. Many of the capabilities that were centrally located in the IAMS have been moved to more remote sites. The system will still provide rapid evaluation, assessment, and decision making assistance for the BLM's wildfire responsibilities.

The principal IAMS inputs remain the same with Remote Automatic Weather Station (RAWS) and Automatic Lightning Detection System (ALDS) information being the primary real time data sets. Additional information on vegetation, slope, elevation, aspect, and terrain data are also used. These are coupled with advanced fire modeling capabilities to facilitate the BLM's fire and resource management objectives.

The BLM's RAWS Program primarily collects meteorological data for fire weather forecasting. In past years, the network also provided considerable support to non-fire entities and was operated year around. However, with increased pressure on operational dollars, the BLM Office of Fire and Aviation Management has decided to "downsize" the network. Current plans are to reduce the fire network by about one fourth in the western states. With continued funding pressures, the requirement to replace aging equipment, and the considerable costs associated with maintaining such a large network, BLM's strategy is to reduce the total number of RAWS, move to a single station classification (all stations configured the same), operate only during the traditional western fire season (RAWS no longer maintained in winter months), and to use any savings in operating funds to replace aging equipment and upgrade the remaining network. The BLM's Resource Management and Oregon O&C (West-Side) RAWS networks will continue to operate and to be supported as in the past. These networks are much smaller and have specific program requirements that differ from fire management.

The BLM began contracting with a private vendor via the National Weather Service for ALDS data effective April 1, 1997. Data is received at the NIFC in Boise, Idaho, and retransmitted via the existing ALDS/IAMS telecommunications network. The BLM is looking at moving into a file server arrangement in 1998 to further reduce recurring costs associated with telecommunications. Current plans are to continue the operation of the Alaska ALDS as an independent government-owned and operated system.

The BLM's Remote Sensing Support Group at NIFC provides a full range of specialized management, maintenance, data, and support services for the BLM and numerous other Government agencies. This interagency staffed and funded facility performs work under long-term interagency agreements with those agencies within the government having similar equipment and requirements. Staffing levels within this Group are being adjusted to meet the overall interagency requirements.

In addition to the meteorological monitoring BLM conducts primarily to support fire management activities, the BLM also conducts site-specific climate monitoring at over 200 locations on the Public Lands in the eleven western states and Alaska. The operation of these sites ranges from seasonal to annual measurements of precipitation. temperature, soil

moisture and other meteorological parameters necessary to assess local climatic influences. These data are primarily used for natural resources management and planning at the local level.

In 1991, the BLM Global Change Research Program established five monitoring sites in BLM wilderness and wilderness study areas to establish baseline conditions for assessment of long term ecosystem trends. A total of 20 sites are planned to be established over the initial 5-year period. A standardized monitoring platform will be operated at these sites to include measurements of climate and atmospheric chemistry.

National Park Service (NPS)

The Park Service monitors air quality and visibility in several national parks and monuments. Gaseous pollutants data are collected on continuous and integrated (24-hour) bases. Surface meteorological data are collected and analyzed for hourly averages. Precipitation chemistry is determined on week-long integrated rainfall samples. Twenty-four average particle concentrations (mass, elemental analyses, some chemical constituent analyses) are measured twice weekly. Atmospheric light extinction is measured continuously and satellite-telemetered to a central location for analyses.

The NPS also conducts and contracts research to develop and test air quality models to assess long-range transport, chemical transformation, and deposition of air pollutants. These models are used to estimate source contributions to, and to identify source regions responsible for, observed pollutant loadings.

U.S. Geological Survey (USGS or Survey)

The Survey's Water Resources Division (WRD) collects streamflow, precipitation, and other climatological data for a number of projects concerning rainfall/runoff, water quality and hydrologic processes. Currently, the Geological Survey collects hydrometeorological data from approximately 4500 remote Data Collection Platforms. The data are transmitted to Wallops, Virginia, via GOES and rebroadcast to a domestic communication satellite (DOMSAT). Data are received from the DOMSAT by local readout ground stations (LRGS) procured by the Geological Survey under a 1992 contract. The Survey currently operates 12 LRGS' which provide near-real-time data to the Survey's computerized National Water Information System.

USGS/WRD is also helping the National Weather Service calibrate the NEXRAD weather radar for precipitation analysis. WRD is operating 36 rainfall collection sites data in the Susquehanna River Basin which provide hourly updates of precipitation. This pilot program will continue through the end of calendar year 1997 with the objective of identifying procedures for data collection and exchange, and developing a model local agreement that can be used by other NWS/USGS Offices in an operational program.

The Survey's Geologic Division, through the National Geomagnetic Information Center (NGIC) in Golden, Colorado, collects data on temporal variations of the Earth's magnetic field from a global network of over 70 geomagnetic observatories. These observatories (which include 13 operated directly by USGS/NGIC) all belong to the INTERMAGNET program. Under INTERMAGNET, data from a global network of geomagnetic observatories are transmitted in near-real-time via satellites and computer links (E-mail) to collection and dissemination points called Geomagnetic Information Nodes (GIN's). Five GIN's are now located in Europe, North America, and Asia.

Magnetic field data are key inputs to the National Space Environment Forecast and Warning Program, which is coordinated by the OFCM, and to the new inter-agency National Space Weather Program. These data are used for nowcasting, forecasting, and modeling of "space weather" -- particularly the effects of geomagnetic disturbances. These effects range from: satellite computer upsets and early re-entry, to disruption of radio communications, to degradation of navigation systems (such as GPS), and to outages of power distribution grids. The roles and responsibilities of agencies participating in the National Space Environment and Warning Program are detailed in the "National Plan for Space Environment Services and Supporting Research, 1993-1997" (FCM P10-1993) which was prepared by the OFCM Committee for Space Environment Forecasting.

The Survey is continuing a joint research program with NASA and USDA to map snowpack

water equivalent using satellite passive microwave techniques. The satellite observations are being compared to snowpack water equivalent data from a variety of sources: the Department of Agriculture's Natural Resources Conservation Service automatic Snow Telemetry (SNOTEL) sites; grain size and water equivalent data collected by Survey field teams; and measurements and model estimates by the NOAA National Operational Hydrological Remote Sensing Center (NOHRSC). The object of the program is to develop algorithms for making near real-time assessments of snowpack water equivalent and extent from space to be used operationally by water resource management agencies in the western United States.

As part of its glaciology program, the Survey maintains a benchmark program on three benchmark glaciers representative of different climatic zones of the western United States, one in Washington, one on the south coast of Alaska and one in the interior of Alaska. At each glacier the program measures the winter snow accumulation, summer snow and ice ablation, air temperature, and runoff in the glacier basin. Analysis of this 36 year long record is providing a greater understanding of the climate variability and its effects on water resources of the western United States.

The Survey participates in the Committee on Volcanic Ash of the OFCM. This committee is preparing the OFCM National Plan for Volcanic Ash. This committee is preparing the National Plan for Volcanic Ash and Aviation Safety. Through its Volcanic Hazards Program, the Survey is responsible for monitoring volcanoes in the United States. Of the approximately 56 historically active volcanoes in the United States, 44 are in Alaska. Until the past decade the Alaskan volcanoes have been largely unstudied. Despite the low population density of much of the State, Alaska's volcanoes underlie the heavily traveled air routes of the North Pacific region.

The OFCM Committee on Volcanic Ash has supported expansion of Survey monitoring activities in the remote Aleutian chain of explosive volcanoes. During FY 1996, Survey and the Alaskan Volcano Observatory (AVO) expanded its network of real-time seismic monitoring stations to 4 additional volcanoes in the Eastern Aleutian Islands and the Western Alaskan Peninsula regions of Alaska. This brings to 10 the number of volcanoes under continuous, real-time surveillance by the AVO. Data and information from the AVO monitoring activities are integrated directly into the regional operational activities of the FAA, DOD, and NWS to provide warnings for pilots and aircraft operators in the Alaskan region.

The Survey also carries out research in past climate change, regional hydrology, the carbon cycle, coastal erosion, volcanic activity, and glaciology. As part of its glaciology program, the Survey continues to measure the winter snow accumulation, summer ice ablation, and net balance on three glaciers representative of different climatic zones of the western United States, one in Washington, and two in Alaska. The analysis of this 35 year long record is providing a greater understanding of the climate variability in the western United States. The Survey collects precipitation samples in a number of studies for the determination of atmospheric contribution to the chemical constituent loads to runoff, and for defining the effect of atmospheric deposition on water quality and the aquatic environment.

Bureau of Reclamation

Reclamation activities requiring the collection and use of meteorological data include water scheduling, flood hydrology, irrigation project management, and reservoir operations, as well as projects related to hydroelectric energy resources. One example of this is the Agricultural Water Resources Decision Support (AWARDS) system which integrates high-resolution NEXRAD radar rainfall estimates, surface environmental data, crop models, and quantitative precipitation forecasts, with watershed reservoir-canal systems and irrigation district water distribution systems. AWARDS provides operational support for: (1) early warnings to reduce hydrologic risk for loss of property and lives, (2) improved efficiency in canal and reservoir operations, and (3) improved efficiency in irrigation scheduling for water conservation and water quality.

Reclamation is developing a Snow Accumulation Algorithm (SAA) for the national NEXRAD WSR-88D radar network. This development is a cooperative effort with primary support from the WSR-88D Operational Support Facility in Norman, Oklahoma. The prototype SAA was successfully field tested in real-time during the 1996-97 winter at Cleveland and Minneapolis National Weather Service Forecast Offices. The SAA is being improved with

data sets from all climatic regions in the Nation which have frequent snowfall. Reclamation's NEXRAD research team, in partnership with National Weather Service's River Forecast Centers (NWSRFC), is also developing calibrated NEXRAD precipitation analyses and runoff models for watersheds above facilities, such as Olympic Dam, where early warning systems are needed.

Multi-agency work on projecting potential effects of climate change and climate variability on western water resources and Bureau operations is continuing under collaborative work with the Global Water and Energy Cycles Experiment (GEWEX) Continental-scale International Project (GCIP) with NOAA's Office of Global Programs, and the National Centers for Environmental Prediction (NCEP). The NWSRFCs provide detailed streamflow forecasts for Reclamation's operations. Of note is technology transfer effort in the Central Valley Operations Office in Sacramento, where a direct workstation link to the NWS River Forecast System and other hydrometeorological forecast products will provide Reclamation's water managers access to detailed products of immediate value to water management operations.

A Technology Advancement study in collaboration with NCEP and the National Center for Atmospheric Research (NCAR) are examining the utility of mesoscale models for simulation and prediction of extreme precipitation events. These modeling efforts are taking current technologies and applying them to very heavy precipitation events to determine maximum precipitation and better understand limits of extreme precipitation in watersheds above Reclamation facilities for safety of dams studies and early warning applications.

Currently, Reclamation's HYDROMET system collects data from approximately 400 hydrometeorological data collection platforms (DCPs) which transmit data in the "real-time" through the GOES to the Bureau's DRGS in Boise, Idaho. AGRIMET is another network of 60 DCPs dedicated to analysis of crop water use and water conservation in the Pacific Northwest. Data collected and products created in Boise are electronically transferred to other Bureau, Federal and state offices. Funding for Reclamation's Global Change Response Program ended in the mid-1990s. Reclamation's weather modification research program has not been funded since 1989 except for reimbursable work.

Minerals Management Service

The Minerals Management Service's Environmental Studies Program gathers offshore environmental data in support of mineral leasing responsibilities. Currently, the Service supports five data buoys which transmit via NOAA satellites from offshore. Wind data are used in the Service's Oil Spill Risk Analysis Model to predict effects of potential spills.

MMS also is collecting meteorological and air quality data within the Breton National Wildlife Refuge, off Louisiana. The data are collected for the purpose of assessing air quality impacts from pollutant sources on the OCS. In FY 1998 MMS will start collecting data to study the atmospheric boundary layer over the Gulf of Mexico using two radar profilers placed on offshore platforms. One will be located near shore near the Louisiana/Texas border; the other in deeper waters about 100-150 km offshore. Also, hourly observations will be transmitted to the National Weather Service on a real-time basis to enhance their forecasting capabilities. MMS plans to collect three years of data.

Bureau of Indian Affairs

The Bureau of Indian Affairs collects atmospheric data to evaluate potentially irrigable Indian Trust lands in the Southwest. The Bureau also shares fire weather data with other Federal agencies while participating in fire weather forecasting at the National Interagency Fire Center.

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The National Aeronautics and Space Administration (NASA) Headquarters Weather Support Office has continued to improve NASA's weather support capabilities for both manned and unmanned space launch vehicles. It is expected that these improvements will strengthen and enhance the information provided to the ground-based decision-makers and astronaut observers to insure that NASA achieves the best operational posture for Space Shuttle launches and landings. The goal of the operations program is to provide the specialized meteorological data needed by operational forecasters at Cape Canaveral Air Station of Kennedy Space Center (KSC) and Johnson Space Center to support the Space Shuttle program. The focus is on detecting and forecasting the mesoscale weather events which strongly impact Shuttle ground processing, launches, and landing operations.

### Operations

The goal of the operations program is to provide the specialized meteorological data needed by operational forecasters at Cape Canaveral Air Station and Johnson Space Center to support the Space Shuttle program. The focus is on detecting and forecasting the mesoscale weather events which strongly impact Shuttle ground processing, launch, and landing operations. Forecasts and observations for NASA/Kennedy Space Center (KSC) are provided by Air Force meteorologists and contractors. KSC cost shares with the Air Force the expense of operating and maintaining (O&M) the Eastern Range's extensive meteorological network--KSC contributes 40 percent. KSC funds O&M of the Doppler Radar Wind Profiler (DRWP) and the Lightning Detection and Ranging (LDAR) systems.

This operations program requires exploitation of the latest technology. The Applied Meteorology Unit (AMU), collocated with the Air Force's Range Weather Operations, provides a facility to evaluate and, if warranted, transition new meteorological technology into operations. For instance, the AMU strives to develop techniques and systems to help predict and avoid the impacts of KSC's frequent mesoscale summer thunderstorms which endanger the ground processing, launch, and landing operations of the American Space Program--Space Shuttle, DOD, and commercial. Special attention has been given to evaluating mesoscale numerical models. The AMU functions under a joint NASA, Air Force, and national Weather Service Memorandum of Agreement. A major FY 1996-1997 initiative under contract is to replace the meteorological data display/analysis/distribution system, which is obsolete. The Air Force plans to pay most of the costs.

### Supporting Research

The supporting research activities are sponsored by the NASA's Office of Mission to Planet Earth (MTPE). The mission objective of the MTPE Enterprise is to understand the total Earth system and the effects of natural and human-induced changes on the global environment. MTPE is playing a crucial role in the new interdisciplinary field of research called Earth system science. This new field was born as a consequence of the recognition that the Earth's land surface, oceans, atmosphere, ice sheets and biota are both dynamic and highly interactive. It is an area of research with immense benefits to the nation, yielding new knowledge and tools for weather forecasting, agriculture, urban and land use planning, and other areas of economic and environmental importance. In concert with other agencies and global research community, MTPE is providing the scientific foundation needed for the complex policy choices that lie ahead on the road to sustainable development. MTPE has established three broad goals: (1) expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft and in situ platforms; (2) disseminate information about the Earth system; and (3) enable productive use of MTPE science and technology in the public and private sectors.

The pursuit of Earth system science would be impractical without the continuous, global observations provided by satellite-borne instruments. MTPE comprises an integrated slate of spacecraft and in situ measurement capabilities; data and information

management systems to acquire, process, archive and distribute global data sets; and research and analysis programs to convert data into new knowledge of the Earth system. Numerous users in academia, industry, federal, state and local government tap this knowledge to produce products and services essential to achieving sustainable development. MTPE is NASA's contribution to the U.S. Global Change Research Program (USGCRP), an interagency effort to understand the processes and patterns of global change.

The Earth Observing System (EOS), the centerpiece of MTPE, is a program of multiple spacecraft (the AM, PM, Chemistry series, Landsat-7, and others) and interdisciplinary science investigations to provide a 15 year data set of key parameters needed to understand global climate change. The first EOS satellite launches begin in 1998. Preceding EOS are a number of individual satellite and Shuttle-based missions which are helping to reveal basic processes. The Upper Atmosphere Research Satellite (UARS), launched in 1991, collects data on atmospheric chemistry. The Total Ozone Mapping Spectrometer (TOMS) instrument, launched in 1978 and 1991, measures ozone distribution and depletion. Two additional TOMS instruments were launched in 1996, one on the Japanese Advanced Earth Observing System (ADEOS) mission and the other on a dedicated U.S. Earth probe. The French and U.S. collaborated on the Ocean Topography Experiment (TOPEX/Poseidon), launched in 1992, to study ocean topography and circulation. The NASA Scatterometer (NSCAT), also launched on the Japanese ADEOS in 1996, maps ocean winds. In 1997, the Tropical Rainfall Measuring Mission (TRMM) will measure tropical precipitation. Complementing EOS will be a series of small, rapid development Earth System Science Pathfinder (ESSP) missions to study emerging science questions and make innovative measurements in parallel with the 15 year mission of EOS. The first ESSP mission should be ready for launch in 2000.

Data from MTPE missions, both current and future, are captured, processed into useful data products, and broadly distributed by the EOS Data and Information System (EOSDIS). EOSDIS will ensure that data from these diverse missions will remain available in active archives for use by current and future scientists. Since these data are useful beyond the Earth system science research community, EOSDIS will be accessible by environmental decision-makers, resource managers, commercial firms, social scientists and the general academic community, educators, state and local government--anyone who wants the information. Following the recommendation of the National Research Council, MTPE is exploring the creation of a federation of Earth science information partners in academia, industry and government to broaden the participation in the creation and distribution of EOSDIS information products.

The intellectual capital for these missions, and the key to generating new knowledge from them, is vested in an active program of research and analysis. MTPE's research and analysis program funds over 1,700 researchers from nearly every U.S. state. There are also scientists from seventeen other nations, funded by their own countries but, collaborating with U.S. researchers. These researchers develop Earth system models from MTPE data, conduct laboratory experiments, run aircraft campaigns, develop new instruments, and thus expand the frontier of our understanding of our home planet. MTPE-funded scientists are recognized as world leaders in their fields, as exemplified by the awarding of the 1995 Nobel Prize in chemistry to two who identified the threat of cholorflorocarbons to upper atmospheric ozone. The research and analysis program is also the basis for generation of application pilot programs which enable universities, commercial firms, and state and local governments to turn scientific understanding into economically valuable products and services.

In 1996, the first MTPE Science Research Plan was published. The plan lays out a strategy for study in five Earth system science areas of maturing scientific understanding and significant societal importance: land-cover and land use change; seasonal-to-interannual climate variability and prediction; natural hazards research and applications; long-term climate natural variability and change research; and atmospheric ozone research. The plan also outlines some twenty related areas of research which round out the MTPE contribution to Earth system science.

The challenges of Earth system science, sustainable development, and protection of people, property and the environment from natural disasters, require collaborative efforts among a broad range of

national and international players. As mentioned above, the USGCRP coordinates research among thirteen U.S. government agencies. MTPE has extensive collaborations with the National Oceanic and Atmospheric Administration (NOAA) on seasonal-to-interannual climate prediction. MTPE is the responsible agent in NASA for managing the development of NOAA's operational environmental satellites. NOAA, NASA, and the Department of Defense (DOD) are collaborating on a convergence of the civilian and military weather systems. MTPE collaborates with the U.S. Geological Survey (USGS) on a range of land surface, solid Earth and hydrology research. NASA, NOAA and USGS collaborate in the Landsat-7 program, and NASA, DOD and USGS are working together on a third flight of the shuttle radar laboratory modified to yield digital terrain data on most of the Earth's surface. MTPE participates in the World Climate Research Program, the International Geosphere/Biosphere Program, and the ozone assessments of the World Meteorological Organization. Most of MTPE's satellite missions have international participation, ranging from simple data sharing agreements to joint missions involving provision of instruments, spacecraft, and launch vehicles.

Upcoming activities over the next two years in the MTPE program include, in the Earth probes program, launch of the Tropical Rainfall Measuring Mission (TRMM) in late 1997. The Lewis and Clark land imaging spacecraft, developed in partnership with commercial firms, will be launched in 1997. The MTPE mission operations program will begin operations and data processing of the TRMM as well as activities for currently orbiting satellites, including TOPEX/Poseidon, UARS, NSCAT and TOMS. The experiments of opportunity program will be focused on Shuttle Imaging Radar-C (SIR-C) and launch the Measurement of Air Pollution from Satellites (Maps) on MIR, a cooperative commercial venture. Within the EOS, a preliminary design review will be held for PM-1 in 1997. Instruments for AM-1 and Landsat-7 will be delivered in 1997. The EOSDIS will release Version 1 in 1997 and prepare for the release of Version 2.

The EOSAM-1 will be launched in June 1998. This mission will provide key measurements that will significantly contribute to our understanding of the total Earth system. The AM-1 instrument complement will obtain information about the physical and radiative properties of clouds, air-land and air-sea exchanges of energy, carbon, and water, measurements of trace gases, and volcanology.

Landsat-7 will be launched no later than December 1998. Landsat-7 will carry a single instrument, the enhanced thematic mapper plus, which will make high spatial resolution measurements of land surface and surrounding coastal regions. This mission will provide data continuity with previous Landsat measurements. Landsat data is used for global change research, regional environmental change studies, national security and other civil and commercial purposes.

The Earth probes program is the component of MTPE that addresses unique, specific, highly-focused mission requirements in Earth science research. The program was designed to have the flexibility to take advantage of unique opportunities presented by international cooperative efforts or technical innovation, and to complement the Earth Observing System by providing the ability to investigate processes that require special orbits or have unique requirements. The currently approved Earth probes are the Total Ozone Mapping Spectrometer (TOMS), NASA Scatterometer (NSCAT), Tropical Rainfall Measuring Mission (TRMM), Lewis & Clark, and Earth System Science Pathfinders (ESSP).

Because winds are a critical factor in determining regional weather patterns and global climate, NSCAT has been developed to measure near-surface wind speeds and directions over the global oceans every two days, under all weather and cloud conditions. The NSCAT data will be useful for both oceanography and meteorology, and will permit the first global study of the influence of winds on ocean circulation, providing data on the effects of the oceans on the atmosphere and improved marine forecasting on winds and waves. The lead center for this program is JPL, and the main contractor for the instrument development is the Harris Corporation.

The NSCAT was launched in August 1996. When NSCAT was first initiated in October 1984, it was planned for launch aboard the Navy Remote Sensing Satellite (N-ROSS). After final cancellation of N-ROSS in March 1988, NSCAT was selected in August 1989, for flight on the Japanese Advanced Earth Observing System (ADEOS). Since a majority of the instrument design had been completed during the period that NSCAT was to fly on N-ROSS, the

last few years of the program centered on making design changes to the instrument so that it could be accommodated on the ADEOS spacecraft and completing the instrument. The launch of the Japanese ADEOS spacecraft was slipped from February 1996 when the Japanese experienced anomalies with the spacecraft during integration and test. The ADEOS spacecraft was launched on a NASDA H-II rocket from Tanegashima, Japan on August 17, 1996.

The scientific objectives of the TOMS program are to measure the long-term changes in total ozone and to verify the chemical models of the stratosphere used to predict future trends. The TOMS flights build on the experience that began in 1978 with the launch of a TOMS instrument (flight model 1) on Nimbus-7 and continued with the TOMS instrument (flight model 2) on the Russian Meteor-3, launched in 1991. As with the earlier developments, GSFC has the responsibility for flight project development, and post-launch mission operations and data analysis. Prime contractors are Orbital Sciences Corporation (OSC) for the TOMS instruments and Pegasus launch services, and TRW for the TOMS-EP spacecraft. The TOMS program consists of a set of instruments (flight models 3, 4, and 5, designated FM-3, FM-4, and FM-5) and one spacecraft. Launch of the EP spacecraft by a Pegasus XL launch vehicle occurred on July 2, 1996. The FM-4 launched on the Japanese ADEOS satellite on August 17, 1996. The FM-5 was completed in 1995 and is planned for a cooperative mission with Russia in 2000.

The latent heat released during precipitation is a significant factor in the large-scale computer models used to predict weather and climate change, yet two-thirds of the global rainfall occurs over the tropics where rain measurements are scarce. The TRMM objective is to obtain a minimum of three years of climatologically significant observations of tropical rainfall. In addition, TRMM will provide precise estimates of the vertical distribution of latent heat in the atmosphere. The TRMM data will be used to understand the ocean-atmosphere coupling, especially in the development of El Niño events, which form in the tropics but effects of which are felt globally, causing floods in some areas, yet droughts in others. GSFC has the responsibility for flight project development, and post-launch mission operations and data analysis. The contractors for the instruments are Hughes Santa Barbara Research Center for the Visible and Infrared Scanner (VIRS), and Hughes Space and Communications for the TRMM Microwave Imager (TMI). The TRMM Phase A study was completed in July 1988, and Phase B completed in February 1991. Award of major contracts began in May 1992. The TRMM launch is planned for November 1997.

The Japanese space agency (NASDA) is an active partner with three Earth probes, providing the ADEOS spacecraft and H-II launch vehicle for the TOMS (FM-4) and NSCAT, and the Precipitation Radar instrument and H-II launch vehicle for TRMM.

The Earth System Science Pathfinder (ESSP) is a science-driven program intended to identify and develop short development time, small satellite missions to accomplish scientific objectives in response to national and international research priorities not addressed by current programs. ESSP will provide periodic "windows of opportunity" to accommodate new scientific priorities and infuse new scientific participation into the MTPE program. By launching ESSP missions on a regular basis, NASA will provide a mechanism by which pressing questions in Earth system science may be addressed in a timely fashion, permitting a continual improvement in our understanding of the Earth system and the processes that affect it.

The programmatic guidelines for the first ESSP AO were specific. The first two ESSP missions will be focused on high-priority Earth system science research, limited to a total mission life cycle cost from NASA of $60 million and $90 million respectively. They will be managed by the principal investigator as a single point of contact accountable for total mission implementation and success, developed in less than 36 months from development authority to proceed, and compatible with EOSDIS standards, including the immediate release of mission data to the scientific community.

The Lewis and Clark missions will demonstrate different land imaging capabilities and other measurements of scientific interest to MTPE. The Lewis mission is a medium resolution Hyperspectral instrument. The Clark mission is a high resolution multi-spectral imager. Both spacecraft will be launched in FY 1997. The "Clark" spacecraft is being built by CTA Incorporated of Rockville, Maryland. The "Lewis" spacecraft is being built by TRW and managed out of their Rodentia Beach, California, office. NASA is managing both projects from NASA Headquarters. Lewis will carry 25 new

technologies and Clark will carry 36, including composite structures, advanced avionics and high-efficiency power systems. Lewis will also have three advanced sensors to meet the needs of the commercial remote sensing and Earth science communities: a 384-band Hyperspectral imager; a Linear Etalon Array to scan the Earth and its horizons; and an instrument to measure the Ultra-Violet UV cosmic background. Clark will have a high-resolution imager capable of 15-meter multi-spectral and 3-meter panchromatic measurements; an instrument to measure pollution in the troposphere; and an x-ray spectrometer to capture bursts from solar flares.

The "LightSAR" program is consistent with direction included in House Report 104-812 which stipulates that NASA's FY 1998 budget request should include additional funding to accomplish this program. The "LightSAR" program is currently one of the missions competing for possible funding under NASA's Earth Systems Science Pathfinder (ESSP) program and may also compete in the upcoming MTPE Data Purchase solicitation.

This program offers a unique capability to undertake short duration flights of instruments on the Space Shuttle and other platforms. The MTPE program has used the capability of Shuttle/Spacelab development in the important areas of design, early test and checkout of remote sensing instruments for free flying missions, and short term atmospheric and environmental data gathering for scientific analysis. Instrument development activities have supported a wide range of instrumentation, tailored for Space Shuttle and airborne missions.

The goal of applied research and data analysis is to advance our understanding of the global climate environment, the vulnerability of the environment to human and natural forces of change, and the provision of numerical models and other tools necessary for understanding global climate change.

The applied research and data analysis program is divided into two major components: MTPE science and MTPE operations, data retrieval, and storage. The activities that report MTPE science include research and analysis, EOS science, airborne science and applications, commercial remote sensing and Uncrewed Aerial Vehicle (UAV) science program. Operations, data retrieval and storage consists of several independent activities responsible for the operation of currently functioning spacecraft and flight instruments, the purchase and management of scientific data, high performance computing and communications, and the provision of computing infrastructure. Each of the major components of applied research and data analysis has its own set of goals, strategies for achieving goals, performance measures, and accomplishments and plans.

The goal for the MTPE science program is to contribute to the integration of the Earth and environmental sciences into an interdisciplinary scientific understanding of the Earth system and the effects of human-kind on the global environment. Major emphasis is placed on providing early warning and fast response to global environmental changes which pose risks to society. The science program also provides the analysis and integration of critical data and models needed for national and international assessments. An objective of current planning is to achieve the most essential long-term objectives of EOS, and to increase effort on science with near-term payoff, within a sustainable level of funding. The observational program will become resilient, better, and cheaper in the future by (1) taking advantage of the experience being gained in preparation of the first round of EOS flight missions to reduce observing requirements in the future and to simplify the design of instruments for more cost-effective continued operation, (2) finding alternative means to carry out some of the essential measurements at the same level of quality through cooperation with other agencies and nations, and (3) infusing new ideas and technologies into the EOS program through small satellite missions which have lower infrastructure and flight costs.

The Research and Analysis (R&A) science program is essential to the discovery of new concepts and to the design of future missions. The primary mode of research coordination occurs through the USGCRP, the Committee on the Environment and Natural Resources (CENR) Subcommittee on Global Change Research, and the various boards and committees at the National Academy of Sciences.

The strategy of interdisciplinary research is to increase scientific understanding of the global environment and its vulnerability to both human and natural forces of change (e.g. pollution, climate variability, deforestation). Viewing the Earth from space is essential to comprehending the cumulative

influence of human activities on its natural resource base. An important priority is to provide accurate assessment of the extent and health of the world's forest, grassland, and agricultural resources. Observations from space are the only source of objective information on the human use of land in a time of rapid land use change. A related priority is to improve understanding and prediction of seasonal-to-interannual climate variation. Reducing uncertainties in climate predictions to a season or a year in advance will dramatically improve agriculture and energy planning. In addition, the natural hazards research priority places emphasis on the use of remote sensing observations for the characterization and mitigation of drought and flood impacts. There is increasing evidence that predictions of extreme weather events can be improved by understanding their links to interannual climate phenomena like El Niño events. Special attention in measuring and modeling the relative forces like clouds, aerosols and greenhouse gases in long-term climate change, in order to improve our understanding of and prediction of climate on time scales of decades to centuries. A continuing priority is understanding the causes and consequences of changes in atmospheric ozone. Efforts are continuing to make excellent progress on resolving questions related to stratospheric ozone depletion. Emphasis is now being placed on the changing composition of the lower atmosphere, which is sensitive to the unprecedented growth of pollutant emissions in rapidly developing regions throughout the world. Work will continue in the core research programs in MTPE. These programs provide the disciplinary strength that we draw from to solve interdisciplinary priority problems.

EOS interdisciplinary science consists of focused research centered around a specific Earth science data set and interdisciplinary research geared toward a broader probe into Earth science systemic functions. The quality of data utilized is monitored by the scientists at interdisciplinary instrument computing facilities and the research is supplemented by graduate student participation in the EOS science fellowship program.

There are currently over 1,700 scientific activities being funded under the research and analysis program. Approximately 900 are carried out by universities, 100 by national research laboratories, and 700 by the federal government. The distribution of the activities encompasses forty-five of the fifty states.

The airborne science program funds operations of two ER-2's and a DC-8 aircraft. A C-130Q is needed to support selected Earth science investigations. The program also funds operation and support of a core of remote sensing instruments and a facility for analyzing and calibrating data from those instruments. The specifically modified aircraft serve as test beds for newly developed instrumentation and their algorithms prior to spaceflight. The instrumented aircraft provide remote sensing and in situ measurements for many Earth science research and analysis field campaigns, including stratospheric ozone, tropospheric chemistry, and ecological studies throughout the world. The ER-2 aircraft, in particular, are unique in that they are the highest flying subsonic civilian research aircraft and were key in collecting in situ data for our understanding of ozone depletion and stratospheric transport mechanisms.

The Commercial Remote Sensing Program (CRSP), transferred from the Office of Space Access and Technology, will continue to fund cooperative efforts with industrial partners aimed at enabling development of a viable commercial remote sensing industry. The cooperative effort will work to apply space-based data and instrument technology in the development of usable, customer-defined information products. Industry will make significant co-investments, funding the CRSP at about an equal level with NASA.

The Uncrewed Aerial Vehicle (UAV) science program, a new initiative beginning in FY 1997, will augment the MTPE airborne program by making in situ and remote sensing measurements initially focused on the atmosphere; staying over a target for extended periods to measure detailed temporal changes, provide unique views of cloud structures and provide calibration and verification of MTPE's satellite instrumentation. During FY 1997 an AO will be initiated for the selection of three or four scientific investigations carried out using commercially available UAV flight time.

The advanced geostationary studies will investigate the application of the latest technology in developing small compact geostationary satellites that will support both research and operational objectives. For example, one candidate under consideration has the capability to provide the first adequately calibrated observations from geostationary orbit that support climate research. The satellite and instrument would

be developed over a four year time period. The first spacecraft would carry an imager and a second spacecraft would carry a sounder. The imager has spectral bands which provide data on cloud albedo, vegetation, cirrus clouds, cloud ice, limited ozone, and both high-level and low-level water vapor along with total water vapor. This would provide stable measurements for MTPE research that have previously been unattainable from geostationary orbit.

In FY 1997, NASA will initiate a data purchase program designed to acquire from commercial sources data sets not otherwise available that are necessary to accomplish broad research goals of Earth system science. The budget authority will be liquidated only as acceptable data is delivered and the proposed contract(s) will be executed with FY 1997 funds only after a broad, agency competition. The purchase will be managed by the Stennis Space Center. A RFP will be issued in FY 1997 to solicit data purchase proposals. It is anticipated that selection of more than one activity will occur. Such innovative methods of procurement were suggested in the Vice President's National Performance Review. Data product generation, data archival, science analysis, and all other NASA requirements are included in other elements of the MTPE budget.

In FY 1996, continuing into FY 1997 and FY 1998, the following are significant accomplishments in the five priority areas MTPE science is focusing: land cover/land use change, seasonal-to-interannual climate variability, long-term climate system variability, natural hazards, and atmospheric ozone.

Land Cover/Land Use

Major progress was made in characterizing the role of the northern forests as a control on water, heat, and momentum transfers between the surface and the lower atmosphere during the Boreal Ecosystem-Atmosphere Study (BOREAS). Data has since been introduced into experimental weather prediction models significantly improving skill in predicting regional weather.

Seasonal-to-Interannual Climate Variability

Progress continues on forecasting of El Niño events. A study was completed in FY 1996 at GSFC that documented the critical importance of accurate characterization of soil moisture for accurate predictions of global precipitation patterns.

Long-Term Climate System Variability

Global observations by the SAGE and the ERBE provided a unique understanding of the climate effects of the Mount Pinatubo volcanic eruption. The NASA-Goddard Institute for Space Studies (GISS) climate model produced a prediction of effects of Mount Pinatubo aerosols on surface temperature which showed excellent agreement with subsequent observations. Analysis of data obtained on the LIDAR In-Space Technology Experiment (LITE), using the Shuttle, demonstrated the capability of space-based LIDAR to improve significantly global measurements of both natural and anthropogenic aerosols. A national network, the Solar Irradiance Research Network, of aerosol measurements has been initiated at ten secondary schools nationwide.

Natural Hazards

Recent research has demonstrated the utility of SAR for accurate documenting changes in topographic features of the earth's surface. MTPE is implementing with other government agencies a high density global positioning system geodetic array in southern California to measure surface deformation produced by underlying geological faults. Preliminary design research for a "LightSAR" is investigating optimal mission characteristics for supporting the science of SAR interferometry as a method of surface change detection.

Atmospheric Ozone

Analysis of global data from the UARS confirmed that ozone depleting chemicals reaching the stratosphere are primarily of industrial origin. New analysis techniques developed for the TOMS provided the first global data set on surface UV radiation. These results provided the first confirmation of global trends in increasing UV radiation related to ozone depletion. The two TOMS that were launched in FY 1996 (TOMS-EP and TOMS-ADEOS) will provide data for continued ozone and UV trends determination with improved resolution and precision.

## ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) is responsible for working with state, local, and other federal government agencies to provide user-appropriate and scientifically credible air quality meteorological programs to support regulatory applications. Applied research and meteorological support is furnished primarily by EPA's National Exposure Research Laboratory in Research Triangle Park, North Carolina, through an interagency agreement with the National Oceanic and Atmospheric Administration (NOAA), which provides approximately 50 research meteorologists to the EPA.

Meteorological support to the EPA Office of Research and Development, the EPA Office of Air and Radiation, the EPA regional offices, and to state and local agencies includes: (1) development and application of air quality dispersion models for pollution control, direct and indirect exposure assessments, and strategy creation; (2) preparation and performance of dispersion studies and air quality model evaluations; and (3) review of meteorological aspects of environmental impact statements, state implementation plans, and variance requests. Meteorological expertise and guidance are also provided for the air quality standard, modeling guideline, and policy development activities of the EPA.

In light of the 1990 Amendments to the Clean Air Act, air quality models and the manner in which they are used are expected to evolve considerably over the next few years. In the area of pollutant deposition, the evaluation of nitrogen and oxidant chemistry, in addition to sulfur chemistry, will clarify the roles of model formulation, cloud processes, radiative transfer, and surface/vertical exchanges in air quality model predictions, leading to a better understanding of model predictions relative to control strategy assessments. Further development and evaluation of existing air quality models will take place to accommodate the inter-pollutant effects resulting from the variety of control programs that are now or may be in place, such as the proposed revisions to the National Ambient Air Quality Standards for ozone and particulate pollution. These inter-pollutant effects include trade-offs among controls on ozone, sulfur oxides, nitrogen oxides, and volatile organic compounds, as well as developing predictable methods of forecasting the impacts on various measures of air quality.

With respect to inhalable particulate model development, dispersion models are being enhanced to accurately predict aerosol growth from precursors over regional and local transport distances. To assist in the evaluation of the contribution of various sources to regional air degradation, inert tracer and tagged species numerical models are being developed. These models will introduce separate calculations for inert or reactive chemical species emitted from a particular source or region. The calculations will proceed to simulate transport and transformation to a receptor point, where the contribution of the particular source could be isolated.

With respect to oxidant air quality modeling, the roles of biogenic volatile organic compounds, rural nitrogen oxides, and vertical transport will be elucidated. A better understanding will be developed of the fundamental aspects of the ozone nonattainment problem such as differences in urban and rural rates of and/or sources of photochemical production and the interaction through transport of these ozone precursors. Much of this research will be performed under the program entitled North American Research Strategy on Tropospheric Ozone (NARSTO).

Atmospheric research in the areas of climate and climate change includes ozone distribution in the global troposphere, the relationship between that ozone distribution and climate (including temporal and spatial aspects), and regional climate studies addressing the interaction of climate with the biosphere. The climatology program involves both analytical and statistical climatology as well as support for regional-scale climate model development. Climate change issues and their feedbacks with the biosphere are being stressed.

Research in human exposure modeling includes microenvironmental monitoring and modeling, and development of exposure assessment tools. Microenvironmental algorithms are being developed based on field data to predict air quality in buildings, attached garages, and street canyons. These improved algorithms are then incorporated into microenviron-

mental simulation models for conducting human exposure assessments within enclosed spaces in which specific human activities occur.

In addition to these major areas, dispersion models for inert, reactive and toxic pollutants are under development and evaluation on all temporal and spatial scales, e.g., indoor, urban, complex terrain, mesoscale, and regional. Other efforts include construction and application of air pollution climatologies; modeling of agricultural pesticide spray drift and of fugitive particles from surface coal mines; modeling of trace metal deposition to the Great Lakes, nutrient deposition to Chesapeake Bay, and mercury deposition to the Florida Everglades; modeling of accidental releases of toxic compounds forming dense gas clouds and of open burning/open detonation of surplus military munitions; determination and description of pollutant effects on atmospheric parameters; and conversely, determination of meteorological effects on air quality. Measurement data obtained during field programs and from wind tunnel and water channel/towing tank experiments in the EPA Fluid Modeling Facility will be used to continue development and evaluation of these models in the FY 1998-1999 period, along with developing models for pollutant dispersion around natural and manmade obstacles.

EPA participation in the interagency High Performance Computing and Communications (HPCC) Program is enabling increased efficiency in air quality meteorological modeling through research on parallel implementation of the Mesoscale Meteorological Model (MM5), with the subsequent transfer of these achieved efficiencies to the user community. The HPCC Program is also developing a flexible environmental modeling and decision support tool (Models-3) to deal with multiple scales (urban to regional) and multiple pollutants simultaneously, thus facilitating a more comprehensive and cost effective "one atmosphere" approach to related single-stressor and multi-stressor human and ecosystem problems. Models-3 provides a framework to support the constant evolution of environmental models to handle more complex issues such as fine particulates, visibility, toxic pollutants, and multi-media (air and water) environmental assessments in an integrated manner.

The EPA is a participant in the United States Weather Research Program (USWRP), mainly by providing research-in-kind in the area of meteorological simulation modeling on local, meso, and regional spatial scales of pollutants from fossil-fueled power plants, vehicle exhausts, and other emissions sources. The detailed understanding and modeling of the mesoscale circulations that control the atmospheric dispersal of these pollutants will also be applied to coping with accidental releases of toxic or radioactive materials.

The EPA also maintains relations with foreign countries to promote exchange of research meteorologists and research results pertaining to meteorological aspects of air pollution. One of the most active areas of cooperative research is with Russia under the 1972 Nixon-Podgorny Agreement forming the US/USSR Joint Committee on Cooperation in the Field of Environmental Protection and under the 1993 Gore-Chernomyrdin Agreement forming the US/Russia Commission on Economic and Technological Cooperation. Other agreements are in place with Canada, Japan, China, Mexico, and several European countries.

## DEPARTMENT OF STATE

The Department of State (DOS) plays an active role in international climate/meteorological policy making as a result of the growing worldwide concern with global environmental issues, including the depletion of the stratospheric ozone layer and global warming. The role of DOS has principally revolved around preparation and negotiation of the United States position in three fora: (1) the Conference of the Parties to the Vienna Convention and its Montreal Protocol on Substances that Deplete the Ozone Layer, (2) the Intergovernmental Panel on Climate Change (IPCC); and (3) negotiation under the United Nations Framework Convention on Climate Change.

Stratospheric ozone depletion has been recognized as a critical health and environmental problem for more than a decade. Under DOS leadership, the United States worked to negotiate international agreements to phase-out ozone-depleting substances, which should lead to a recovery of the ozone layer in the next

century. To date, these treaties have been signed and ratified by more than 130 countries (including the United States), representing 99 percent of the world's production of ozone depleting substances.

The IPCC, which is jointly sponsored by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), held its first session in 1988. This organization serves as a government forum to assess the state of scientific, technical, and economic information regarding climate change. The IPCC is currently organized in three working groups, examining: (1) the state of the science; (2) impacts and possible response strategies, including mitigation and adaptation; and (3) economics and other cross-cutting issues. The IPCC released its first assessment report in 1990; supplementary reports were released in 1992 and 1994. A full second assessment report from each of the working groups was scheduled for publication in late 1995.

The Framework Convention on Climate Change was negotiated beginning February 1991; the convention was open for signature in Rio de Janeiro at the Earth Summit in June 1992. As of April 1995, it had been ratified by 129 countries, including the United States. The first meeting of the Conference of the Parties to the Convention was held in Berlin in March/April 1995. The convention calls for all countries to develop inventories of their emissions and sinks of greenhouse gases and calls upon developed countries to aim to return these emissions to their 1990 levels by the year 2000. At its first session, the conference decided to begin negotiations on next steps under the convention to elaborate policies and measures and to set quantified limitation and reduction objectives for greenhouse gases.

In addition to its primary role in the fora listed above, DOS is active on the Committee on Environment and Natural Resources (CENR) of the National Science and Technology Council (NSTC). The CENR was established in 1993 to coordinate scientific domestic programs. Furthermore, while the emphasis on global environmental issues is a key new component of the department's focus, traditional DOS responsibilities, described in earlier federal plans, continue. These include, but are not limited to, international aspects of food policy, disaster warnings and assistance, WMO and UNEP activities, and international meteorological programs.

## NUCLEAR REGULATORY COMMISSION

The U.S. Nuclear Regulatory Commission (NRC) licenses and regulates all nuclear facilities subject to the Atomic Energy Act of 1954 as amended. The licensing and operation of these nuclear facilities require the identification of meteorological and climatological conditions that can affect the safe operation of the facility, and that provide input to the assessment of the radiological impacts of any airborne releases from the facility.

Within the NRC, reviews of facility siting, design, construction and operation are conducted by the Office of Nuclear Reactor Regulation and the Office of Nuclear Material Safety and Safeguards. These reviews include consideration of meteorological factors. The NRC Office for Analysis and Evaluation of Operational Data and the NRC Regional Offices assure that commitments by NRC applicants, permittees and licensees are carried out, and also conduct NRC responses to nuclear facility emergencies. The Office of Nuclear Regulatory Research develops regulations, guides, criteria, and other standards related to the protection of public health and safety and the environment in the licensing and operation of nuclear facilities. This Office also develops and conducts confirmatory research programs in support of activities of the other Offices and in support of rule-making and standards activities.

The primary meteorological area in which the NRC will have an interest during FY 1998 and beyond is improvements in the meteorological capabilities of the NRC and the operators of nuclear facilities to cope with emergencies involving the unplanned releases of radioactive materials. The NRC also maintains an interest in the transport and dispersion of airborne, hazardous non-radioactive materials and their potential effects on the safe operation of nuclear facilities.

## DEPARTMENT OF ENERGY

For nearly 50 years, the Department of Energy (DOE) and its predecessors, the Atomic Energy Commission and the Energy Research and Development Administration, have supported meteorological operations and atmospheric research at the DOE field offices. The need for meteorological services began with the development, fabrication, and testing of atomic weapons and the national security and safety issues associated with them. In addition, environmental protection legislation specifies requirements for meteorological services to protect public health and safety and the environment.

The Department of Energy (DOE) addresses many areas relating to energy efficiency use and resources, improved environmental quality and a secure national defense. Atmospheric science research and operations have been an integral part of DOE since the cold war era. Even today's global climate change debates and outcomes are relying on information collected through basic atmospheric science research programs that one day will reduce substantial uncertainties in these areas. It is vital to understand the nature of the atmospheric domain with its various dynamic and chemical aspects of energy-related phenomena.

DOE coordinates programmatic activities throughout its various Offices such as Defense Programs, Energy Research, Environmental Management and Energy Efficiency and Renewables. These Offices are responsible for the management of scientific research programs such as Atmospheric Release Advisory Capability (ARAC), Global Climate Change Research and various clean up activities at former cold war production sites.

Meteorological services at DOE facilities range from complex research to daily operational support. Some examples of research are investigations of potential global climatic change, ultraviolet and infrared radiation studies, and studies of atmospheric boundary layer processes. Operational support includes daily weather forecast services, special project support, on-site meteorological monitoring, climatological services, and emergency response assistance. Some sites maintain 24-hour weather watches for severe weather conditions that could impact site operations, damage property, or threaten lives.

Several DOE field offices cover large areas, and some sites contain complex topography and heterogenous surface characteristics, creating locally driven conditions that influence on-site weather. For these reasons and to protect the environment and public health and safety, on-site meteorological monitoring has been and remains an essential part of DOE atmospheric science programs.

Some DOE sites contribute to the national weather observing network by taking standard surface and upper-air observations. Many of these sites are in remote areas where weather observations would be sparse if not for the presence of DOE meteorological monitoring programs. Weather observations taken at several DOE field sites are entered to the national weather database via the NWS Automation of Field Operations and Services (AFOS) system--the NWS' primary meteorological data distribution and display system. AFOS also interconnects field offices and serves as the distribution system for NWS meteorological products that are centrally produced by the National Centers for Environmental Prediction (NCEP). DOE facilities with AFOS units are connected to the NWS AFOS network through NOAA's Air Resources Laboratory (ARL) that supports the DOE/Nevada Operations Office in Las Vegas, Nevada, which serves as the hub for the NWS/DOE AFOS network.

An accidental release of radioactive or toxic material into the atmosphere can have potentially serious health and environmental consequences. Meteorological processes play a key role in determining the fate of pollutants released into the atmosphere. For example, the processing, fabricating, and underground testing of nuclear weapons all have the potential for industrial accident scenarios. In addition to these activities, the use of nuclear material in the generation of electric power and the storage of nuclear waste from power generation, weapons' complexes, and medical and commercial processes are all potential sources of nuclear material that could be accidentally released into the atmosphere. Consequently, a central theme within the DOE community has been to protect public health, safety, and the environment on and around DOE facilities. Therefore, DOE has required and supported on-site meteorological monitoring, directed the

development of emergency response capabilities at DOE facilities, funded research on the modeling of the transport, dispersion, deposition, and resuspension of radioactive and toxic materials, and advocated on-site weather forecasting services tailored specifically for the special operational and emergency management requirements at each DOE facility. Much of the research and most of the operational support has been provided by the atmospheric research programs at the six major field offices directly involved in national defense programs. Over the years, these programs have grown to address many environmental, safety, and health issues. Due to the complexity of these activities, it was recognized that efforts should be made to coordinate meteorological operations and research among the field offices to enhance cost effectiveness.

Based on a need to facilitate more coordination and cooperation among the meteorological activities at the DOE field offices, the DOE Meteorological Coordinating Council was created in 1994. The mission of the council is to coordinate meteorological support and research to meet DOE objectives. The objectives of the council are to: (1) promote cost-effective support for all DOE facilities; (2) plan for future needs, requirements, and missions; (3) advocate awareness of atmospheric science applications and benefits to DOE; and (4) facilitate the use of common methods, procedures, and standards. The council is composed of senior DOE personnel and managers of DOE meteorological programs. The following narrative highlights the meteorological activities of the DOE sites.

The Idaho National Engineering Laboratory (INEL) is managed by the Idaho Operations Office and is on 890 square miles of rolling, arid terrain in southeastern Idaho at the foot of the Lost River and Lemhi mountain ranges. Meteorological services and supporting research are provided by ARL's Field Research Division (FRD) with the mission to support emergency response exercises and INEL operations with meteorological data, weather predictions, dispersion calculations, and consultation. ARL/FRD designs, arranges, and conducts field studies as needed to evaluate the performance of transport and dispersion models over local, regional, and continental scales, and to obtain high quality databases for the model improvement. They are recognized for their unique field experimentation capabilities, for expertise in conducting tracer studies, and for using direct and remote sensing technologies in support of tracer experiments.

To meet other mission requirements, ARL/FRD operates and manages a large meteorological monitoring network to characterize the meteorology and climatology of the INEL site. The network consists of 30 wind towers that provide wind and temperature data. The overall Meteorological Monitoring Program is designed to provide representative data for the INEL area to meet specific operational and potential emergency response situations. Most towers are 15 meters tall; however, four towers range from 45 to 75 meters in height. All towers are instrumented at multiple levels. Eleven have relative humidity, precipitation, and solar radiation sensors. Continuous wind and temperature profiles are obtained from a 915 MHz Doppler wind profiler and a Radio Acoustic Sounding System (RASS). Wind profiles generally extend to 5,000 feet above ground; temperature profiles extend to 1,500 feet. All meteorological data are quality-controlled and archived for future use. Additional use of this database is made in operational weather forecasts tailored to meet INEL and contractor requirements and to prepare climatological summaries that are distributed to users.

DOE operations at the Nevada Test Site (NTS) are managed by the Nevada Operations Office (NV). NTS is the Nation's underground nuclear weapons testing facility and occupy 1,350 square miles of south central Nevada. The topography of the NTS is complex with a system of dry lake beds and mountains. Elevations range from nearly 2,700 feet above mean sea level (MSL) to 7,600 feet MSL; the climate is arid.

Meteorological services are provided by ARL's Special Operations and Research Division (SORD). Over the last 40 years, ARL/SORD personnel have built a solid technical reputation in meteorological operations in the nuclear weapons testing arena. They are recognized for expertise in the transport, dispersion, and deposition of radioactive materials and for developing a rapid emergency response capability for the unlikely occurrence of an accident resulting from the release of radioactive material into the atmosphere.

Both basic and applied research are carried out on problems of mutual interest to DOE and to NOAA. Emphasis is on the maintenance of meteorological support to national defense projects and to the stewardship of nuclear weapons. These capabilities focus on those facets of meteorology having a direct bearing on the transport, dispersion, deposition (fallout), and resuspension of radioactive and/or toxic materials.

ARL/SORD provides full meteorological support to all DOE/NV operations on and off the NTS. The staff is responsible for conducting a modern program in support of nuclear and non-nuclear projects authorized by NV. Furthermore, ARL/ SORD provides technical support to the NV emergency preparedness and response activities, operates a thorough meteorological monitoring program for the NTS, and provides meteorological and climatological services required in support of NV and contractor programs at the NTS and elsewhere, as necessary. ARL/SORD personnel also consult with senior scientists and engineers at the DOE National Laboratories, NASA, private contractors, EPA, USGS, USFS, and other NOAA laboratories.

The SORD meteorological monitoring network consists of thirty-one 10-meter towers and two 30-meter towers. Wind direction and speed are measured at the 10-meter level on all the towers and temperature and relative humidity is sampled at the 2-meter level. Data from these towers are transmitted via microwave radio to a central processor that checks the data, creates data files, and archives the data every 15 minutes. The data files are accessed by microcomputers to create graphics products for operational use and for immediate display at 15 minute intervals.

ARL/SORD is the DOE node for distribution of NWS AFOS products. Other weather products supplied to DOE contractors, the National Laboratories, NWS, and Nellis Air Force Base include real-time cloud-to-ground lightning flash graphical products and local forecast products. ARL/SORD also provides meteorological monitoring support and weather forecast services to Nuclear Emergency Search Team (NEST) and Federal Radiological Monitoring and Assessment Center (FRMAC) activities. Monitoring support includes surface and upper-air data collection and analysis. Weather forecast service entails maintaining a constant weather watch for conditions that might impact NEST/FRMAC operations and personnel, issuing site-specific, mesoscale wind, stability, and weather forecasts, and providing consultation to the on-scene commander and to National Laboratories personnel.

The DOE Oak Ridge Operations Office (OR) is located on nearly 100 square miles of hilly and heavily vegetated terrain in eastern Tennessee and is supported by ARL's Atmospheric Turbulence and Diffusion Division (ATDD). ARL/ATDD's primary mission is atmospheric research. Attention is focused on the physics of the lower atmosphere, with special emphasis on the processes contributing to atmospheric transport, dispersion, and air-surface exchange, and on the development and improvement of predictive capabilities using the results of this research. The program is organized around three ARL-wide themes: air quality, emergency preparedness, and climate variability. The objectives are: (1) to develop better methods for describing atmospheric transport, diffusion, and air-surface exchange in numerical simulations; (2) to extend the applicability of these techniques to non-ideal situations such as non-stationary conditions, complex terrain, and nonhomogeneous vegetation; and (3) to develop and test improved numerical models incorporating these new methods. Most ARL/ATDD programs are air quality-related. They include studies of complex terrain flows, Lagrangian stochastic dispersion modeling, the behavior of the nocturnal boundary layer, and -- of increasing interest to decision makers -- model uncertainties. Surface energy balance and $CO_2$ exchange studies are related to questions of global climate, and therefore cover a wide range of ecosystems ranging from the temperate to the Arctic; long-term studies of $CO_2$ exchange aimed at process-level understanding have been under way at the Walker Branch Watershed forest in Oak Ridge for several years. Special experimental capabilities include portable automated solar-powered systems to directly and continuously measure air-surface exchange of momentum, heat, water vapor, and $CO_2$, along with local surface energy budgets, and a unique approach to measuring such exchanges from low-flying light airplanes to explore spatial variability of the data at low cost. Recent emergency preparedness activities include independent evaluations of atmospheric dispersion models for several agencies, and the design and co-management of large tracer dispersion studies. Activities aimed at climate variability include the daily operation of NOAA's integrated solar irradiance study (ISIS) network that provides long-term data on incoming solar radiation and surface radiation balance at sites across the U.S. Research programs are undertaken with the assistance of personnel of the Energy/Environment Systems Division of Oak Ridge Associated Universities (ORAU), and in close collaboration with scientists from Oak Ridge and other National Laboratories and from other government agencies, universities, and research organizations in the U.S. and abroad.

Operationally, ARL/ATDD personnel provide meteorological consultation and supplemental data to local OR users for air quality analyses, environmental

reports, and emergency preparedness. Local climatological data are routinely collected and distributed. Under NOAA funding, ARL/ATDD operates a regional tower network of 15 sites ranging from the Cumberland mountains to the west of Oak Ridge to the Smoky Mountains on the east; wind, temperature, and precipitation data are recovered every 15 minutes by telemetry and made available to users. ARL/ATDD also works closely with the ORAU to enhance educational opportunities in atmospheric science.

Meteorological services to the DOE Richland Operations Office has been provided by Battelle Pacific Northwest Laboratories (PNL) for nearly 50 years. Not only has operational support been provided, but also supporting research into atmospheric processes has been a key part of PNL's support to DOE-Richland. The facility covers 560 square miles within the arid and sparsely vegetated Columbia River basin in southeaster Washington. Key DOE research activities at PNL's Environmental Science Research Center include the Global Change Research Program (GCRP), the Atmospheric Radiation Measurement (ARM) program, the Atmospheric Chemistry Program (ACP), the Core Carbon Dioxide Research program, the Computer Hardware Advanced Mathematics and Model Physics (CHAMMP) program and the Mexico City Air Quality Study.

GCRP focuses on the study of basic geophysical processes and development of databases that are critical for understanding global and regional climatic change. The ARM program is designed to characterize empirically the radiative processes in the atmosphere with high spatial, temporal, and spectral resolution and accuracy at four to six climatologically important sites distributed worldwide. The goal of the CHAMMP program is to produce a climate modeling system having 10,000 times the capacity of the current generation of models and computers. In addition, carbon dioxide emissions research is aimed at providing a scientific basis for forecasting future emissions of carbon dioxide and other radiatively important gases.

PNL's Meteorological and Climatological Services Project (MSCP) office provides meteorological monitoring and operational support. The monitoring system consists of an array of twenty-three 10-meter towers and three 60-meter towers instrumented with temperature and wind direction and speed sensors. Data from this network are transmitted via UHF radio to a computer that decodes the data and plots graphics products for immediate display and use by Hanford Meteorological Station personnel. Other meteorological data are received via the NWS/DOE AFOS network. Meteorological services include emergency response functions, weather forecasting for on-site operations and special projects, and climatological support. MSCP support to the Hanford site includes: (1) extensive data acquisition via a site-wide meteorological monitoring network, (2) around-the-clock weather forecasting services, (3) hourly surface observations, 6-hourly synoptic observations, and twice-daily pilot balloon releases, and (4) monthly and annual climatological data summaries, plus meteorological input to annual environmental reports.

Support to the Rocky Flats Office (RFO) is provided by EG&G, Rocky Flats, Inc. This facility is located along the eastern slopes of the Rocky Mountains, approximately 15 miles northwest of Denver, Colorado, and is one of the smaller sites, covering only 10 square miles. Part of the former Rocky Flats nuclear weapons facility has been transformed into the National Wind Technology Center as a research facility to aid industry in developing advanced wind energy systems for the future.

EG&G scientific and technical personnel provide meteorological and climatological services in support of RFO site operations. Weather forecasts are issued twice daily to support on-site operations and other weather-sensitive activities. A constant weather watch is maintained during routine working hours for severe thunderstorms, lightning, winter storms, and strong winds. In addition, EG&G manages and operates a meteorological monitoring program that uses local NOAA/ERL meteorological data. They also conduct dose assessments, run dispersion models, and support an emergency response preparedness program. The Colorado Department of Public Health has formally approved the Rocky Flats emergency response program. On-site meteorological monitoring is provided by wind and temperature data collected from a 60-meter tower. This tower is equipped with standard meteorological sensors at the surface, 10 meters, 25 meters, and 60 meters above the ground. Data are transmitted to the forecast office and to the Emergency Operations Center every 15 minutes. These data are also archived for future use. EG&G plans to have a SODAR/RASS system operationally on-site, and there are plans to access meteorological data from five Colorado Department of Public Health and Environment 10-meter towers near the plant.

The Savannah River Operations Office (SR) is located in extreme southwestern South Carolina, along the banks of the Savannah River. The Savannah River Site (SRS) covers an area of approximately 300 square miles and is managed by the Westinghouse Savannah River Company--the primary producer of tritium for use in nuclear weapons. The climate is typical of the southeastern U.S. with hot, humid summers and mild, wet winters. SRS is heavily vegetated with evergreen trees and contains many streams, a swamp, and a 2,700-acre reservoir built as a cooling pond for the plant reactors.

Support to SR operations is provided by the Westinghouse Savannah River Meteorological Program and includes daily weather forecast services for the SRS. Meteorological data is obtained from a local network of eight 200-foot towers with sensors at the 200-foot level, a 200-foot tower instrumented at four levels, and a 1,000-foot tower. Additional local upper-air data are collected from three acoustic Doppler radars, a Beukers rawinsonde system, and an airsonde and tethersonde system. Other meteorological data are received via the NWS/DOE AFOS network. Research on atmospheric transport and dispersion is also conducted to provide SRS with the best modeling capability available to support emergency response operations and other programs.

The Lawrence Livermore National Laboratory (LLNL) is operated by the University of California for the DOE Oakland Operations Office. Within the LLNL Environmental Programs Directorate, the Atmospheric Sciences Division (ASD) conducts research on climate and weather processes on regional to global spatial scales. At the regional scale the focus is to develop advanced models for accurately predicting the transport, diffusion, deposition, transformation, and atmospheric effects of accidental releases or pollutants. On the global scale, ASD researches the mechanisms of global environmental and climate change through the development and diagnosis of state-of-the-art models that represent key processes affecting the atmosphere, oceans, and biosphere. Two major programs within ASD include PCMDI and ARAC.

The Program for Climate Model Diagnosis and Intercomparison (PCMDI) develops and distributes software tools to facilitate model diagnosis and intercomparison, documents the features of models that are in use by the world climate community, and archives extensive collections of model output data. The Program also provides quality global observational products for application as model validation data.

The Atmospheric Release Advisory Capability (ARAC) Program is a centralized national resource responsible to the U.S. Department of Energy (DOE), the U.S. Department of Defense (DOD), and other federal agencies under the auspices of the Federal Radiological Emergency Response Plan (FRERP). ARAC's mission is to deliver realistic real-time graphical dose and exposure assessments to emergency decision makers to assist in the protection of populations at risk for releases of radiological and other hazardous material to the atmosphere. ARAC supports all elements of the DOE Emergency Preparedness and Response Program, including the Nuclear Emergency Search Team (NEST), the Accident Response Group (ARG), the Federal Radiological Monitoring and Assessment Center (FRMAC), and the Radiological Assistance Program (RAP).

ARAC maintains and operates the ARAC Emergency Operations Center that consists of redundant computer systems with uninterruptable power, automated continuous worldwide meteorological data acquisition, detailed worldwide terrain and geographic mapping databases, and a suite of three-dimensional, complex terrain, atmospheric dispersion models prepared to assess explosions, fires, vents, spills, or other releases of radiological or hazardous material. The ARAC Center is staffed by meteorologists and computer technicians with 24-hour on-call response. Part of the ARAC Program provides on-site and off-site emergency response services to about 40 DOE and DOD facilities around the U.S. via a dedicated Site Workstation System linked to the ARAC Center at LLNL. Each Site Workstation also collects on-site meteorological data from one or more towers. The response time for the delivery of an initial ARAC assessment is less than 15 minutes for a computer-linked site and 45-90 minutes for a non-computer-linked site.

## FEDERAL EMERGENCY MANAGEMENT AGENCY

The Federal Emergency Management Agency (FEMA) is the central agency within the federal government responsible for emergency preparedness training and exercises, mitigation, response, and recovery. Working closely with state and local governments, FEMA funds emergency programs and offers technical guidance and training. FEMA also coordinates federal disaster relief resources in a catastrophic disaster. These coordinated activities ensure a broad-based program to protect life and property and provide recovery assistance after a disaster. The agency was formed in 1979 by Presidential Executive Order 12127, replacing five former agencies and consolidating the Nation's emergency-related programs, including meteorological emergencies.

In carrying out its role, FEMA works with all of the agencies to assure that the delivery of meteorology-related information is conducted in keeping with established goals and objectives. As administrator of the National Flood Insurance Program, FEMA publishes Flood Insurance Rate Maps for all flood-prone communities, which serve as the official demarcation for flood risk. FEMA also publishes hurricane evacuation maps based on model simulation results from NWS's National Hurricane Center for regions subject to hurricanes.

FEMA's priority interests with the Office of the Federal Coordinator for Meteorology (OFCM) are in promoting standards and procedures which will enhance the ability of the Nation to mitigate and recover from emergencies and disasters. These interests extend to national standards for geographic information systems (GIS) used for delivery of meteorological products and services by other agencies. FEMA also actively supports the OFCM-sponsored Working Group for Post-Storm Data Acquisition (WG/PSDA) and the WG/PSDA's efforts to develop a *National Plan for Post-Storm Data Acquisition* to coordinate and support the collection, by the federal agencies, of perishable data after major storms. For meteorologically-related matters, the Hazard Identification and Risk Assessment Division, Mitigation Directorate, is the principal contact point within FEMA. (FEMA Web Site: *www.fema.gov*)

APPENDIX E

# WORLD WEATHER PROGRAM

The Department of Commerce (DOC) was designated by the President, following Senate Concurrent Resolution 67 (1968), to be the lead agency for coordinating U.S. participation in the World Weather Program (WWP). Previous to 1983, DOC published a separate report on WWP Plans. Beginning with the 1983 edition of the ***Federal Plan for Meteorological Services and Supporting Research***, a section on the WWP has been included, obviating the need for a separate report. Included at the end of this appendix are bilateral and regional international cooperative activities not under the WWP. While not exhaustive, most government programs are included.

## GOALS AND ORGANIZATION

The goals of the WWP are to extend the time, accuracy, range, and scope of weather prediction and to understand the physical basis of climate and climatic change. The ability of the United States and other nations to use their existing scientific capability to understand the climate and to increase their weather predicting skills is limited by the lack of global weather data. Available weather data are inadequately observed over 80 percent of the Earth's surface and mostly over the oceans; coverage over the remaining 20 percent is, in places, barely adequate.

Development of the technology and the systems to obtain these observations, especially over the oceans, presents formidable problems. With the use of satellites, aircraft, ships, radar, anchored and drifting buoys, and balloons, however, an integrated system can be developed to observe and collect comprehensive data about the atmosphere over the entire globe. This system is too complex to be implemented by a single nation--a fact clearly recognized by the leaders of many nations whose international cooperation in meteorology has been a tradition for more than a century. In 1961, this continuing need for international cooperation prompted the President of the United States to propose to the United Nations (UN) the establishment of an international effort in weather prediction. The UN responded by calling upon the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) to develop measures to improve weather forecasting capabilities and to advance the knowledge of the basic physical forces that determine climate.

The WMO, with 186 members, is a specialized agency created by the UN to facilitate international cooperation in the fields of meteorology and hydrology. The WMO responded to the UN request with the concept of the World Weather Watch (WWW), an operational system to bring the global atmosphere under improved surveillance and to provide for the rapid collection and exchange of weather data as well as for the dissemination of weather products from centralized processing centers.

More recently, the WMO, through its commission structure, is working towards the design and implementation of improved observations for a Global Climate Observing System (GCOS) through enhancements to the Global Observing System (GOS) and other appropriate measures. These efforts are expected to yield an enhanced GOS for both operational and research purposes and are part of the effort to strengthen the WMO's commitment to improve the understanding of climate and related environmental matters, as articulated by the Second World Climate Conference in 1990 and repeated at the United Nations Conference on the Environment and Development.

The responsibilities of U.S. federal agencies in the WWP are as follows:

- Department of Commerce (DOC). Represents the U.S. at WMO and, through NOAA, provides the focal point to coordinate our Nation's efforts in these international programs, implements those service improvements in the existing international weather system for which the U.S. accepts responsibility, and develops new technology.
- Department of State (DOS). Maintains relations with developing nations and, tnrough NOAA and the WMO, assists developing nations in

improving their national weather services. DOS also develops appropriate multilateral and bilateral arrangements to further international participation.

- National Science Foundation (NSF). Stimulates and supports basic research by non-government scientists on atmospheric and ocean circulations and modeling. It also promotes the education and training of atmospheric and ocean scientists at universities.
- Department of Defense (DOD). Although the mission of DOD weather services is basically internal, the nature of DOD's operations is global. As such, the observation, telecommunications, and data-processing programs of the military weather services provide significant indirect support to the WWW through DOD's interface with NOAA's National Weather Service (NWS). Information from the research and development activities of these services is exchanged routinely with other similar national agencies and is often presented at national forums.
- Department of Transportation (DOT). Through the U.S. Coast Guard, provides personnel to support NOAA's National Data Buoy Center (NDBC) in developing, operating, and evaluating data buoy systems. Coast Guard cutters and aircraft provide operational support to deploy, service, and retrieve buoys built for test or operational purposes. DOT's observation and telecommunications programs also provide significant indirect support to the WWW through DOT's interaction with the NWS.
- National Aeronautics and Space Administration (NASA). Performs research and develops space technology required for an effective global weather system.

## THE WORLD WEATHER WATCH

The World Weather Watch (WWW) is an integrated system which functions on three levels--global, regional, and national. The WWW is divided into three essential elements that are closely linked and interdependent--the Global Observing System (GOS), Global Data Processing System (GDPS), and Global Telecommunication System (GTS).

These elements are coordinated and closely integrated through three WWW support functions: (1) The data management function coordinates, monitors, and manages the flow of data and products within the WWW system to assure their quality and timely delivery. It also includes the definition and use of code forms for data exchange; (2) The systems-support activity provides guidance, technical and scientific information, and training to those involved in the planning, development, and operation of WWW components; and (3) The implementation coordination function assures the timely completion of the WWW implementation and effective support and maintenance of the WWW system.

### Global Observing System (GOS)

The GOS is a coordinated system of methods, techniques, and facilities for making weather observations on a worldwide scale. It is a composite system containing surface-based and space-based (satellite) subsystems. The main elements of the subsystem are:

- Regional, basic-synoptic networks, manned and automated, for both surface and upper-air observations.
- Fixed sea stations, composed of ocean weather stations, fixed and anchored platform stations, and island and coastal stations.
- Mobile sea stations, including moving ships and drifting buoys.
- Aircraft meteorological stations, including automated aircraft reporting systems.

The space-based (satellite) subsystem provides vital support for meteorological and hydrological predictions and warnings. The use of satellites enables the routine collection of environmental observations from even the most remote locations. Two categories of satellites are used: those in polar orbits and those in geostationary orbits.

Presently, operational meteorological satellites in polar orbits are operated by Russia (the METEOR-3 series) and the United States. The United States operates the civilian NOAA POES (Polar-orbiting Operational Environmental Satellite) series along with the defense DMSP (Defense Meteorological Satellite Program) series of polar-orbiting spacecraft. NOAA currently launches satellites, alternately, into afternoon and morning orbits to maintain an uninterrupted stream of polar data. The current operational NOAA polar-orbiting satellites are

NOAA-14 (launched in an afternoon orbit in December 1994) and NOAA-12 (launched in a morning orbit in May 1991). The current operational DMSP polar-orbiting satellites are F-12 (launched in August 1994) and F-13 (launched in March 1995).

Operational geostationary weather satellites are currently operated by Japan, India, Russia, EUMETSAT (Europe), and the United States. Japan's Geostationary Meteorological Satellite (GMS) is positioned at 140°E, India's Indian National Satellite (INSAT) is at 74°E, Russia's GOMS/Elektro #1 satellite is at 76°E (operational since June 1996), and EUMETSAT's METEOSAT is at 0°. The U.S. normally operates two Geostationary Operational Environmental Satellites (GOES)--one at 75°W and the other at 135°W. GOES-8, launched in April 1994, is operational at 75°W and GOES-9, launched in May 1995, is operational at 135°W.

To help ensure data continuity from geostationary orbit, NOAA has signed a long-term mutual back-up agreement with EUMETSAT.

In the future, NOAA's POES will be combined with the DMSP to form a converged system called NPOESS (National Polar-orbiting Operational Environmental Satellite System). NOAA, DOD, and NASA are working together to implement NPOESS and have created an Integrated Program Office (IPO). NOAA heads the IPO and is responsible for operating the NPOESS and for relations with national and international civilian users of the system. The DOD has the lead responsibility for NPOESS acquisitions, launch, and systems integration. NOAA will facilitate the development and incorporation of new, cost-effective technologies to enhance the NPOESS capabilities. Negotiations continue with the Europeans for their assumption of NOAA's morning polar orbit mission just after the turn of the century. This complements longstanding plans by NOAA and the meteorological operational satellites.

Broadcast of data from both the NOAA and GOES series of U.S. satellites is free, unrestricted, and does not require any prior notification. Data can be received directly by any properly-equipped ground station within the satellites' line-of-sight. The United States, through NOAA, develops information and products from these data for further distribution over the GTS.

The WWW is a flexible system which can be adapted to changing technology and operational conditions. The latest technological and scientific developments in observations, data processing, and telecommunications are under constant review with an eye towards improving the GOS, GDPS, and GTS.

Over the last few years, several systems intended to improve the operation of the GOS have continued to undergo development and deployment. Among these systems is the family of automated aircraft reporting systems known as the Automated Meteorological Data and Reporting (AMDAR) systems. This family of systems includes the Aircraft to Satellite Data Relay (ASDAR) System and the ARINC Communications Addressing and Reporting System (ACARS). ARINC is Aeronautical Radio Incorporated--a wholly owned subsidiary of the airlines.

To date, a total of 19 ASDAR units out of the 23 originally purchased have been installed and are flying; ten units on British Airways, three on KLM, two each on aircraft of Air Mauritius and South African Airways, and one each on aircraft of SAUDIA and Lufthansa. A contract was signed on December 16, 1996, between the National Meteorological Institute of Spain, the National Meteorological Service of Argentina and Aerolineas Argentinas to fit the ASDAR unit originally purchased by Spain onto an Aerolineas Boeing 747-200. Aerolineas Argentinas has also offered to fit two more ASDARs, one belonging to the UK and the other to the Operating Consortium of ASDAR Participants (OCAP) onto other Boeing 747-200s.

A cooperative effort among ARINC, NWS, and the FAA is providing thousands of automated meteorological reports from ACARS-equipped aircraft flying over the U.S. The ARINC meteorological data collection and reporting system collects, organizes, and disseminates automated position/weather reports to the NWS. The standardized weather data is being sent to the NWS in the Binary Universal Form for the Representation of Meteorological Data (BUFR) code. Upwards of forty thousand reports a day in varied formats and internal codes are received by ARINC and the quantity is increasing to 150,000 within the decade.

Large quantities of weather reports, particularly over oceanic and other data-sparse areas, will be realized via satellite communications and navigation systems. This source of data is of prime interest to the U.S. and other members of the International Civil Aviation Organization (ICAO) and the WMO's

Automatic Aircraft Reporting study group. The group developed amendments to the ICAO Technical Regulations and made substantial progress toward standardizing meteorological down-link codes (automatic binary, automatic character, manual routine, and special air-reports).

The Forty-Ninth Session of WMO's Executive Council (Geneva, June 1997) endorsed a proposal by OCAP that a Panel on Aircraft Meteorological Data Reporting composed of Members of WMO that operate, or intend to operate, national AMDAR Programs to coordinate and promote global AMDAR development be established. It is to be noted that the OCAP Program is due to terminate by the end of 1999. The initial organizational meeting of the AMDAR Panel is expected to be held in The Netherlands before the end of calendar year 1997.

In addition to these aircraft-based systems, other observation systems are being deployed to improve the GOS. For example, the Automated Shipboard Aerological Program (ASAP) has about 12 systems reporting regularly; one U.S. ASAP ship is now operating with a second expected in FY 1996. There has also been deployment of substantial numbers of drifting buoys. A number of nations including the U.S. are implementing test networks or single sites of ground-based Doppler radars called wind profilers to provide nearly continuous soundings of wind. During the past year, there were approximately 88 systems in use worldwide. A demonstration network of 29 wind profilers is being operated principally in the central part of the U.S. to assess the utility of the data in operational and research meteorological analysis and prediction. A report on the multiyear meteorological and engineering assessment was completed in November 1994. Data continues to be made available on the GTS to those countries requesting it.

To improve the methodology used in developing and deploying observing systems, NOAA is developing the North American Atmospheric Observing System (NAOS) program. NAOS objectives are to: (1) define a cost-effective, requirements-driven "best mix" of observing platforms and instruments and (2) reduce observing system risks and uncertainties. While the initial focus of the program will be to modernize the composite upper-air network, NAOS is expected to guide the resource-allocation process for most future observing systems developed and/or fielded by NOAA.

The concept of the Operational World Weather Watch Systems Evaluation (OWSE) has also been developed as a framework for regional implementation. The OWSE-Africa, which was created to evaluate the very extensive use of a geostationary meteorological satellite (operated by the European operational satellite consortium, EUMETSAT) to improve telecommunications and data availability in Africa, has been completed. It was designed to implement and test the data collection system for receipt of meteorological observations from various countries in Africa. Thus far, approximately 100 data collection platforms have been installed in Kenya, Ethiopia, Ghana, Sudan, Nigeria, Sierra Leone, Zaire, Egypt, Madagascar, St. Helena, Guinea, and Cape Verde. Evaluations have been carried out to gauge the improvement of observation receipt, and preliminary results show that high-receipt rates are achieved when systems are operating. Further, results indicate that high-receipt rates may be achieved for data originating in Africa, but infrastructure and maintenance issues remain for full operational deployment to be successful.

Efforts are underway to design and implement a GCOS, building upon the WWW, Global Atmospheric Watch, Integrated Global Ocean Services System, and other existing systems to further the knowledge and understanding of climate and the prediction of climate and climate change. Efforts to date have established planning groups to address needs and requirements for atmospheric, oceanic, and land-surface data. Upper-air and surface-observing networks are being defined to provide basic measurements for the GCOS. Links to existing organizational structures are being established, and a high priority has been given to making observational enhancements.

Global Data Processing System (GDPS)

The purpose of GDPS is to make available all processed information required for both real-time and non-real-time applications. GDPS provides products and processed information, based on recent advances in atmospheric science, using powerful numerical computer methods. Members have real-time, unrestricted access through the GTS to GDPS products which allow all countries to benefit from their participation in the WWW.

The GDPS is organized as a three-level system. It consists of World Meteorological Centers (WMC), Regional/Specialized Meteorological Centers (RSMC), and National Meteorological Centers (NMC). NMCs carry out GDPS functions at the national level. In general, real-time functions of the system involve preprocessing of data including real-time quality control, analysis, and prognosis, including derivation of appropriate meteorological parameters. The non-real-time functions include data collection and archival, and additional quality control, storage, and retrieval, to include cataloging observational data and processed information for operational and special applications and for research.

WMCs are located in Melbourne, Moscow, and Washington; they provide products used for general short, medium, and long-range weather forecasts on a global scale. Melbourne specializes in forecast products for the Southern Hemisphere.

The RSMCs with geographical specialization are located at Algiers, Algeria; Antananarivo, Malagasy; Beijing, China; Bracknell, United Kingdom; Brasilia, Brazil; Buenos Aires, Argentina; Cairo, Egypt; Dakar, Senegal; Darwin, Australia; Jeddah, Saudi Arabia; Khabarovsk, Russia; Lagos, Nigeria; Melbourne, Australia; Miami, Florida; Montreal, Canada; Moscow, Russia; Nairobi, Kenya; New Delhi, India; Novosibirsk, Russia; Offenbach, Germany; Rome, Italy; Tashkent, Uzbekistan; Tokyo, Japan; Tunis, Tunisia; Washington, D.C.; and Wellington, New Zealand.

RSMCs with activity specialization are found at The European Center for Medium Range Forecasts; Réunion Island (France); Toulouse, France; and Washington, D.C.

The regional centers at Bracknell, Miami, Montreal, New Delhi, and Tokyo have dual geographical and activity specialization responsibilities. These centers provide regional products used for short and medium-range forecasting of small, mesoscale, and large scale meteorological systems by WMCs. Products of RSMCs can be used by members at the national level for further processing or interpretation to provide assistance or service to users.

In the World Area Forecast System (WAFS), two centers (Washington and London) are designated by the ICAO as World Area Forecast Centers (WAFC). They issue upper-wind and temperature forecasts with global coverage to associated Regional Area Forecast Centers (RAFC). The regional centers also prepare and distribute forecasts of weather elements defined by ICAO as significant weather.

In the planned implementation of the final phase, the two WAFCs would prepare and issue computer-based wind and temperature forecasts as they now do. In addition, those centers will automate all of the significant weather elements. While some of these elements are now prepared automatically, others are developed through forecaster-initiated graphic interaction.

The dissemination of aeronautical information via global satellite broadcast began in 1995. The U.S. provides the links to two of the three satellites specified in the system.

Global Telecommunication System (GTS)

The GTS provides communication services for the collection, exchange, and distribution of observational data and processed information among the WMCs, RSMCs, and NMCs of the WWW to meet the member needs for real-time or quasi-real-time exchange of information for both operational and research purposes. The GTS also supports other WMO programs, joint programs with other international organizations, and environmental programs as decided by the WMO Congress and is organized on three levels:

- The Main Telecommunication Network (MTN).
- The Regional Meteorological Telecommunication Networks (RMTN).
- The National Meteorological Telecommunication Networks (NMTN).

The GTS is supported by the telecommunications functions of the WMCs, Regional Telecommunications Hubs (RTH), RSMCs, and NMCs.

The MTN links the WMCs at Melbourne, Moscow, and Washington with the RTHs at Algiers; Beijing; Bracknell; Brasilia; Buenos Aires; Cairo; Dakar; Jeddah; Maracay, Venezuela; Nairobi; New Delhi; Norrköping, Sweden; Offenbach; Prague; Rome; Sofia; Tokyo; Toulouse; and Wellington. It ensures the rapid and reliable exchange of observational data and processed information required by the members.

The RMTNs consist of an integrated system of links which interconnects RTHs, NMCs, and RSMCs to WMCs. The RMTNs provide for the collection of observational data and the selective distribution of meteorological information to member nations.

In summary, the GTS enables the NMCs to receive and distribute observational data and meteorological information to meet the requirements of members. Ongoing WWW activities for FY 1996-1997 include:

- GTS network redesign to take into consideration new technical opportunities, such as Internet-like services.
- Improvement of the capacity of MTN links and inclusion of graphics (e.g., Washington-Brasilia, Washington-Buenos Aires, Washington-Tokyo).
- Continued implementation of satellite-serviced data collection platforms to enhance the collection of meteorological data from upper-air and surface-observing sites.
- Continued implementation of satellite direct-readout stations that are compatible with polar-orbiting satellites and the WEFAX (weather facsimile) component of the geostationary satellites.

Voluntary Cooperation Program (VCP)

From the beginning of WWW, it was clear that all countries need better weather observations and improved communications systems. To help remedy deficiencies and to fully implement the WWW, the WMO established a Voluntary Assistance Program in 1967. The name of the program was changed to Voluntary Cooperation Program (VCP) in 1979.

The WMO-VCP helps the developing countries to implement the WWW program by providing equipment, services, and long-term and short-term study fellowships. Since the inception of the VCP, the U.S. has provided short-term fellowships in electronics, communications, operation and maintenance of weather data collection systems and electrolytic hydrogen generators, and tropical meteorology and river flood forecasting to students from more than 50 countries. Long-term fellowships, through which the students receive baccalaureate or advanced degrees, have been completed by candidates from over 48 countries. Highest priorities are given to those facilities needed to support the global aspects of WWW. The goal of VCP is to eliminate deficiencies in global observations and communications and to establish ground-readout stations for Automatic Picture Transmission (APT) reception so that the countries may benefit more fully from weather satellite services.

The DOS provides funding for VCP projects with NOAA administering and carrying out programs designed to aid meteorological/hydrological and climate projects in recipient countries. In FY 1996, DOS funding for WWW/VCP programs was cut to $1.3 million.

VCP Projects for FY 1996-1997 include:

- Implementation and updating of surface and upper-air observational programs in the tropics, the Southern Hemisphere, and Africa as resources and priorities permit.
- Support of WAFS implementation and utilization.
- Continued support for the implementation of VCP projects in Latin America and the Caribbean areas in support of the hurricane and tropical storm programs.

BILATERAL AND REGIONAL INTERNATIONAL COOPERATIVE PROGRAMS

United States - Peoples Republic of China (PRC) Protocol in the Field of Atmospheric Science and Technology

For more than 15 years, this protocol has covered a broad area of research and operational activities in the field of atmospheric science and technology. Program areas include the following:

- Climate Studies (which includes scientific experiments and research on monsoons and Tropical Ocean Global Atmosphere (TOGA)).
- Mesoscale Meteorology (which includes operational techniques for forecasting torrential rains).
- Training and Participation.
- Atmospheric Chemistry.
- Satellite Meteorology and Meteorological Satellites.
- Modernization Activities.

The cooperative activities between the U.S. and China under this program have decreased over the

past 2 years. The main cooperative activity has been within the Training and Participation Program with a dozen Chinese scientists and trainees working at NOAA facilities for up to 18 months.

U.S.-Mexico Meteorological and Hydrologic Program

The U.S. and Mexico have signed a new cooperative agreement enhancing the scope of their cooperation in the fields of meteorology, hydrology, and climatology which began over 50 years ago. The new agreement facilitates the following activities:

- The establishment, operation, maintenance, and repair of meteorological and hydrologic observation systems in Mexico.
- The international dissemination of observations from these systems.
- The exchange of meteorological, hydrologic, and related data and products between the U.S. and Mexico.
- The cooperation necessary to assure prompt transmission through telecommunications networks of these data and products.
- The coordination and training related to the exchange of data and products between the National Meteorological Services of both countries.

Over the past few years, the Mexican Meteorological Service has undergone an impressive modernization effort, which included upgrading upper-air observation systems, installing Doppler weather radars, and establishing hundreds of automatic weather stations. This cooperative agreement will facilitate the exchange of data and information to the benefit of both countries.

APPENDIX F

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AAS | Advanced Automation System (FAA) |
| ABCS | Army Battle Command System (Army) |
| AC | Active Component (DOD) |
| ACARS | ARINC Communication Addressing and Reporting System |
| ACE | Aviation Combat Element (USMC) |
| ACFP | Advanced Computer Flight Plan (AF) |
| ACP | Atmospheric Chemistry Program (DOE) |
| ACRIM | Active Cavity Radiometer Irradiance Monitor (NASA) |
| ACU | Acquisition Control Unit |
| ADAS | AWOS/ASOS Data Acquisition System (FAA) |
| ADEOS | Advanced Earth Observing System (Japan) |
| ADFC | Altimetry Data Fusion Center (Navy) |
| ADLP | Aeronautical Data Link Program (FAA) |
| ADWS | Automatic Digital Weather Switch (AF) |
| AESS | Allied Environmental Support System (Navy) |
| AF | Air Force (USAF) |
| AFB | Air Force Base |
| AFCCC | Air Force Combat Climatology Center |
| AFGWC | Air Force Global Weather Center |
| AFOS | Automation of Field Operations and Services (NOAA/NWS) |
| AFSS | Automated Flight Service Station (FAA) |
| AFWA | Air Force Weather Agency |
| AGFS | Aviation Gridded Forecast System (FAA) |
| AIP | Airport Improvement Program (FAA) |
| AIRMoN | Atmospheric Integrated Research Monitoring Network (NOAA/OAR) |
| AIRS | Atmospheric Infrared Sounder (NASA) |
| AL | Aeronomy Laboratory (NOAA/ERL) |
| ALDARS | Automated Lightning Detection and Reporting System (DOI) |
| ALDS | Automatic Lightning Detection System (DOI) |
| AMA | AWIS Meteorological Applications (OFCM) |
| AMC | Army Materiel Command (Army) |
| AMDAR | Automatic Meteorological Data and Reporting |
| AMOS | Automated Meteorological Observing System (Navy) |
| AMSR | Advanced Microwave Scanner Radiation (NASA) |
| AMSS | Automatic Meteorological Sensors System (Army) |
| AMSU | Advanced Microwave Sounding Unit |
| AMU | Applied Meteorology Unit (NASA) |
| ANC | Air Navigation Commission (ICAO) |
| ANG | Air National Guard |
| AOC | Aircraft Operations Center (NOAA) |
| AOML | Atlantic Oceanographic and Meteorological Laboratory (NOAA/ERL) |
| APT | Automatic Picture Transmission |
| ARAC | Atmospheric Release Advisory Capability (DOE) |
| ARG | Accident Response Group (DOE) |
| ARGOS | French Satellite Data Collection System |
| ARINC | Aeronautical Radio Incorporation |
| ARL | Army Research Laboratory (Army)/Air Resources Laboratory (NOAA) |
| ARM | Atmospheric Radiation Monitoring (DOE) |

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|---|---|
| ARNG | Army National Guard |
| ARO | Army Research Office |
| ARS | Agricultural Research Service (USDA) |
| ARSPACE | Army Space Command |
| ARSR | Air Route Surveillance Radar (FAA) |
| ARTCC | Air Route Traffic Control Center (FAA) |
| ARTYMET | Artillery Meteorological (Army) |
| ASAP | Automatic Shipboard Aerological Program (WWP) |
| ASCOT | Atmospheric Studies in Complex Terrain (DOE) |
| ASDAR | Aircraft to Satellite Data Relay |
| ASOS | Automated Surface Observing System |
| ASR | Airport Surveillance Radar (FAA) |
| ASTER | Advanced Spaceborne Thermal Emission and Reflection Radiometer |
| ATC | Air Traffic Control (FAA) |
| ATCCS | Army Tactical Command and Control System |
| ATM | Asynchronous Transfer Mode |
| ATDD | Atmospheric Turbulence and Diffusion Division (NOAA/ARL) |
| AVAPS | Atmospheric Vertical Profiling System (AF) |
| AVHRR | Advanced Very High Resolution Radiometer (NOAA) |
| AVO | Alaskan Volcano Observatory (FAA) |
| AWARDS | Agricultural Water Resources Decision Support (DOI/BUREC) |
| AWC | Aviation Weather Center (NOAA/NCEP) |
| AWDS | Automated Weather Distribution System (AF) |
| AWE | Advance Warfighting Experiment (Army) |
| AWIPS | Advanced Weather Interactive Processing Systems (NOAA) |
| AWIS | Automated Weather Information Systems |
| AWN | Automated Weather Network (AF) |
| AWOS | Automated Weather Observing System (FAA) |
| AWS | Air Weather Service (AF) |
| BBS | Bulletin Board System |
| BE | Battlefiedl Environment (Army) |
| BED | Battlefield Environment Directorate (Army) |
| BOREAS | Boreal Ecosystem-Atmosphere Study (NASA) |
| BLM | Bureau of Land Management (DOI) |
| BUFR | Binary Universal Form for the Representation of Meteorological Data |
| BUREC | Bureau of Reclamation (DOI) |
| C2 | Command and control (DOD) |
| C4I | Command, Control, Communications, Computer and Information (DOD) |
| CAAM | Computer Assisted Artillery Meteorology (Army) |
| CAP | Civil Air Patrol |
| CARDS | Comprehensive Aerological Reference Data Set (NOAA/NCDC) |
| CAWIS | Committee for Automated Weather Information Systems (OFCM) |
| CDA | Command and Data Acquisition |
| CDAS | Command and Data Acquisition Station |
| CDCL | Climate Diagnostics Center Laboratory (NOAA/ERL) |
| CDFS | Cloud Depiction and Forecast System (AF) |
| CDMS | Centralized Data Management System (AF) |
| CDR | Critical Design Review |
| CECOM | Communications and Electronics Command (Army) |
| CEMSCS | Central Environmental Satellite Computer System (NOAA/NESDIS) |

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|---|---|
| CENR | Committee on Environment and Natural Resources |
| CERES | Clouds and Earth's Radiant Energy System (NASA) |
| CFEP | Communications Front-End Processor (AF) |
| CGCP | Climate and Global Change Program (NOAA) |
| CHANCES | Climatological and Historical Analysis of Clouds for Environmental Simulations (AF) |
| CHAMMP | Computer Hardware Advanced Mathematics and Model Physics (DOE) |
| CIDE | Communications Interfaces and Data Exchange (OFCM) |
| CINC | Commanders-in-Chief (DOD) |
| CIRA | Cooperative Institute for Research in the Atmosphere (NOAA) |
| CMDL | Climate Monitoring and Diagnostics Laboratory (NOAA/ERL) |
| COADS | Comprehensive Ocean-Atmosphere Data Set (NOAA/NCDC) |
| COAMPS | Coupled Oceanographic and Atmospheric Model (Navy) |
| COARE | Coupled Ocean-Atmosphere Response Experiment |
| COE | Corps of Engineers (Army) |
| COMEDS | CONUS Meteorological Data System (AF) |
| COMET | Cooperative Program for Operational Meteorology, Education and Training |
| CONUS | Continental United States |
| COPC | Committee for Operational Processing Centers (OFCM) |
| COTS | Commercial Off-the-Shelf |
| CPC | Climate Prediction Center (NOAA/NCEP) |
| CRREL | Cold Regions Research and Engineering Laboratory (Army) |
| CRSP | Commercial Remote Sensing Program (NASA) |
| CS | Climate Services (OFCM) |
| CSA | Chief of Staff of the Army |
| CSREES | Cooperative State Research, Education, and Extensive Service (USDA) |
| CWSU | Center Weather Service Unit (FAA) |
| CY | Calendar Year |
| DCP | Data Collection Package |
| DCS | Data Collection System (NOAA/NESDIS) |
| DDN | Defense Data Network |
| DF | direction finder |
| DISS | Digital Ionospheric Sounding System (AF) |
| DLP | Data Link Processor (FAA) |
| DMSO | Defense Modeling and Simulation Office (AF) |
| DMSP | Defense Meteorological Satellite Program (AF) |
| DOC | Department of Commerce |
| DOD | Department of Defense |
| DOE | Department of Energy |
| DOI | Department of Interior |
| DOMSAT | Domestic Communications Satellite |
| DOS | Department of State |
| DOT | Department of Transportation |
| DPS | Distributed Processing System |
| DRGS | Direct readout ground stations (DOI) |
| DRWP | Doppler Radar Wind Profiler (NASA) |
| DTR | Diurnal Temperature Range |
| DTSS | Digital Topographic Support System (Army) |
| DUAT | Direct User Access Terminal (FAA) |
| E2DIS | Environmental Effects for Distribution Interactive Simulation (AF) |
| EDIS | Environmental Data and Information Service (NOAA) |

| | |
|---|---|
| EMC | Environmental Modeling Center (NOAA/NCEP) |
| ENSO | El Niño-Southern Oscillation |
| EO | electro-optical |
| EOS | Earth Observing System (NASA) |
| EOSDIS | EOS Data and Information System (NASA) |
| EOSP | Earth Observing Scanning Polarimeter (NASA) |
| EOTDA | electro-optical tactical decision aid (AF) |
| EPA | Environmental Protection Agency |
| ERB | Earth Radiation Budget |
| ERC | Extended Research Checkout |
| ERL | Environmental Research Laboratories (NOAA) |
| ESD/IPC | Environmental Satellite Distribution/Interactive Processing Center |
| ESSP | Earth System Science Pathfinders (NASA) |
| ETL | Environmental Technology Laboratory (NOAA/ERL) |
| ETM+ | Enhanced Thematic Mapper Plus (NASA) |
| EUMETSAT | European Organization for the Exploitation of Meteorological Satellites |
| EUSA | Eighth U.S. Army |
| EUV | Extreme Ultraviolet |
| EXCIMS | Executive Council for Modeling and Simulation |
| FAA | Federal Aviation Administration |
| FALOP | Forward Areal Limited Observing Program (DOD/USAF) |
| FCMSSR | Federal Committee for Meteorological Services and Supporting Research |
| FEMA | Federal Emergency Management Agency |
| FHWA | Federal Highway Administration |
| FMF | Fleet Marine Force |
| FMH | Federal Meteorological Handbook (OFCM) |
| FNMOC | Fleet Numerical Meteorology and Oceanography Center (Navy) |
| FOSDIC | Film Optical Sensing Device for Input to Computer |
| FORSCOM | U.S. Army Forces Command |
| FRD | Field Research Division (NOAA/ARL) |
| FRERP | Federal Radiological Emergency Response Plan (DOE) |
| FRMAC | Federal Radiological Monitoring and Assessment Center (DOE) |
| FS | Forest Service (USDA) |
| FSAS | Flight Service Automation System (FAA) |
| FSDPS | Flight Service Data Processing System (FAA) |
| FSL | Forecast Systems Laboratory (NOAA/ERL) |
| FTE | Full-time Equivalent |
| FTP | File Transfer Protocol |
| FSS | Flight Service Station (FAA) |
| FU | Forecast Unit |
| FY | fiscal year |
| G-IV | Gulfstream IV (NOAA) |
| GAC | Global Area Coverage |
| GAO | General Accounting Office |
| GCCS | Global Command and Control System |
| GCIP | GEWEX Continental-scale International Project (DOI) |
| GCOS | Global Climate Observing System |
| GCPS | Global Climate Perspectives System |
| GCRP | Global Change Research Program |
| GDPS | Global Data Processing System (WWP) |

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|---|---|
| GEOSAR | Geostationary Earth Orbit Search and Rescue (NOAA/NESDIS) |
| GEWEX | Global Energy and Water-Balance Experiment |
| GFDL | Geophysical Fluid Dynamics Laboratory (NOAA/ERL) |
| GFMPL | Geophysical Fleet Mission Program Library (Navy) |
| GHCN | Global Historical Climatology Network |
| GIN | Geomagnetic Information Nodes (DOI) |
| GIS | Geographic Information System |
| GISS | Goddard Institute for Space Studies (NASA) |
| GMS | Geostationary Meteorological Satellite (Japan) |
| GODAR | Global Oceanographic Data Archaeology and Rescue |
| GOES | Geostationary Operational Environmental Satellite (NOAA) |
| GOS | Global Observing System (WWP) |
| GPCP | Global Precipitation Climatology Program |
| GPS | Global Positioning System |
| GPS/MET | GPS for Meteorology |
| GRIB | Gridded Binary (FM 92-X Ext.) |
| GSAS | Geostationary Satellite Archive System (NOAA/NESDIS) |
| GSFC | Goddard Space Flight Center (NASA) |
| GTS | Global Telecommunications System (WWP) |
| GTSPP | Global Temperature-Salinity Pilot Project |
| GTWAPS | Global Theater Weather Analysis and Prediction System (AF) |
| GWDS | Graphics Weather Displays Systems (FAA) |
| HDSS | Hierarchical Data Storage System |
| HELSTF | High Energy Laser System Test Facility (Army) |
| HF | high frequency |
| HFRB | high frequency radio broadcast |
| HIRS/2 | High-resolution Infrared Sounder (NOAA/NESDIS) |
| HMMWV | High Mobility Multi-purpose Wheeled Vehicle (Army) |
| HPC | Hydrometeorological Prediction Center (NOAA/NCEP) |
| HPCC | High Performance Computing and Communications |
| HRD | Hurricane Research Division (NOAA/ERL) |
| HRPT | High Resolution Picture Transmission (NOAA/NESDIS) |
| IAMS | Initial Attack Management System (DOI) |
| ICAO | International Civil Aviation Organization |
| ICMSSR | Interdepartmental Committee for Meteorological Services and Supporting Research |
| ICSU | International Council of Scientific Unions |
| IEW | Intelligence and Electronic Warfare (Army) |
| IFM | Ionospheric Forecast Model (AF) |
| IHC | Interdepartmental Hurricane Conference (OFCM) |
| IIP | International Ice Patrol (USCG) |
| IITA | Information Infrastructure Technology and Applications (NASA) |
| IMDES | Interdepartmental Meteorological Data Exchange System |
| IMETS | Integrated Meteorological System (Army) |
| IMOSS | Interim Mobile Oceanography Support System (Navy) |
| IMS | Ionospheric Measuring System (AF) |
| INEL | Idaho National Engineering Laboratory (DOE) |
| INSAT | India's Indian National Satellite (WWP) |
| IPACS | Integrated Polar Acquisition and Control Subsystem (NOAA/NESDIS) |
| IPCC | Intergovernmental Panel on Climate Change (WWP) |
| IPB | Intelligency Preparation of the Battlefield (Army) |
| IPO | Integrated Program Office |

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|---|---|
| IR | infrared |
| IRAMSS | IREMBASS with AMSS (Army) |
| IREMBASS | Improved Remotely Monitored Battlefield Sensor System (Army) |
| ISCCP | International Satellite Cloud Climatology Program |
| ISIS | Integrated Solar Irradiance Study (NOAA) |
| ITS | Intelligent Transportation System (FHWA) |
| ITWS | Integrated Terminal Weather System (FAA) |
| IWEDA | Integrated Weather Effects Decision Aid (Army) |
| IWRS | Improved Weather Reconnaissance System |
| IWRPC | Improved Weather Reconnaissance System Program Council |
| J-TRWS | Joint TESS Remote Workstation (Navy) |
| JAG | Joint Action Group |
| JASL | Joint Archive for Sea Level |
| JAWOP | Joint Automated Weather Observation Program (OFCM) |
| JCRMOD | Joint Center for Research in the Management of Ocean Data |
| JEDA | Joint Environmental Data Analysis |
| JGOFS | Joint Global Ocean Flux Study |
| JMCIS | Joint Maritime Command Information system (USMC) |
| JMFU | Joint METOC Forecast Unit |
| JMOC | Joint METOC Operations Center |
| JMS | Joint METOC Segment (Navy) |
| JMV | Joint METOC Viewer (Navy) |
| JPL | Joint Propulsion Laboratory (NASA) |
| JTWC | Joint Typhoon Warning Center (AF/Navy) |
| KM | Kilometer |
| KMR | Kwajalein Missile Range (Army) |
| KSC | Kennedy Space Center |
| LAC | Local Area Coverage |
| LAN | local area network |
| LCD | Local Climatological Data |
| LCM | life-cycle management |
| LDAR | Lightning Detection and Ranging (NASA) |
| LITE | Lidar In-space Technology Experiment (NASA) |
| LLNL | Lawrence Livermore National Laboratory (DOE) |
| LLWAS | Low Level Wind Shear Alert System (FAA) |
| LLWAS-NE | LLWAS-Network Expansion (FAA) |
| LOD2 | Lightweight Omega Digital Dropwindsonde (AF) |
| LRGS | local readout ground stations (DOI) |
| MACOM | Major Army Command |
| MAGTF | Marine Air Ground Task Force |
| MAJCOM | Major Command (AF) |
| MAPS | Measurement of Air Pollution From Satellite (NASA) |
| MARD | Modernization and Associated Restructuring Demonstration (NOAA) |
| MC | Meteorological Codes |
| MCDW | Monthly Climate Data for the World |
| MCSST | Multichannel Sea Surface Temperature (Navy) |
| MDS | Meteorological Distribution System (Army) |
| MEPED | Medium Energy Proton and Electron Detector |
| MES | Marine Environmental Services (OFCM) |

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|---|---|
| MET | Mobile Environmental Teams (Navy)<br>Meteorological Teams (Army) |
| METAR | Aviation Route Weather Report |
| METMF(R) | Meteorological Mobile Facility (Replacement) (Navy) |
| METOC | Meteorological and Oceanographic (DOD) |
| MHG | Meteorological Hydrogen Generator (Army) |
| MHS | Microwave Humidity Sensor (NASA) |
| MIDDS | METOC Integrated Data Display System (Navy) |
| MIMR | Multifrequency Imaging Microwave Radiometer (NASA) |
| MISR | Multi-Angle Imaging Spectrometer (NASA) |
| MIST | Meteorological Information Standard Terminal (AF) |
| MME | Mobile Meteorological Equipment (OFCM) |
| MMS | Meteorological Measuring System (Army)<br>Mineral Management Service (DOI) |
| MMW | Millimeter Wave (Army) |
| MPS | Meteorological Profiler System (Army) |
| MOA | Memorandum of Agreement |
| MO&DA | Mission Operations and Data Analysis (NASA) |
| MODIS | Moderate Resolution Imaging Spectrometer (NASA) |
| MOPITT | Measurement of Pollution in the Troposphere (NASA) |
| MOU | Memorandum of Understanding (Army) |
| MOSS | Mobile Oceanography Support System (Navy) |
| MRS | Miniature Rawinsonde System (Navy) |
| MS | Monitoring the Stratosphere (OFCM) |
| MSCP | Meteorological and Climate Services Project (DOE) |
| MSL | mean sea level |
| MSM | Magnetospheric Specification Model (AF) |
| MST | Meteorological Support Teams (USMC) |
| MSU | Microwave Sounding Unit |
| MTF | Model test facility |
| MTN | Main Telecommunications Network (WWP) |
| MTPE | Mission to Planet Earth (NASA) |
| MWP | Meteorologist's Weather Processor (FAA) |
| MWSS | Marine Wing Support Squadron |
| M1FC | Model 1 Full Capacity (FAA) |
| NADIN | National Airspace Data Interchange Network (FAA) |
| NAOS | North American Atmospheric Observing System (NOAA) |
| NARSTO | North American Research Strategy on Tropospheric Ozone (EPA) |
| NAS | National Airspace System (FAA) |
| NASA | National Aeronautics and Space Administration |
| NASS | National Agricultural Statistics Service (USDA) |
| NATCOM | National Communications Center (FAA) |
| NAVAF | Navy-Air Force |
| NAVICECEN | Naval Ice Center |
| NAVOCEANO | Naval Oceanographic Office |
| NAWPC | National Aviation Weather Program Council (OFCM) |
| NAWPP | National Aviation Weather Program Plan |
| NBC | Nuclear, Biological, and Chemical (Army) |
| NC | NOAA Corps Operations |
| NCAR | National Center for Atmospheric Research |
| NCDC | National Climatic Data Center (NOAA/NESDIS) |

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| NCEP | National Center for Environmental Prediction (NOAA/NWS) |
| NCO | NCEP Central Operations (NOAA/NCEP) |
| NDBC | National Data Buoy Center (NOAA/NWS) |
| NDI | non-developmental item |
| NEMOC | Naval European Meteorology and Oceanography Center |
| NESDIS | National Environmental Satellite, Data, and Information Service (NOAA) |
| NESS | National Environmental Satellite Service (NOAA) |
| NEST | Nuclear Emergency Search Team (DOE) |
| NEXRAD | Next Generation Weather Radar (WSR-88D) |
| NFDRS | National Fire Danger Rating System (DOI/BLM) |
| NGDC | National Geophysical Data Center (NOAA/NESDIS) |
| NGIC | National Geomagnetic Information Center (DOI) |
| NHC | National Hurricane Center (NOAA/NWS) |
| NHOP | National Hurricane Operations Plan (OFCM) |
| NIC | National Ice Center (DOT/USCG) |
| NIFC | National Interagency Fire Center (DOI) |
| NITES | Naval Integrated Tactical Environmental Subsystem |
| NLMOC | Naval Atlantic Meteorology and Oceanography Center |
| NMC | National Meteorological Center(s) (WWP) |
| NMOC | Naval Meteorology and Oceanography Command |
| NMP | New Millenium Program (NASA) |
| NMTN | National Telecommunications Network (WWP) |
| NPMOC | Naval Pacific Meteorology and Oceanography Center |
| NOAA | National Oceanic and Atmospheric Administration |
| NODC | National Oceanographic Data Center (NOAA/NESDIS) |
| NODDES | Naval Oceanographic Data Distribution and Expansion System |
| NODDS | Naval Oceanographic Data Distribution System |
| NOGAPS | Navy Operational Global Atmospheric Prediction System |
| NOHRSC | National Operational Hydrological Remote Sensing Center (DOI) |
| NORAPS | Navy Operational Regional Atmospheric Prediction System |
| NOS | National Ocean Service (NOAA) |
| NOTAM | Notice to Airmen |
| NOWS | NVG Operations Weather Software (AF) |
| NPL | NOAAPORT Liaison (OFCM) |
| NPMOC | Naval Pacific Meteorology and Oceanography Center |
| NPOESS | National Polar-orbiting Operational Environmental Satellite System |
| NPS | National Park Service (DOI) |
| NRC | Nuclear Regulatory Commission |
| NRCS | Natural Resources Conservation Service (USDA) |
| NRL | Naval Research Laboratory |
| N-ROSS | Navy Remote Sensing Satellite |
| NSCAT | NASA Scatterometer (NASA) |
| NSF | National Science Foundation |
| NSIDC | National Snow and Ice Data Center |
| NSSFC | National Severe Storms Forecast Center (NOAA) |
| NSSL | National Severe Storms Laboratory (NOAA) |
| NSTC | National Science and Technology Council |
| NSWP | National Space Weather Program (OFCM) |
| NTCIP | National Transportation Communications for ITS Protocol (FHWA) |
| NTS | Nevada Test Site (DOE) |
| NTSB | National Transportation Safety Board |

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|---|---|
| NV | Nevada Operations Office (DOE) |
| NVDS | NOAA Virtual Data System |
| NVG | night vision goggle (DOD) |
| NWLON | National Water-Level Observation Network (NOAA/NOS) |
| NWS | National Weather Service |
| OAML | Oceanographic and Atmospheric Master Library (Navy) |
| OAR | Office of Oceanic and Atmospheric Research (NOAA) |
| OASIS | Oceanographic and Atmospheric Support and Information System (Navy)/ Operational and Supportability Implementation System (FAA) |
| OCAP | Operating Consortium of ASDAR Participants (WWP) |
| ODCSINT | Office of the Deputy Chief of Staff for Intelligence (Army) |
| ODCSOPS | Office of the Deputy Chief of Staff for Operations (Army) |
| OFCM | Office of the Federal Coordinator for Meteorology |
| OGP | Office of Global Programs (NOAA) |
| OMB | Office of Management and Budget |
| ONR | Office of Naval Research |
| OPARS | Optimum Path Aircraft Routing System (Navy) |
| OR | Oak Ridge Operations Office (DOE) |
| ORA | Office of Research and Applications (NOAA/NESDIS) |
| ORD | Operational Requirements Documents (Navy) |
| ORAU | Oak Ridge Association Universities |
| OSDPD | Office of Satellite Data Processing and Distribution (NOAA/NESDIS) |
| OSF | Operational Support Facility |
| OSO | Office of Satellite Operations (NOAA/NESDIS) |
| OTW | Owning the Weather (Army) |
| OTIS | Optimum Thermal Interpolation System (Navy) |
| OTSR | Optimum Track Ship Routing (Navy) |
| OWSE | Operational World Weather Watch Systems Evaluation (WWP) |
| P3I | Preplanned Product Improvement |
| PACS | Polar Acquisition and Control Subsystem |
| PC | Program Council (OFCM) |
| PCGRAFAX | PC-based High Frequency Facsimile System (Navy) |
| PCMDI | Program for climate Model Diagnosis and Intercomparison (DOE) |
| PD | Project Director (Army) |
| PICS | PC Imaging Communications System (Navy) |
| PIREP | Pilot Report |
| PL/GP | Phillips Laboratory, Geophysics Directorate (DOD/AFSC) |
| PMC | Program Management Committee (NOAA) |
| PMEL | Pacific Marine Environmental Laboratory (NOAA/ERL) |
| PNL | Pacific Northwest Laboratories (DOE) |
| POM | Princeton Ocean Model (Navy) |
| POPS | Primary Oceanographic Prediction System (Navy) |
| PORTS | Physical Oceanographic Real-Time System (NOAA/NOS) |
| PRC | Peoples Republic of China |
| PRECP | Processing of Emissions by Clouds and Precipitation (DOE) |
| PSDA | Post-Storm Data Acquisition (OFCM) |
| PUP | Principal User Processor |
| PW | Precipitable water |
| R&A | Research and Analysis |
| R&D | Research and Development |

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|---|---|
| RAFC | Regional Area Forecast Center (WWP) |
| RAMDIS | RAMM Branch Advanced Meteorological Satellite Demonstration and Interpretation System (NASA) |
| RAP | Radiological Assistance Program (DOE) |
| RASS | Radio Acoustic Sounding System |
| RAWS | Remote Automatic Weather Station (USDA/DOI) |
| RC | Reserve Component (DOD) |
| RDTE | Research and Development, Test and Evaluation (Army) |
| RFC | River Forecast Center (NOAA/NWS) |
| RFO | Rocky Flats Office (DOE) |
| RMTN | Regional Telecommunications Network (WWP) |
| RMWS | Remote Miniature Weather Sensor (Army) |
| RSMC | Regional/Specialized Meteorological Centers (WWP) |
| RTH | Regional Telecommunications Hub (WWP) |
| RUC | Rapid Update Cycle (NOAA) |
| RVR | Runway Visual Range (FAA) |
| SAA | Satellite Active Archive<br>Snow Accumulation Algorithm (DOI/BLM) |
| SAMS | Surface Automated Meteorological System |
| SARSAT | Search and Rescue Satellite Aided Tracking |
| SATCOM | Satellite Communications System (NOAA) |
| SBUV | Solar Backscatter Ultraviolet Instrument (NOAA/NESDIS) |
| SCAR | Smoke, Clouds, and Radiation (NASA) |
| SDHS | Satellite Data Handling System (AF) |
| SEC | Space Environmental Center (NOAA/NCEP) |
| SELDADS | Space Environmental Laboratory Data Acquisition and Display System (NOAA) |
| SEM | Space Environment Monitor (NOAA) |
| SEON | Solar Electro-Optical Network (AF) |
| SERCAA | Support of Environmental Requirements Cloud Analysis and Archive (AF) |
| SERDP | Strategic Environmental Research and Development Program (AF) |
| SETT | Space Environmental Technology Transition (AF) |
| SEU | Single event upsets |
| SFDF | Satellite Field Distribution Facility (NOAA/NWS) |
| SFMR | Stepped Frequency Microwave Radiometer |
| SIR-C | Shuttle Imaging Radar-C (NASA) |
| SMOOS | Shipboard Meteorological and Oceanographic Observing Sensor (Navy) |
| SMS | Semi-Automatic Meteorological Station (Army) |
| SNOTEL | Snow Telemetry |
| SOCC | Satellite Operations Control Center (NOAA/NESDIS) |
| SOF | Special Operations Forces |
| SORD | Special Operations and Research Division (NOAA/ARL) |
| SPAWARS | Space and Naval Warfare Systems Command |
| SPC | Storm Prediction Center (NOAA/NCEP) |
| SPECI | Aviation Selected Special Weather Report |
| SPOSC | Shared Processing Operations Steering Committee |
| SR | Savannah River (DOE) |
| SRBL | Solar Radio Burst Locator (AF) |
| SRDC | Surface Reference Data Center (NOAA/NESDIS) |
| SSDC | Space and Strategic Defense Command (Army) |
| SSM/I | Special Sensor Microwave (NASA) |
| SRS | Savannah River Site (DOE) |

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|---|---|
| SSU | Stratospheric Sounding Unit (NOAA) |
| STIWG | Satellite Telemetry Interagency Working Group (OFCM) |
| STT | Small Tactical Terminal (AF) |
| SWIM | Solar Wind Interplanetary Measurements (AF) |
| SWO | Staff weather officer |
| SXI | Solar X-Ray Imager (AF) |
| $T^2$ | Technology transfer |
| TAF | Aerodrome Forecast |
| TAMSS | Target Area Meteorological Sensor System (Army) |
| TAO | Tropical Atmosphere Ocean |
| TACWX | Tactical weather (DOD) |
| TDA | Tactical Decision Aid (Army) |
| TDWR | Terminal Doppler Weather Radar (FAA) |
| TEC | Topographic Engineering Center (Army) |
| TECOM | Test and Evaluation Command (Army) |
| TED | Total Electron Detector |
| TESS | Tactical Environmental Support System (Navy) |
| TF | Terminal Forecast |
| TIROS | Television Infrared Observation Satellite (NOAA/NESDIS) |
| TMI | TRMM Microwave Imager (NASA) |
| TOE | Table of Organization and Equipment (Army) |
| TOGA | Tropical Ocean and Global Atmosphere |
| TOMS | Total Ozone Mapping Spectrometer (NASA) |
| TOVS | TIROS N Operational Vertical Sounder (NOAA/NESDIS) |
| TPC | Tropical Prediction Center (NOAA/NCEP) |
| TRACON | Terminal Radar Approach Control (FAA) |
| TRADOC | Training and Doctrine Command (Army) |
| TRB | Test Review Board |
| TRMM | Tropical Rainfall Measuring Mission (NASA) |
| TWR | Tactical Weather Radar (AF) |
| UARS | Upper Atmosphere Research Satellite (NASA) |
| UAV | unmanned/uncrewed aerial vehicle (Army/NASA) |
| UCAR | University Corporation for Atmospheric Research |
| UN | United Nations |
| UNEP | United Nations Environment Program (WWP) |
| URI | University Research Institute (Army) |
| USA | U.S. Army |
| USAF | U.S. Air Force |
| USAFAS | U.S. Army Field Artillery School |
| USAIC | U.S. Army Intelligence Center |
| USAIC&FH | U.S. Army Intelligence Center & Fort Huachuca |
| USAKA | U.S. Army Kwajalein Atoll |
| USAR | U.S. Army Reserve |
| USAREUR | U.S. Army, Europe |
| USARPAC | U.S. Army, Pacific |
| USARSO | U.S. Army, South (Army) |
| USASSDC | U.S. Army Space and Strategic Defense Command |
| USASOC | U.S. Army Special Operations Command |
| USCG | U.S. Coast Guard |
| USDA | U.S. Department of Agriculture |

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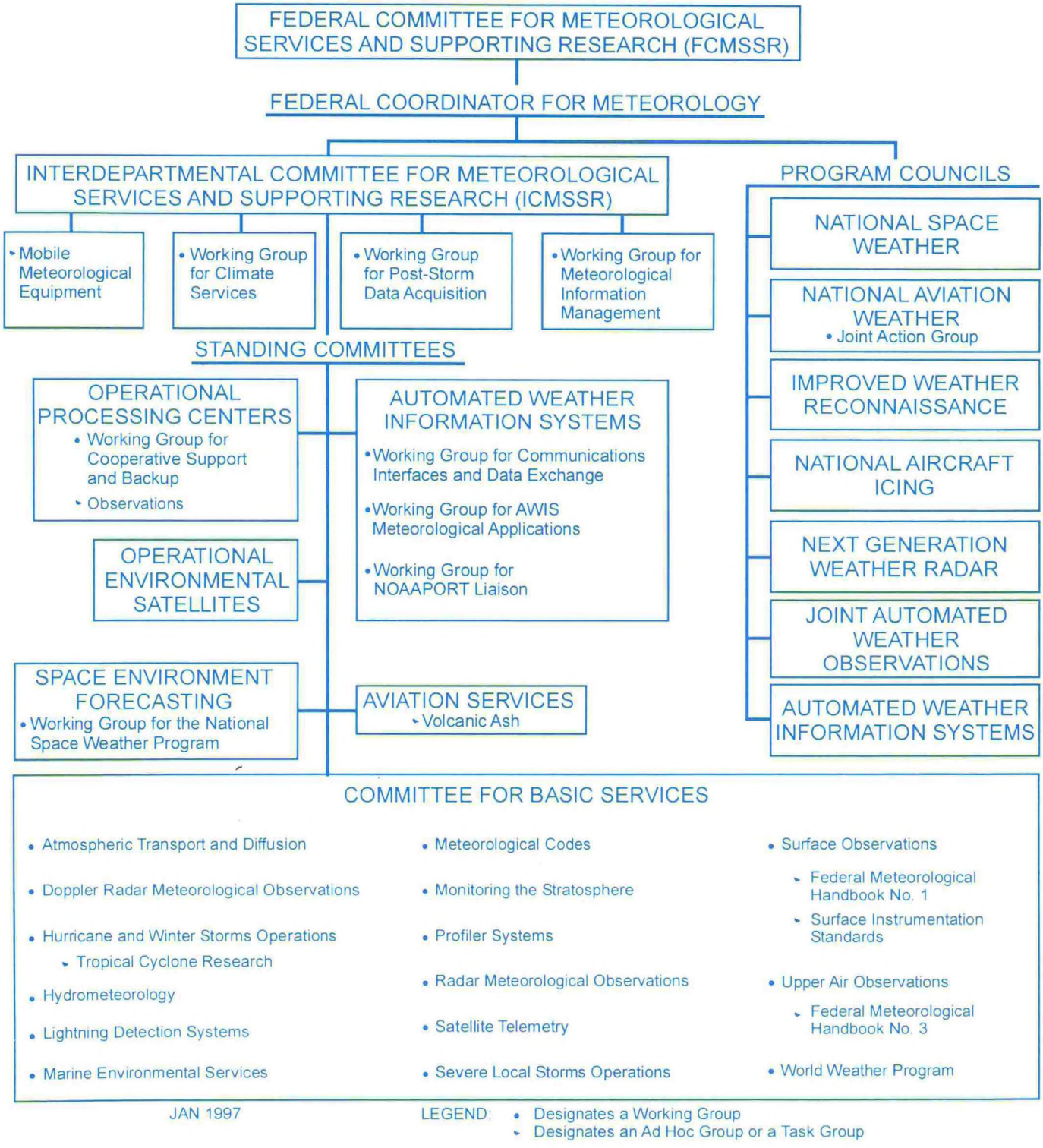
|---|---|
| USGS | U.S. Geological Survey |
| USHCN | U.S. Historical Climatology Network |
| USIABP | U.S. Interagency Arctic Buoy Program |
| USMC | U.S. Marine Corps |
| USN | U.S. Navy |
| USWRP | U.S. Weather Research Program |
| UTC | Coordinated Universal Time (Zulu) |
| VA | Volcanic Ash |
| VAAC | Volcanic Ash Alerting Center (FAA) |
| VAS | VISSR Atmospheric Sounder |
| VCI/TCI | Vegetation and Temperature Condition Indices |
| VCP | Voluntary Cooperation Program |
| VIRS | Visible and Infrared Scanner (NASA) |
| VISSR | Visible and Infrared Spin Scan Radiometer |
| VORTEX | Verification of the Origins of Rotation Experiment |
| VOS | Voluntary Observing Ship (WWP) |
| WAFC | World Area Forecast Center (WWP) |
| WAFS | World Area Forecast System (WWP) |
| WAM | Wave model (Navy) |
| WAOB | World Agricultural Outlook Board (USDA) |
| WARP | Weather and Radar Processor (FAA) |
| WDC | World Data Center (WWP) |
| WEFAX | Weather Facsimile |
| WES | Waterways Experiment Station (Army) |
| WETM | Weather Team (DOD) |
| WFO | Weather Forecast Office (NOAA/NWS) |
| WG | Working Group |
| WIDA | Weather Impact Decision Aids (AF) |
| WMC | World Meteorological Center(s) (WWP) |
| WMO | World Meteorological Organization |
| WMSCR | Weather Message Switching Center-Replacement (FAA) |
| WOCE | World Ocean Circulation Experiment |
| WPDN | Wind Profile Demonstration Network (NOAA) |
| WSC | Warfighting Support Center (Navy) |
| WSFO | Weather Service Forecast Office (NOAA/NWS) |
| WSMO | Weather Service Meteorological Office (NOAA/NWS) |
| WSMR | White Sands Missile Range (Army) |
| WSO | Weather Service Office (NOAA/NWS) |
| WSP | Weather Systems Processor (FAA) |
| WSR-88D | Weather Surveillance Radar-1988 Doppler (NEXRAD) |
| WSU | Weather Support Unit |
| WWP | World Weather Program |
| WWW | World Weather Watch (WMO); World wide web |

# APPENDIX G

## PREVIOUS FEATURE ARTICLES

| | | | |
|---|---|---|---|
| 1996 | FY 1997 | Space Weather - A New Challenge for Meteorologists | Col Jud Stailey, USAF |
| 1995 | FY 1996 | The Role of Federal Agencies in International Aviation Meteorology | Mr. Blaine K. Tsugawa, OFCM |
| 1994 | FY 1995 | Data Continuity in the Climatological Record | Dr. Nathaniel B. Guttman, NCDC<br>Mr. Andrew H. Horvitz, NWS<br>Mr. Arthur L. Booth, NOAA-EOSDIS |
| 1993 | FY 1994 | Training and Professional Development in the Modernized Weather Services | Mr. Eli Jacks, NWS<br>Mr. LeRoy Spayd, NWS |
| 1992 | FY 1993 | Mesoscale Meteorology | Mr. Floyd F. Hauth, OFCM |
| 1991 | FY 1992 | Some Recent Developments in Lightning Mapping Systems | Dr. Donald R. MacGorman, NOAA<br>Dr. Frederick R. Mosher, NOAA<br>Ms. Jan S. Lewis, NOAA |
| 1990 | FY 1991 | The Next Generation Weather Radar - A System for Locating and Tracking Severe Weather | Mr. E. Don Sarreals, NEXRAD JSPO |
| 1989 | FY 1990 | Strategic Plan for the Modernization and Associated Restructuring of the National Weather Service | Verbatim reproduction of a plan required by Congress and submitted by DOC and OMB. |
| 1988 | FY 1989 | Supercomputers for Meteorological Services and Supporting Research | (Source or author unknown) |

*U.S. GOVERNMENT PRINTING OFFICE 1998/432-031


FEDERAL COMMITTEE FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH (FCMSSR)
FEDERAL COORDINATOR FOR METEOROLOGY
INTERDEPARTMENTAL COMMITTEE FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH (ICMSSR)
• Mobile Meteorological Equipment
• Working Group for Climate Services
• Working Group for Post-Storm Data Acquisition
• Working Group for Meteorological Information Management
STANDING COMMITTEES
OPERATIONAL PROCESSING CENTERS
• Working Group for Cooperative Support and Backup
• Observations
OPERATIONAL ENVIRONMENTAL SATELLITES
SPACE ENVIRONMENT FORECASTING
• Working Group for the National Space Weather Program
AUTOMATED WEATHER INFORMATION SYSTEMS
• Working Group for Communications Interfaces and Data Exchange
• Working Group for AWIS Meteorological Applications
• Working Group for NOAAPORT Liaison
AVIATION SERVICES
• Volcanic Ash
PROGRAM COUNCILS
NATIONAL SPACE WEATHER
NATIONAL AVIATION WEATHER
• Joint Action Group
IMPROVED WEATHER RECONNAISSANCE
NATIONAL AIRCRAFT ICING
NEXT GENERATION WEATHER RADAR
JOINT AUTOMATED WEATHER OBSERVATIONS
AUTOMATED WEATHER INFORMATION SYSTEMS
COMMITTEE FOR BASIC SERVICES
• Atmospheric Transport and Diffusion
• Doppler Radar Meteorological Observations
• Hurricane and Winter Storms Operations
• Tropical Cyclone Research
• Hydrometeorology
• Lightning Detection Systems
• Marine Environmental Services
• Meteorological Codes
• Monitoring the Stratosphere
• Profiler Systems
• Radar Meteorological Observations
• Satellite Telemetry
• Severe Local Storms Operations
• Surface Observations
• Federal Meteorological Handbook No. 1
• Surface Instrumentation Standards
• Upper Air Observations
• Federal Meteorological Handbook No. 3
• World Weather Program
JAN 1997
LEGEND: • Designates a Working Group
• Designates an Ad Hoc Group or a Task Group