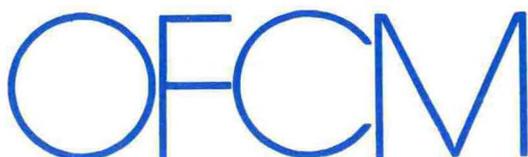


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# The Federal Plan for Meteorological Services and Supporting Research

FISCAL YEAR 1992



OFFICE OF THE FEDERAL COORDINATOR  
FOR METEOROLOGICAL SERVICES  
AND SUPPORTING RESEARCH

**FCM P1-1991**



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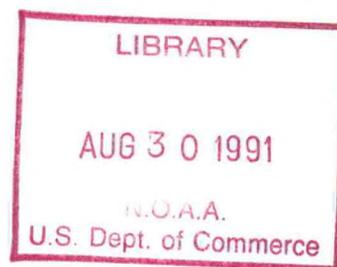
## FISCAL YEAR 1992



**U.S. DEPARTMENT OF COMMERCE**  
Robert A. Mosbacher, Secretary

**NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION**  
John A. Knauss, Under Secretary

**APRIL 1991**  
**WASHINGTON, D.C.**



## PREFACE

This Federal Plan, the 27th in the series that began in 1965, continues the tradition of summarizing the meteorological services and supporting research activities of all agencies of the Federal Government. As in the past, the Plan provides the Congress and the Executive Branch with a coordinated, overall plan for Government meteorological services and for those research and development programs that directly support and improve meteorological services. The Plan covers the meteorological programs of all agencies for FY 1991 and FY 1992.

The first section of the Plan provides an overview and general summary of the entire document. Essential budget information is provided in graphic formats which summarize the significant aspects of the budget tables included in Section 3. The second section highlights interagency cooperation that is essential to meet the needs for meteorological services. Section 3 contains a discussion of resources requested in the President's budget for FY 1992 as compared to planned resources for FY 1991. The emphasis is on changes in resources and the related changes in programs. Fiscal data are current as of the end of February 1991. Section 4 provides a review article on "Recent Developments in Lightning Mapping Systems". Many of these developments have been coordinated through the Working Group for Lightning Detection Systems. The appendices contain descriptions of agencies' weather activities, a description of the World Weather Program, and a list of acronyms.

This Plan does not include information on basic research in the atmospheric sciences. By long-standing agreement, the more fundamental research activities have been coordinated and reported by the Subcommittee on Atmospheric Research (SAR) of the Committee on Earth and Environmental Sciences under the Federal Coordinating Council for Science, Engineering and Technology. This division of responsibilities explains the absence in this report of any substantial references to large basic research programs, such as global climate change.

A SAR report for FY 1987-1990 is now being prepared. The SAR report is retrospective and serves a very different purpose from that of this Federal Plan, but there are similarities. Representatives of the OFCM and the SAR have coordinated approaches to these two reports; however, the distinctions between "supporting" research and "basic" research are sometimes debatable. Some duplications, some omissions, and some double reporting of funding are therefore possible, in spite of efforts to minimize these occurrences.

The principal task of coordinating weather activities is accomplished by the interagency committees shown on the inside front cover. These committees and the organizations shown on the inside of the back cover conduct systematic and continuous reviews of requirements for basic and specialized meteorological services and for supporting research according to guidelines set forth in the Office of Management and Budget Circular A-62.



Robert L. Carnahan

Federal Coordinator for Meteorological  
Services and Supporting Research



THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES  
AND SUPPORTING RESEARCH, FISCAL YEAR 1992

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## SECTION 1

### EXECUTIVE SUMMARY

The President's Budget for FY 1992 requests \$2.43 billion for meteorological services and supporting research. This is seven percent more than the \$2.27 billion planned for FY 1991. As in previous years, about 91 percent of the total is requested for three Departments: Commerce, Defense, and Transportation. Major programs initiated in previous years continue to be funded. Budget support reflected in this document shows recognition of the substantial progress of meteorological science and technology in recent years. This continuing support holds the promise for marked advancements during this decade and beyond in both observing systems and forecasting.

#### Major Programs

Continued support by the Federal Government for major weather observation and communications programs is reflected in the budget requests for FY 1992. These programs include:

(1) Next Generation Weather Radar (NEXRAD), supported by the Departments of Commerce (DOC), Defense (DOD) and Transportation (DOT). The NEXRAD Program Council, chaired by the Federal Coordinator, continues to provide policy guidance for, and oversight of, the procurement, installation, and operation of the Doppler radars;

(2) The automated surface weather observation program, under the policy guidance of an interagency Program Council chaired by the Federal Coordinator. This program is progressing on schedule -- a contract was awarded by the Department of Commerce in February 1991 for up to 1,700 units to be installed during the next five years;

(3) The automated weather information systems programs under development by several agencies as indicated in the budgets. These systems will facilitate the data collection, processing, and interpretation that result in more timely and improved weather forecasts. Rapid distribution of the products to users is an additional goal. A Program Council, a committee, and several working groups within the OFCM structure provide coordination for various aspects of the agencies' programs. Funding for the DOC, DOT and DOD programs is in the FY 1992 budget request.

In response to a request from the Federal Committee for Meteorological Services and Supporting Research, a National Aviation Weather Program Council was established in late 1989. The Program Council has provided policy guidance to an action group established to prepare a National Aviation Weather Program Plan. The draft plan is scheduled to be completed in December 1991.

The acquisition and use of lightning data by the Federal agencies has been an area of considerable interest of OFCM for the past four years. An experimental nationwide network was established under OFCM guidance. The experiment terminated in March 1991. A Request for Proposals for lightning data was issued by the National Weather Service in February 1991. Section 4 provides a special article describing the lightning phenomena and value of lightning data in weather forecasting.

The OFCM is also playing a role in establishing weather data collection and reporting standards by overseeing the revision and subsequent publication of the Federal Meteorological Handbook series. The preparation of these handbooks is being performed by various OFCM committees and

working groups. There are currently ten handbooks in use by Federal agencies and the meteorological community in the U.S. The revised FMH-10, Meteorological Rocket Observations, and a revised FMH-2, Surface Synoptic Codes, were published in 1989. An interim version of FMH-11, Part B, Doppler Radar Theory and Meteorology was published in July 1990. Part C, WSR-88D Products and Algorithms was distributed in April 1991. Another handbook, FMH-1, Surface Observations, is also expected to be published in 1991.

### Resources

The FY 1992 resources requested for Federal meteorological operations and supporting research are \$2.435 billion, representing a seven percent increase from the \$2.275 billion in FY 1991. Substantial increases for system acquisition, particularly for Department of Commerce satellites, account for the largest part of this overall increase. Of the total \$2.435 billion, about \$2.050 billion will be for operations and \$385 million for supporting research. The budget, by agency, is shown in Table 1.1.

Figure 1.1 shows the proportion of the total request for each agency. Each agency's proportion of the proposed spending for meteorological operations is shown in Figure 1.2; as in previous years, the Departments of Commerce, Defense, and Transportation account for approximately 99 percent of the Federal budget for meteorological operations. The proportions of the proposed spending for supporting research is shown in Figure 1.3.

The total Federal budgets for the 13 year period 1980-1992 are shown in Figure 1.4; the budgets are presented in terms of actual and constant dollars (i.e., adjusted for the Consumer Price Index).

The agencies expect that 17,748 people will be engaged in meteorological operations in FY 1992, which is a decrease of 2.6 percent from FY 1991.

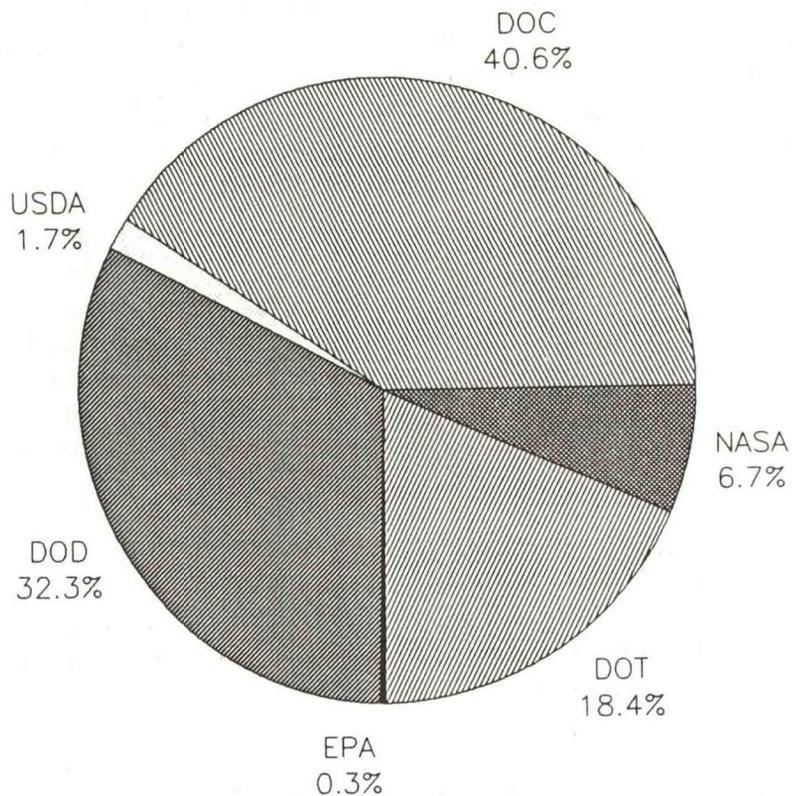


Figure 1.1 Total Federal Budget for Meteorological Operations and Supporting Research, FY 1992

Table 1.1. Federal Budget for Meteorological Operations and Supporting Research, Fiscal Year 1992 (in thousands of dollars)

<u>Agency</u>	<u>Operations</u>	<u>% of TOTAL</u>	<u>Supporting Research</u>	<u>% of TOTAL</u>	<u>TOTAL</u>	<u>% of TOTAL</u>
Agriculture	9,740	0.5	31,060	8.1	40,800	1.7
Commerce	940,707	45.9	48,436	12.6	989,143	40.6
Defense	676,317	33.0	111,303	28.9	787,620	32.3
Interior	870	0.0	0	0.0	870	0.0
Transportation	413,322	20.1	33,828	8.8	447,150	18.4
Envir. Prot. Agency	0	0.0	7,150	1.9	7,150	0.3
NASA	8,841	0.4	153,200	39.8	162,041	6.7
Nuclear Reg. Comm.	200	0.0	150	0.0	350	0.0
<b>TOTAL</b>	<b>2,049,997</b>	<b>100.0</b>	<b>385,127</b>	<b>100.0</b>	<b>2,435,124</b>	<b>100.0</b>

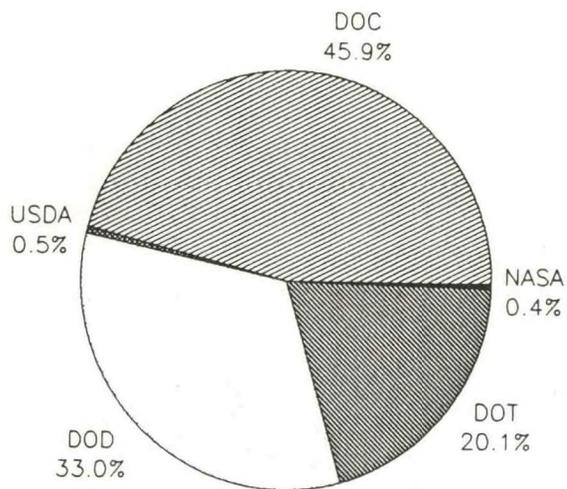


Figure 1.2 Federal Budget for Meteorological Operations, FY 1992 (Percent of Operations budget)

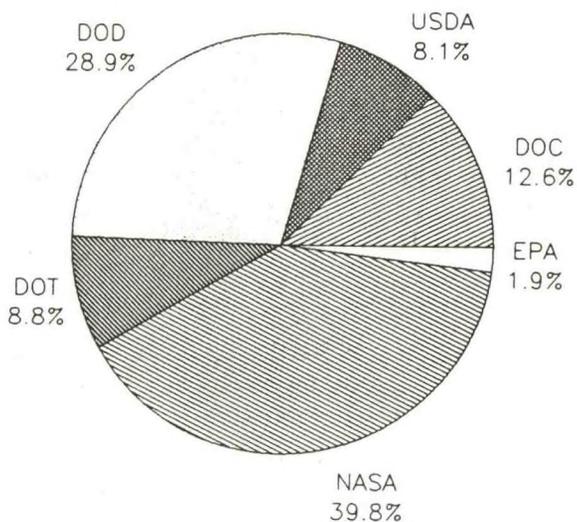


Figure 1.3 Federal Budget for Supporting Research, FY 1992 (Percent of Supporting Research budget)

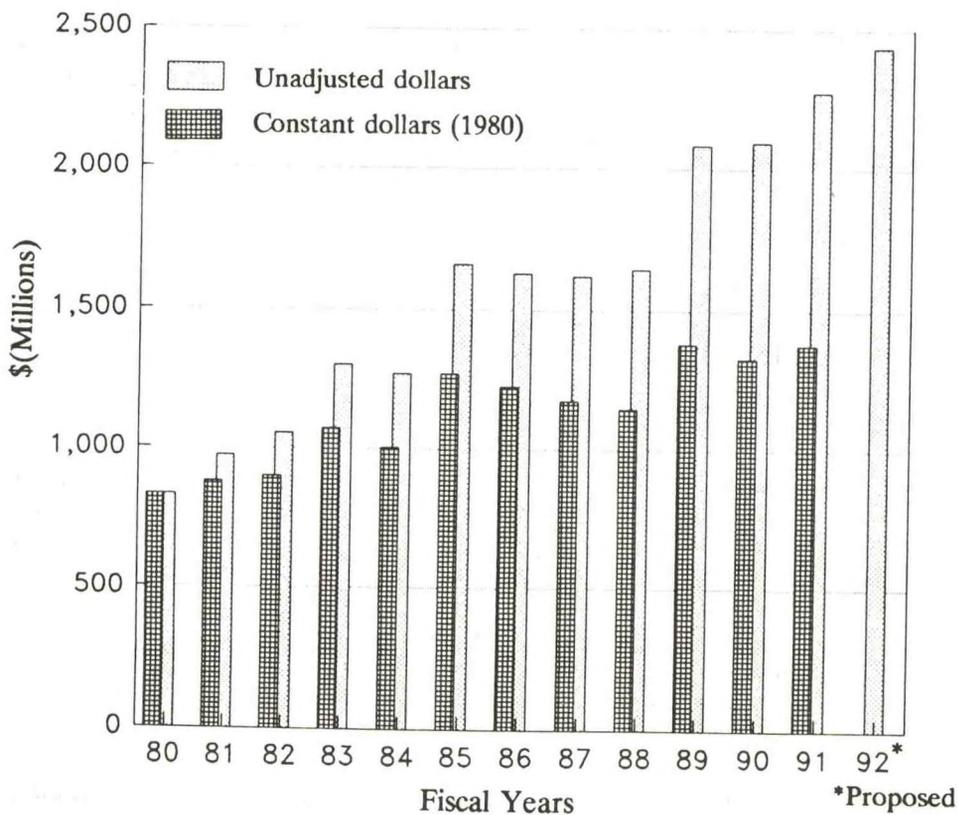


Figure 1.4 Total Federal Budgets for Meteorological Operations and Supporting Research, FY 1980-1992

## SECTION 2

### FEDERAL COORDINATION AND PLANNING

In 1963, activities in meteorology gave rise to concern in Congress and the Executive Office of the President about the adequacy of coordination of Federal meteorological activities. This concern was given expression by the Congress in Section 304 of Public Law 87-843, the Appropriations Act for State, Justice, Commerce, and Related Agencies. Congress directed 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 Office of Management and Budget) issued a report entitled "Survey of Federal Meteorological Activities" (1963). It described each agency's program in some detail, particularly its operational services, and spelled out the relationship between the programs of the various agencies. The report revealed close cooperation but little evidence of systematic coordination. As a result of this study and the concern of Congress, the Director of the Bureau of the Budget issued Circular A-62. The Circular provided the ground rules to be followed in the coordination process. It established a 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 Circular left the task of establishing the coordinating mechanism to the Department of Commerce (DOC), in concert with the other Federal agencies. The Circular reaffirmed the concept of having a central agency, the Department of Commerce, 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 Circular A-62 by the Department of Commerce led to creation of the Office of the Federal Coordinator for Meteorological Services and Supporting Research. The office 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 done by the staff of the Federal Coordinator with the advice and assistance of the Interdepartmental Committee for Meteorological Services and Supporting Research, several special purpose councils, committees, and working groups. The organizational relationships are shown on the inside of the back cover of this document.

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

The mission of the OFCM is to promote coordination and cooperation among those Federal agencies having weather related activities so that the most effective and best possible weather information and user services are provided for the funds made available by the Government. To discharge its mission, the OFCM objectives are meshed with the objectives of those agencies which provide the services and perform the research. The objectives are to:

- ▶ Review Federal weather programs and total Federal requirements for 13 Government agencies. 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;
- ▶ Document agency programs and activities in a series of national plans and reports that enable agencies to revise or adjust their individual ongoing programs and provide a means for communicating new ideas and approaches to the satisfaction of requirements;

- ▶ Perform 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;
- ▶ Provide a structure and program to promote continuity in the development and coordination of plans and procedures for interagency meteorological service operations and supporting research activities.

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, the DOC increased the permanent professional staff from one to seven and assigned an additional professional as Department representative; DOC also provides administrative support to the Office of the Federal Coordinator. The Department of Defense currently provides two staff officers (one Air Force colonel, and one Navy commander) and contributes approximately \$325,000 per year to the operation of the OFCM. DOT/FAA provides one professional staff member and contributes approximately \$325,000 per year. The four regularly assigned agency representatives act as assistant federal coordinators for liaison to their respective agencies. Based on the current staffing plan, there are ten professionals and four full time administrative support personnel within the OFCM. Approximately one-half of these resources is required for the direct support of the Committee structure and preparation of recurring plans (national operations plans and the annual Federal Plan). The remaining staff time is required for responding to special inquiries, investigations and studies.

## COORDINATION OF MULTIAGENCY PROGRAMS

The Federal Committee for Meteorological Services and Supporting Research was established in 1964 with high-level agency representation to provide policy guidance to the Federal Coordinator and to resolve agency differences that arise during the coordination of meteorological activities and the preparation of Federal plans in general. The Committee is chaired by the Under Secretary of Commerce for Oceans and Atmosphere, who is also the Administrator of the National Oceanic and Atmospheric Administration.

Thirteen Governmental agencies that engage in meteorological activities, or that have a need for meteorological services, are represented on the Committee. These include the Departments of Commerce, Agriculture, Defense, Energy, Interior, State, and Transportation as well as the Environmental Protection Agency, Federal Emergency Management Agency, National Aeronautics and Space Administration, National Science Foundation, National Transportation Safety Board and the U.S. Nuclear Regulatory Commission. In addition, the Office of Management and Budget is represented.

The Office of Management and Budget (OMB) and the Federal Committee provide guidance at the policy level to the Federal Coordinator. Guidance from the agencies is provided at the program management level 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.

Six Program Councils have been established within the OFCM structure to coordinate specific interagency cooperative programs. These are: Joint Automated Weather Observations, Automated Weather Information Systems, Aircraft Icing, Aviation Weather, Next Generation Weather Radar, and Improved Weather Reconnaissance. Each of the Councils is comprised of decision-level representatives of the agencies directly concerned with the specific program area.

## Next Generation Weather Radar (NEXRAD)

Delivery of Next Generation Weather Radar (NEXRAD) equipment (WSR-88D) is proceeding.

The WSR-88D is a computerized Doppler weather radar developed to meet the common need of the Departments of Commerce, Defense, and Transportation for improved ability to detect and maintain surveillance over hazardous weather. This need was defined by the three Departments, through 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 a Tri-Agency NEXRAD Program Council chaired by the Federal Coordinator. (The Federal Plan for FY 1991 included a full discussion of the NEXRAD program.)

The WSR-88D system's advanced technology provides automated Doppler signal processing, computerized processing of 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, moderately priced, has a long life-cycle expectancy, and its advanced weather radar products meet the needs of the three Departments for accurate information on the location, severity, and movement of hazardous weather.

The Department of Commerce's National Weather Service (NWS) will use the WSR-88D for more than forecasts and warnings of severe weather. NWS also uses the WSR-88D's rainfall analysis capability to improve its river stage and flood forecasts and provide data to the Nation in support of 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 management, and water based recreation -- all with economic benefit to the United States. The Department of Defense uses NEXRAD data to support military operations and protect defense assets on a worldwide basis. The Department of Transportation's Federal Aviation Administration uses the data to improve flight safety and to manage traffic more efficiently within the National Airspace System.

The NEXRAD program procurement follows the competitive bidding procedures decreed in Office of Management and Budget Circular A-109. The acquisition progressed through the System Definition Phase and Validation Phase design and development efforts, to selection of a system contractor and award of Limited Production and Full Scale Production contracts. Unisys was awarded a Limited Production contract for 10 NEXRAD's in December of 1987. From March to August of 1989 the NEXRAD prototype unit was given a rigorous independent examination during Initial Operational Test and Evaluation Part 2 (IOT&E(2)). NEXRAD proved that it could significantly improve the timeliness and accuracy of forecasts of severe weather occurrences. Unisys was awarded the Full Scale Production option in January 1990 for 165 additional Doppler radars.

The first WSR-88D has been installed near Oklahoma City, Oklahoma, along with WSR-88D support equipment installations for operations and maintenance training at Norman, Oklahoma, and Kansas City, Missouri, respectively. Installation of support equipment is in progress (at the time of this report) at Melbourne, Florida, and Sterling, Virginia. Broadscale activities in support of deployment are also taking place, including depot repair facility preparations, integration of equipment components for shipping, implementation of system support capability, and establishing the spare parts inventory. Radar operations by the Government will not begin until the system contractor has completed all system acceptance requirements.

The Operational Support Facility (OSF) established in 1988 is actively planning for its role of providing 24 hour a day operational support to NEXRAD field units. The OSF is managing the NEXRAD operator training program in Norman, Oklahoma, and is completing its preparations for management and coordination of the life-cycle system support program for the worldwide NEXRAD system.

## Automated Surface Weather Observations

Historically, each agency has independently developed an operational weather system capability in pursuit of its mission; supporting research was frequently carried out jointly. In 1983, in order to coordinate these efforts and in response to OFCM's recommendation, the Joint Automated Weather Observing Program (JAWOP) was established. The JAWOP Council, chaired by the Federal Coordinator, provides policy and oversight for the three Departments' automated surface observation program development efforts.

In 1986, NWS and FAA sought convergence of their automated surface weather observation programs by closely examining system commonality and revalidating system requirements. This resulted in an agreement in 1986 by the JAWOP Council to use the NWS's Automated Surface Observing System (ASOS) at the FAA's towered airport locations. The Administrators of NOAA and FAA agreed that NOAA will procure, install, operate, and maintain the ASOS to meet FAA requirements for both the towered and most of the nontowered airports. Towered airports are the large airports that have a control tower and FAA personnel to control airplane traffic. Nontowered airports are those smaller airports with no control tower or regular observers for weather conditions. The NWS and FAA application of ASOS will make this system the primary federal surface observing system. Immediate needs of the FAA for limited weather observations at small non-towered airports will be satisfied by procuring 160 off-the-shelf automated weather observing systems (AWOS) as an interim capability system until ASOS is fielded.

The ASOS development concluded with preproduction systems qualified through field tests conducted at the Tulsa International Airport (involving the Weather Service Office and the Air Traffic Control Tower), and the NWS Sterling Research and Development Center. The results of these field tests as well as the overall ASOS test program were reviewed by an independent interagency Test Review Board. The Board found sound system performance and recommended proceeding to the production phase. In February 1991, the ASOS production and implementation contract was awarded to AAI Corporation and production was initiated with initial systems fielded in the central United States beginning during the summer.

An earlier NWS demonstration contributed to significant improvements in laser ceilometer technology, a critical component of automated observing efforts. These technical improvements were factored into the NWS's next generation laser ceilometer procurement. Production delivery has begun with field installation underway at primary NWS observing locations. The new ceilometer will be used as part of the ASOS sensor suite at most locations. Both the Air Force and FAA have decided to use the NWS-developed Next Generation Ceilometer for replacement purposes. The Air Force is presently acquiring 287 ceilometers and FAA is acquiring 115 ceilometers through the NWS. The Air Force is also considering use of the NWS developed ASOS for general Air Force application.

The Navy is planning to replace obsolete equipment with the ASOS at Navy and Marine Corps air stations. The Navy will not use ASOS as a fully automated station except at remote sites, such as bombing ranges, where surface observations are not presently taken due to manpower limitations. The Navy requires 86 ASOS units (85 operational and 1 R & D) at 70 continental U.S. sites and 15 overseas sites. In order to satisfy the requirement for automated shipboard observations, the Navy is developing the Shipboard Meteorological and Oceanographic Observing System (SMOOS).

The Air Force activity in automated sensor development is principally focused on the war fighting environment. The Air Force Tactical Weather Observing System (TWOS) will include surface, airborne, and satellite-based observations. Air Force sensor development is the responsibility of the Phillips Laboratory, Geophysics Directorate. They will develop tactical sensors while

continuing to monitor ASOS. A fixed-base automated observing system based on the tactical sensors and ASOS will be developed in the late 1990s.

The U.S. Army's Atmospheric Sciences Laboratory (ASL) has developed and installed the Surface Automated Meteorological System (SAMS) for automated collection and processing of surface weather parameters for supporting the Army's Research, Development, Test, and Evaluation sites. Standard measured parameters are solar radiation, air temperature, humidity, wind speed and direction, barometric pressure, and soil temperature at each data collection platform (DCP). The central site, called the Acquisition Control Unit (ACU), directs the DCPs to acquire and transmit data, calculates a variety of derived parameters, and maintains a listing of the acquired data including reports and plots.

Planned activities for FY 1991 and FY 1992 include:

- ▶ Proceed from ASOS limited production to full-scale production, fielding as many as 25 or more systems per month.
- ▶ NWS, FAA, and DOD (under the auspices of the JAWOP) will continue with selected future enhancement sensor development and testing.
- ▶ OFCM will revise the Federal Meteorological Handbook No. 1 to reflect automated observing procedures.
- ▶ USAF and FAA will continue selective replacement of aging sensors, including the purchase of new laser ceilometers by means of an add-on to the NWS procurement.
- ▶ U.S. Navy will plan for the replacement of the AN/GMQ-29 semi-automated observing systems ashore with ASOS during the FY 1992-1995 timeframe. The first ASOS unit is scheduled for installation at Naval Electronic System Command, Charleston, in October 1991.
- ▶ U.S. Navy's test and evaluation for the Shipboard Meteorological and Oceanographic Observing System (SMOOS) was completed in FY 1991. SMOOS production is expected to begin in FY 1992.

#### Automated Weather Information Systems (AWIS)

Automated Weather Information Systems (AWIS) are required by a number of Federal agencies. The AWIS are being procured to reduce labor intensive functions; to reduce the time required to process and interpret weather data; to reduce the time to produce forecasts, warnings and special tailored products; and to distribute these products to users expeditiously. Major agency systems classified as AWISs are the Department of Commerce's Advanced Weather Interactive Processing System (AWIPS), the Federal Aviation Administration's Central Weather Processor (CWP), the U.S. Air Force's Automated Weather Distribution System (AWDS), and the Naval Environmental Data Network (NEDN). The systems include communications to collect and distribute raw data, information, and processed products. Excluded from AWIS are the observation subsystems and the supercomputers at the major centers.

The AWIS Program Council, which consists of high level representatives from the Departments of Commerce, Defense and Transportation, was established during February 1986 as part of the Federal coordination mechanism for meteorology. This was in response to a 1985 recommendation by the Inspectors General of these agencies. The Council decided to identify major items that needed coordination in both the short and long term; to determine if there was redundancy among

the systems and, if so, whether it should be eliminated; to determine what commonalities existed among the systems; and to produce a Federal Plan for the Coordination of AWIS Programs.

In order to further its agenda, the AWIS Program Council uses the Committee for Automated Weather Information Systems (CAWIS) and its Working Group for Communications Interfaces and Data Exchange (WG/CIDE), Working Group for AWIS Meteorological Applications (WG/AMA), and Working Group for NOAAPORT Liaison (WG/NPL). CAWIS published the Federal Plan for the Coordination of AWIS Programs in May 1988. WG/CIDE publishes standards documents relating to formats and telecommunications procedures. Its most recent Standard Formats for Weather Data Exchange Among Automated Weather Information Systems was published in May 1990. Its most recent Standard Telecommunication Procedures for Weather Data Exchange was published in July 1989. This latter standard is based upon the Federal Information Processing Standard 100 which is compatible with a similar document produced by the International Standards Organization. The thrust of the Working Group's effort is to adopt Federal, American and international standards and, where necessary, to develop standards, procedures and guidelines that are unique to weather information systems. In addition, WG/CIDE designed the Interdepartmental Meteorological Data Exchange System (IMDES). The most recent progress report on the implementation of IMDES was published in July 1990.

WG/AMA is preparing an inventory of meteorological applications programs and techniques and provides a forum for coordination of developments in new or improved meteorological applications. WG/NPL provides an interdepartmental forum for the discussion of NOAAPORT plans and discussion regarding the implementation of NOAAPORT. NOAAPORT is the name given to the service planned for distributing meteorological data and products to AWIPS and other environmental data systems beginning in the NWS modernization era.

#### National Aircraft Icing Program

In late 1983, a subgroup of the Federal Committee for Meteorological Services and Supporting Research and other high-level officials in DOD, FAA, and NASA agreed to promote greater coordination in aircraft icing and to form a National Aircraft Icing Program Council. The Council was established in 1984.

The Council is responsible for developing and maintaining a technology plan and for providing policy guidance for its execution. The Council's Working Group for Aircraft Icing prepared the initial National Aircraft Icing Technology Plan, published in 1986. The planned program has dual objectives: 1) improving aircraft icing technologies for the current generation of aircraft, and 2) promoting advances in aircraft icing technology that will be needed by 1995 to meet national aeronautical goals for new generations of aircraft. This plan presents a comprehensive list of aircraft icing research needs and objectives, describes the efforts now underway, and proposes the areas of need. It recognizes that the scope, definitions, and priorities may change as the National Aircraft Icing Technology Plan is implemented and as the need arises to reflect accomplishments and changes in agency missions and goals.

One section of the technology plan, "Detecting, Monitoring and Forecasting" is addressed in detail in the National Plan to Improve Aircraft Icing Forecasts, prepared by an ad hoc group for the Committee for Aviation Services, and published in 1986.

In 1989, the FAA established a 6-year funding schedule, beginning in FY 1990, to achieve the goals set forth in the icing forecasting plan. In FY 1990, funding was provided by the FAA to the

National Center for Atmospheric Research (NCAR) to develop and conduct an extensive icing research program. The objectives of this program are to develop and evaluate an icing severity index, and an operational icing forecast for aviation. A third objective is to evaluate sensors appropriate for the detection of icing conditions. NCAR will conduct field data collection exercises during four successive winters: two in the Denver area and two in the central U.S. This effort commenced in January 1990 with a combined ground-based and airborne data collection in the Colorado area. The program is being monitored by the Aircraft Icing Program Council.

#### National Aviation Weather Program Council

A new program council was formed in late 1989 and a supporting Joint Action Group in 1990 to address aviation weather issues and provide guidance in the preparation of a national aviation weather program plan. The membership consists of the Departments of Agriculture, Commerce, Defense, Transportation, and the National Transportation Safety Board. The principal activity of this program council is, through a joint action group, preparation of a National Aviation Weather Program Plan. This plan will establish user needs and agency responses in the area of aviation weather services. It is expected that the plan will be completed late in 1991.

### PLANNING, COMMITTEE ACTIVITIES, AND PUBLICATIONS

#### Meteorological Information Management

The development of new, higher-resolution atmospheric observational systems, the operational deployment of large-scale graphic and alphanumeric communications and display systems, and the transition from traditional paper and film displays for graphical and satellite imagery to automated digital displays, mean that a virtual explosion of meteorological information is occurring and will continue for the foreseeable future. The tremendous volume and complexity of new information threatens to overwhelm present-day archival systems and lead to confusion and serious inefficiencies in the application of retrospective data to scientific and operational needs.

At the same time, the explosion of data is coupled to a growing demand for retrospective meteorological data to support research initiatives, such as analysis of global change, and operational uses such as military planning and environmental and engineering studies. These factors have led to a proliferation of retrospective databases and the real possibility of significant duplication of effort and development of incompatible databases by Federal agencies, other producers, and users.

Recognition of this growing problem led ICMSSR to establish the Working Group for Meteorological Information Management. The aims of the Group are to review current agency plans and requirements, develop guidelines for new data systems, develop a national reference system for retrospective databases, and devise a coordination mechanism to ensure, (1) that user needs are considered, and (2) that duplication of effort is eliminated to the extent possible. The Group arranged for a contractor to prepare a draft Federal Plan for Meteorological Information Management. The plan will be published in 1991, after additional agency input. The Working Group will then consider what steps it should take to implement appropriate portions of the plan.

#### Federal Meteorological Handbooks

At the direction of the ICMSSR, the OFCM has undertaken a revitalization of the Federal Meteorological Handbooks (FMH) using the existing interdepartmental coordination infrastructure of committees and working groups. The FMH series includes observing and reporting practices for surface, upper air, radar, and meteorological rocket observations. The titles of ten existing handbooks are: Surface Observations, Surface Synoptic Codes, Radiosonde Observations, Radiosonde

Code, Winds-Aloft Observations, Upper Wind Code, Weather Radar Observations, Manual on Barometry, Aviation Weather Observations, and Meteorological Rocket Observations. Another, Doppler Radar Meteorological Observations, is under development. The OFCM is reevaluating the status of the FMH series and revising each handbook, as required, to:

- ▶ highlight the responsibility for preparation and maintenance;
- ▶ develop a mechanism to make sure the FMHs remain current and complete;
- ▶ assure the merging of information from new or automated technology;
- ▶ meet requirements for utility of the primary users;
- ▶ reinforce the status of each handbook as the Federal standard for observing and reporting the meteorological phenomena and parameters by which the atmosphere is usually described.

Many OFCM working groups of the Committee for Basic Services are participating in this task. To date, revisions have been completed for the Surface Synoptic Codes (FMH-2) and Meteorological Rocket Observations (FMH-10) handbooks. In addition, interim versions of two parts of the Doppler Radar Meteorological Observations (FMH-11) handbook have been completed. These are Part B - Doppler Radar Theory and Meteorology and Part C - WSR-88D Products and Algorithms. When completed, the new revisions and interim versions of handbooks will be available to private sector users through the National Climatic Data Center in Asheville, NC.

#### Working Group for Meteorological Codes

The use of meteorological codes is of fundamental importance for the collection, exchange, and distribution of meteorological information. The Working Group for Meteorological Codes (WG/MC) is the principal means, within the OFCM, for coordinating the employment of these codes by concerned Federal agencies.

An important issue addressed by the WG/MC during its July 1990 meeting was the implementation of modifications to existing meteorological codes proposed by the WMO. The Working Group was particularly concerned with the changes proposed to the aviation codes (METAR, SPECI, and TAF). The group recognized that an important limitation of the proposed code was the lack of provision for reporting cloud layers, cloud types, and cloud amounts. It concluded, however, that this limitation could be remedied by including this information in the remarks section of the code. This would be done as a matter of national practice and the information would be removed before external transmission. Alternatively, the group suggested that the remarks could be distributed under a separate bulletin heading. The Working Group is expected to decide on final U.S. action during the upcoming year.

Another aspect of the proposed code which was considered by the Working Group during its January 1991 meeting was the implementation date of July 1, 1993. The Group was concerned that this date could not be satisfactorily met by the U.S. They agreed that implementation of these changes would require a substantial effort because of the necessity to develop and produce appropriate handbooks, manuals, and documentation; to field train personnel; and to develop new code-handling computer programs. In addition, they noted that budget constraints may inhibit the timely production of this material. The Group decided to study the costs associated with the proposed implementation date and to decide whether this date could be met.

#### National Program for Lightning Detection Systems

In 1983 the Office of the Inspector General, Department of Commerce, issued a management audit report that indicated the significance of the threat of lightning to life and property and the

need to improve severe weather forecasting. It stated that a number of agencies were active in programs directed toward lightning detection and encouraged the Department of Commerce (NOAA) to determine the action necessary to improve the Nation's lightning detection program.

The Department of Commerce member of the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) requested that the Office of the Federal Coordinator for Meteorology (OFCM) undertake a study to document the Federal agencies' interest in lightning detection and existing and planned programs of the agencies. The study, completed in early 1985, revealed that extensive systems exist for the detection and tracking of cloud-to-ground lightning. These systems are organized in networks operated by various Federal agencies, universities and private industry.

In December 1984, ICMSSR agreed that there is a need for a National Plan for Lightning Detection Systems. The National Plan should make maximum interagency use of existing systems and coordinate the ongoing lightning programs of the Federal agencies. Preceding the plan, however, a study of the status of the various agency, university and industry lightning programs was conducted. The study revealed agencies were operating with different levels of experience in lightning detection and at different stages in formulating operational requirements. A report entitled "The Status of National Programs for Lightning Detection Systems", published in 1986, identified issues and problems that needed to be resolved in developing a national plan for lightning detection systems. A field testing program evaluating available lightning detection systems was conducted by the National Severe Storms Laboratory (NSSL). A report by NSSL entitled "An Evaluation of Two Lightning Ground Strike Locating Systems" was published in 1988.

The Working Group for Lightning Detection Systems (WG/LDS) determined that development in several areas had not progressed sufficiently to prepare a final national plan but, to further the many efforts in progress, including an interagency experiment in using National Lightning Data, a Preliminary National Plan for Lightning Detection Systems was published by the OFCM in 1988 to provide a framework for further development. The Working Group has completed a compilation of agency requirements for lightning detection and developed a set of standards for lightning detection systems. These documents formed the foundation for a National Weather Service procurement of operational lightning data from a commercial source and a Request for Proposal was issued in February 1991.

### Profiler System

Research on the profiler concept was formally initiated in NOAA in the early 1980s to explore the development of ground-based systems that would supplement, and in some cases provide an alternative to, the radiosondes used for the past 50 years to obtain upper-air meteorological data. The profiler concept involves some combination of remote sensors to monitor upper-air winds, temperature, and moisture automatically and continuously. Work on instruments that can measure each of these three parameters has progressed somewhat independently and at different rates. Wind profiler development, for example, has reached the stage where instruments are now being produced by industry and a NOAA demonstration network will be implemented during 1991. The development of thermodynamic profilers to measure temperature and moisture has come a long way and shows promise, but more work needs to be done.

Wind Profilers. The NOAA wind profiler demonstration network will consist of 25 wind profilers operating on a frequency of 404.37 MHz (wavelength = 74 cm) located across the central U.S. Additional profilers are located in Maynard, MA and Homer, AK. Network installation began

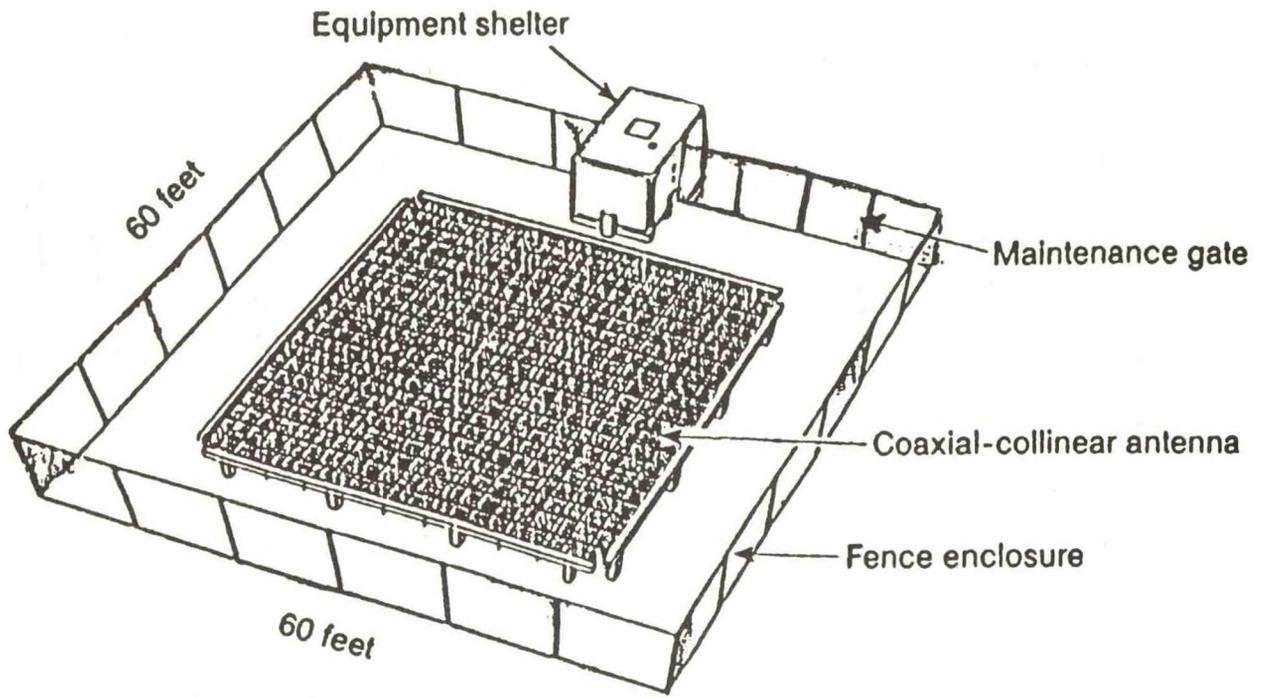


Figure 2.1a Typical 404-MHz demonstration wind profiler network site

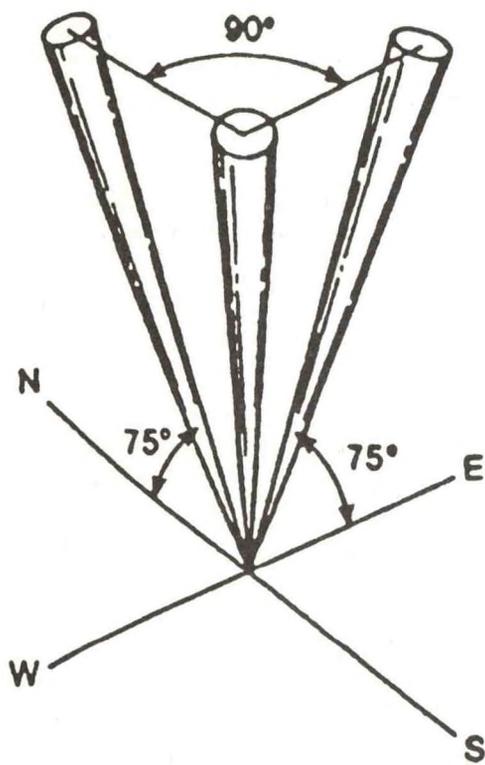


Figure 2.1b Perspective view of wind profiler beam orientation

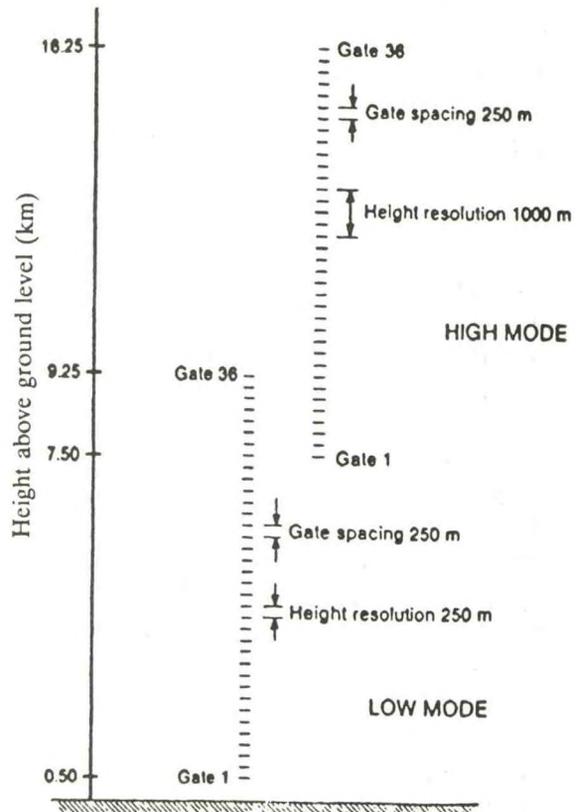


Figure 2.1c Height coverage, gate spacing, and height resolution of network wind profilers

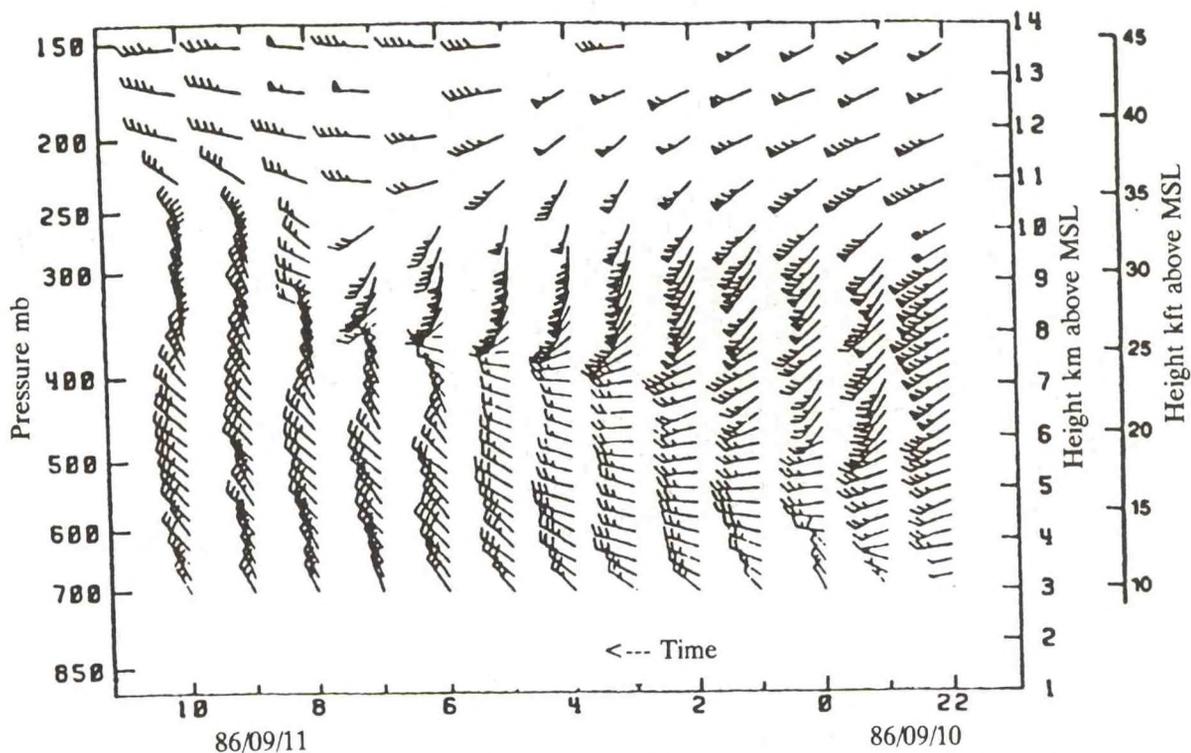


Figure 2.2 High-quality wind profiles measured by the Fleming, Colorado, research profiler during a trough passage.

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 in 1990 and is scheduled for completion by late 1991. After installation, the network is scheduled to operate for approximately 18-24 months providing data for assessing the impact of this new technology on NWS operations, and on a range of atmospheric research problems. This assessment will examine the meteorological uses as well as the engineering aspects of the network.

Figure 2.1a is a depiction of one of the network sites. Figure 2.1b illustrates the three beams of the system -- two beams northward and eastward to measure the horizontal components of the wind and a third beam to measure the vertical component. The network sites are specified to have antenna beam widths  $\leq 5^\circ$ . The network of wind profilers routinely measure winds from 500 meters above the ground well up into the troposphere. Measurements 500 m and below are limited due to ground "clutter".

Data from the network will be collected at the Environmental Research Laboratories (ERL) in Boulder, CO, and redistributed in both real-time and retrospectively to the NWS and several research groups. These data will form the basis of an assessment designed to determine the value of a national network and to aid the decision-making process of implementing such a network. As each wind profiler is installed (and accepted) into the network, wind data are transmitted to the hub (at ERL in Boulder, CO) where the quality control of the data occurs. The profiler hub has been operational for some time and has been sending test data sets to NMC since 1990.

Figure 2.1c depicts the height coverage, gate spacing (or atmospheric sample heights) and height resolution of the network wind profilers. The figure shows the height coverage when operating in the low mode and the high mode. The low mode measures winds from 500 m above the ground to a maximum of 9.25 Km. The high mode measures winds from 7.5 Km to a maximum of 16.25 Km above the ground. The standard data sets from the network wind profilers will be high-quality,

hourly averaged wind profiles, similar to those in Figure 2.2. These hourly wind profiles will have been subjected to quality control checks which are designed to identify and flag nearly all incorrect wind vectors prior to transmission to NMC and the NWS Telecommunications Gateway.

Other agencies have recognized the potential value of wind profilers. Research groups in both the U.S. Army and U.S. Air Force have procured profilers for use in their research and to assess the role of profilers as a military weather support tool. NASA has installed a system at Kennedy Space Center and is examining the role of profilers in test range and space shuttle weather support. The OFCM Working Group for Profiler Systems is coordinating interagency activities in this field.

Thermodynamic Profiling. Within the past year, experimentation has led to several promising advances in remote sensing of temperature and moisture. These advances include the Radio Acoustic Sounding System (RASS), the High-resolution Interferometric Sounder (HIS), the correlation radiometer (CORRAD), and the Raman and Differential Absorption Lidar (DIAL). The NWS has continued to operate a six-channel microwave radiometer alongside their radiosonde launch site at Stapleton International Airport, Denver, CO. Several experiments have been conducted to compare and to combine data from these new technologies.

Comparisons of temperature soundings from NWS radiosondes, from RASS, and the microwave radiometer have been made for many cases. RASS has demonstrated excellent vertical resolution from 1 to 3 Km above the ground. Utilizing a combination of RASS data and the microwave radiometer yielded temperature profiles with rms accuracies better from 1°K up to a height of 8 Km. Experiments with HIS have also shown promise as the data is being analyzed but more work is needed. The Atmospheric Science Laboratory at White Sands Missile Range will be receiving a RASS capability in 1991. In conjunction with a wind profiler, wind and temperature data will be collected independently and simultaneously by a dual signal processor. Experimentation to date with RASS has been limited to radars that operate at 50, 405, and 915 MHz. The upper height range of soundings is wavelength dependent; soundings at 50 MHz were obtained up to 10 Km above ground level.

#### Weather Reconnaissance Program

The U.S. Air Force Reserve provides operational weather reconnaissance to support hurricane forecasting. As of April 1991, the Air Force Reserve's 815th Tactical Airlift Squadron assumes full responsibility for the Air Force fixed-wing weather reconnaissance missions. The squadron, part of the 403rd Tactical Airlift wing, Keesler Air Force Base, Mississippi, operates 12 WC-130 aircraft that are configured with a fully automated, high-density data gathering system that provides extensive information about tropical systems and winter storms. These data are used by the centers to improve the forecasts and warnings of tropical cyclones and East Coast winter storms. The Office of NOAA Corps Operations augments the USAF Reserve operational weather reconnaissance with two fully instrumented WP-3D reconnaissance aircraft. The two NOAA aircraft also support the research requirements of the National Hurricane Center and the National Meteorological Center. OFCM is coordinating development efforts for a new digital sonde to replace the current dropsondes used by the Air Force and NOAA weather reconnaissance systems.

#### No-GOES Contingency Plan

NOAA's Geostationary Operational Environmental Satellite (GOES) program is in an uncertain state as a result of several factors which are beyond the control of the agency. Problems with the development of the new GOES-I satellite have delayed the launch into 1992. NOAA has produced a No-GOES Contingency Plan in the event that an interruption occurs in GOES imaging operations.

The Plan has been distributed to agency representatives on the Committee for Operational Environmental Satellites and to other offices having a broad operational interest. As with all plans that have a potential for impacting the critical operational missions of NOAA, the No-GOES plan must be tested. This test plan document describes the process by which the NOAA No-GOES plans will be demonstrated and evaluated. The goal of the No-GOES test is to demonstrate the ability of NOAA's product generation and distribution system to supply imagery from non-GOES sources.

The NOAA No-GOES test process will consist of several phases. As stated in the NOAA No-GOES Contingency Plan, several enhancements are underway to provide additional capabilities to access, process, distribute, and display non-GOES satellite data. Specifically, observations from the NOAA and Department of Defense (DOD) polar orbiting satellites are being enhanced to render these data in the most useful format for the operational meteorological users. As additional systems, capabilities, and products are established and provided to the user community, the test plan will be demonstrated and evaluated.

### Hydrometeorology

A relatively new working group has been addressing areas for mutual cooperation and coordination in hydrometeorology. One of its first tasks has been development of a handbook for automated flood warning systems, a task still in progress. The group is also planning a workshop, to be sponsored jointly with the Department of the Interior's Office of Water Data Coordination, to address two particular items:

- (1) the archiving of the NEXRAD precipitation data;
- (2) the rain gage networks to calibrate the Doppler radars.

### Space Environment Services and Supporting Research

The National Space Environment Forecast and Warning Program provides Federal agencies and public users real-time space environment data, forecasts of the time of terrestrial impact of significant solar output variations, and warnings of solar events threatening human life or effective and economic operation of modern technical systems. The common needs of the participating agencies have led to a program of shared resources and responsibilities that extend to observations and to operation of forecast centers which provide standard services to meet those needs.

Observations of solar activity with optical and radio telescopes are provided by the Department of Defense (DOD). Solar and near-Earth space environment observations are provided by complementary sensors on DOD and Department of Commerce (DOC) environmental satellites. DOD provides ionospheric and geomagnetic field data from terrestrial networks. Research data, also useful for the forecast and warning services, are obtained from other agencies and shared through real-time communication networks and jointly operated data bases. Research data from the National Science Foundation (NSF) experiments have been made available through these data sharing arrangements. Provision for real-time access to data from National Aeronautics and Space Administration satellites has been made for missions where the data are shown to have operational use and where logistical arrangements for data reception can be worked out. The Departments of Energy (DOE) and Interior (DOI) make space-based and ground-based data available through similar arrangements. The Department of Transportation (DOT) operates radio navigation systems that also provide information on the state of solar-terrestrial disturbances. Universities and private foundations engaged in solar-terrestrial research contribute to the pool of observations. Finally, real-time exchange of data with other countries through the International Ursigram and World Days Service fills gaps in the U.S. observing system. Most of the data gathered in this program are archived in data centers for use in future studies.

The data gathered in the space environmental monitoring program need to be reduced to a set of standardized indices and warnings and used to make forecasts of future levels of activity. A Space Environment Services Center to provide the forecasts and warnings and data bases to the agencies is operated jointly by DOD and DOC to meet common needs. Some agencies, such as DOD, also operate dedicated centers to meet specific agency needs beyond those provided by the common service. Most of the data gathered in the operational portion of the space environment program are archived in the National Geophysical Data Center.

The role and responsibilities of agencies participating in the space environment program are detailed in the National Plan for Space Environment Services and Supporting Research: 1988-1993 (FCM-P10-1988), which was prepared by the OFCM Committee on Space Environment Forecasting and published in 1988.

### Monitoring the Stratosphere

There is considerable public concern and political debate about the possible man-made effects and influences on the ozone layer. Similarly, there are concerns about possible changes in the Earth's global climate. To measure these effects and changes, if any, long-term monitoring of the ozone and other stratospheric trace gases and temperatures is necessary.

In 1982, OFCM published The National Plan for Stratospheric Ozone Monitoring and Early Detection of Change, 1981-1986. The plan developed a program of transition from a reliance on a ground-based network to a combined satellite and ground-based program providing global coverage of ozone and temperature.

The more recent National Plan for Stratospheric Monitoring, 1988-1997 (FCM-P17-88) published in 1988 builds on the previous effort and, in particular, stresses that the problem is not simply one of detecting ozone change. The complex interactions of chemistry, radiation, and dynamics require that meteorological parameters and many chemical species be monitored. Moreover, experience has shown that monitoring, per se, is not a simple engineering problem of taking observations at a station. The stratospheric changes being sought are relatively small, thus monitoring should be considered as a combination of theory, laboratory measurements, field measurements, and interpretation. Sections in the plan give detailed attention to monitoring ozone, meteorology (temperature and winds), solar irradiance, source gases, and trace gases. The agencies' programs and plans for monitoring are described.

From the viewpoint of sensors and sensor platforms, the overall timeframe of 1988-1997 can be subdivided into three general periods. From the present to the early 1990s, the emphasis is on the development of the Network for Detection of Stratospheric Change (NDSC) sponsored by NASA, NOAA, the World Meteorological Organization (WMO), and the Chemical Manufacturers Association (CMA). This is to be a high-technology ground-based program designed to supplement the current ground-based systems and provide, from at least six sites, information on many species and parameters. This Network will serve both to validate/calibrate the available satellite systems and provide information on possible causes of ozone change. Starting in the early 1990s, the NASA Upper Atmosphere Research Satellite (UARS) will make measurements of many of the parameters of interest in this Plan. UARS, which is planned to be launched in late 1991, is a unique instrument of opportunity that will be included within the monitoring program for as long as this satellite lasts. Finally, for the late 1990s, consideration is given to the next-generation NOAA operational satellite systems and the Earth Observing System.

## Federal Meteorological Requirements for the Year 2000

A report of the Federal agencies' requirements for meteorological services and supporting research was published by OFCM in October 1990. The study was requested by the former chairman of the Federal Committee for Meteorological Services and Supporting Research. The report emphasizes requirements and addresses supporting research initiatives as well as systems being developed and acquired to meet the needs of the agencies.

Areas of interdependencies among the agencies and potential areas for mutual support are presented. In particular, twenty areas that are expected to provide the greatest need for increased OFCM attention are recommended in the report. OFCM has selected five of the twenty to address in the immediate future. These are (1) aviation, (2) data archiving, (3) interagency support and coordination mechanisms, (4) mobile meteorological equipment, and (5) rocketsondes.

## Committee and Working Group Changes

A schematic of the Federal Committee structure for meteorological coordination is found on the back inside cover of this Plan. In the past year, ICMSSR disestablished the Task Group for Transfer of Weather Reconnaissance Assets. With the planned transfer of weather reconnaissance assets to the Air Force Reserve, there is no longer a need to continue the TG/TWRA which reported to the Working Group for Hurricane and Winter Storm Operations.

## 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. In most cases, the preparation of Federal plans is facilitated by the existence of individual agency plans for the service or program involved. The Federal Coordinator compiles information from the involved agencies and proposes a unified plan for consideration. Current publications of the Federal Coordinator for Meteorology are listed in Table 2.1. In general, single copies are available upon request to OFCM.

## RELATED FEDERAL METEOROLOGICAL COORDINATION

The focus of OFCM and of this report is on Federal operational meteorological programs and directly supporting research. While not specifically a part of OFCM activities, brief descriptions are given below of Federal coordination activities that relate to other aspects of meteorology.

### Subcommittee for Atmospheric Research

The Subcommittee for Atmospheric Research (SAR) was originally known as the Interdepartmental Committee for Atmospheric Sciences (ICAS). It was established in 1959 by the Federal Council for Science and Technology (FCST) and was the principal mechanism for coordination of research in atmospheric sciences within the Federal Government until 1977. At that time, FCST and its subordinate organizations were abolished and replaced by the Federal Coordinating Council for Science, Engineering and Technology (FCCSET). SAR succeeded ICAS and became a Subcommittee of the FCCSET Committee on Atmosphere and Oceans (CAO). In 1987, the CAO was disestablished and replaced by the Committee on Earth Sciences (CES) which became the Committee on Earth and Environmental Sciences (CEES) in 1990. The SAR is now a subcommittee of the CEES.

Table 2.1 Current Publications of OFCM

<u>Title</u>	<u>Date</u>	<u>Number</u>
Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 1992	April 1991	FCM-P1-1991
National Plan for Space Environment Services and Supporting Research: 1988-1992	July 1988	FCM-P10-1988
National Severe Local Storms Operations Plan	September 1990	FCM-P11-1990
National Hurricane Operations Plan	April 1991	FCM-P12-1991
National Winter Storms Operations Plan	December 1990	FCM-P13-1990
Federal Plans for Mutual Support and Cooperative Backup Among Operational Processing Centers	March 1985	FCM-P14-1985
National Plan for Stratospheric Monitoring, 1988-1997	July 1989	FCM-P17-1989
National Plan for Tropical Cyclone Research	December 1990	FCM-P25-1990
Preliminary National Plan for Lightning Detection Systems	June 1988	FCM-P22-1988
Federal Plan for the Coordination of Automated Weather Information System Programs	May 1988	FCM-P23-1988
Federal Meteorological Handbook No. 1 - Surface Observations	April 1988	FCM-H1-1988
Federal Meteorological Handbook No. 2 - Surface Synoptic Codes	December 1988	FCM-H2-1988
Federal Meteorological Handbook No. 10 - Rocketsonde Observations	December 1988	FCM-H10-1988
Federal Meteorological Handbook No. 11- Doppler Radar Meteorological Observations		
Part B - Doppler Radar Theory and Meteorology	June 1990	FCM-H11B-1990
Part C - WSR-88D Products and Algorithms	February 1991	FCM-H11C-1991
Directory of Atmospheric Transport and Diffusion Models, Equipment, and Projects	March 1991	FCM-I3-1991
Tropical Cyclone Studies	December 1988	FCM-R11-1988
Tropical Cyclone Studies Supplement	August 1989	FCM-R11-1988 S
Interdepartmental Meteorological Exchange System Report, IMDES	July 1990	FCM-R12-1990
Federal Meteorological Requirements 2000	October 1990	FCM-R13-1990
Standard Formats for Weather Data Exchange Among Automated Weather Information Systems	May 1990	FCM-S2-1990
Standard Telecommunication Procedures for Weather Data Exchange	July 1989	FCM-S3-1989
Federal Standard for Siting Meteorological Sensors at Airports	May 1987	FCM-S4-1987

The primary goal of SAR is to improve the planning and coordination of atmospheric research activities among the agencies involved. Agencies represented on SAR are the U.S. Departments of Agriculture, Commerce, Defense (Army, Navy, Air Force), Energy, Interior, State, and Transportation. The Environmental Protection Agency, National Aeronautics and Space Administration, and National Science Foundation are also represented. Observers from several other agencies such as the Office of the Federal Coordinator for Meteorological Services and Supporting Research, the National Climate Program Office, the Office of Science and Technology Policy, the Office of Management and Budget, and the National Academy of Sciences/National Research Council complete the SAR.

SAR publishes a biennial report of the National Atmospheric Sciences Program that is distributed widely. The latest published report is for the years 1984-1987. The next SAR report is being prepared now and will highlight 1987-1990 activities and budgets.

### National Climate Program

The National Climate Program (NCP) was established in 1978 by Public Law 95-367 to help "understand and respond to natural and man-induced climate processes and their implications." This interagency program of research and applications is managed by the National Climate Program Office (NCPO) for the Secretary of Commerce. The Act also mandates the development of an Intergovernmental Climate Program to support "Federal and State cooperative activities in climate studies and advisor services." The office prepares a five-year climate plan. The latest plan, for the years 1988 to 1992, focuses on three main areas: climate data, analysis, and services; climate modeling and prediction; and, the impact of climate change on the environment.

National activities (1990) of the office included:

- ▶ Oversight of the Regional Climate Centers (six);
- ▶ Support for the Experimental Climate Forecast Centers;
- ▶ Staff support for the Mitigation and Adaptation Working Group of the CEES;
- ▶ Preparation of the Annual Report and various climate newsletters;
- ▶ Assessment of the impacts on drought-stricken regions.

International activities (1990) of the office included:

- ▶ Support of the WMO's World Climate Program activities;
- ▶ Support of the WMO/UNEP Intergovernmental Panel on Climate Change;
- ▶ Coordination of Working Group VIII (climate) of the U.S./U.S.S.R. bilateral on environmental activities;
- ▶ Coordination (with the NCPO's Canadian counterpart office) of activities under the U.S./Canada MOU on climate.

### World Weather Program

International activities relating to meteorological services and data exchange 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.

## SECTION 3

### RESOURCE INFORMATION AND ANALYSES

Resources included in the Federal Government budget request for FY 1992 for meteorological services and supporting research total \$2.435 billion. This is an increase of 7.0 percent from the amount appropriated for FY 1991. Of the total, the Department of Commerce budget represents 40.6 percent, Department of Defense 32.3 percent, and Federal Aviation Administration about 18.3 percent with the remaining 8.8 percent for other agencies.

The tables in this section summarize fiscal information of the Federal Government for the fiscal years 1991 and 1992. The funds shown are those used to provide meteorological services and supporting research which has as its immediate objective the improvement of these services. Fiscal data are current as of the end of February 1991 and are subject to later changes. The data for FY 1992 do not have legislative approval and do not constitute a commitment by the U.S. 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 for meteorological programs in the Federal agencies be prepared.

#### AGENCY OBLIGATIONS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

The fiscal information in Table 3.1 is presented by agency for meteorological operations and supporting research and shows the planned (appropriated) funding level for FY 1991, the budget request for FY 1992, the percent change, and the individual agencies' percent of the total Federal funding for FY 1991 and FY 1992.

#### DEPARTMENT OF AGRICULTURE (USDA)

The USDA budget request for FY 1992 is \$40.80 million for operations and supporting research. This is an increase of 39.6 percent from the planned funding level of \$29.22 million for FY 1991. The FY 1992 funding for meteorological operations (\$9.74 million) permits USDA to assist the Department of Commerce in determining farmers' needs for weather information and in disseminating such information to them. Major USDA activities related to weather observations include the need to complete incremental modernization of the snow telemetry (SNOTEL) system operated by the Soil Conservation Service 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 work, the irrigation water supply estimates, and Bureau of Land Management operations. The Digital Weather Image Processing System (DWIPS) has enhanced global monitoring of crop conditions by the Joint Agricultural Weather Facility.

The supporting research component of the USDA request (\$31.06 million) focuses on understanding the interactions of weather and climate with plant and animal production and water resources management. The mission of the supporting research is to develop and disseminate information and techniques to ensure an abundance of high-quality agricultural commodities and products while minimizing adverse effects of agriculture on the environment. The increase reflects an enhanced effort on plant response to ultraviolet band (UVB) radiation and has been coordinated with the Environmental Protection Agency's UVB program. The Forest Service program initiated in FY 1988 has increased the priority research program for the long-term monitoring network to assess potential effects of global climate change and variability on forest health and productivity. Work has begun in the forestry ecological systems modeling. FY 1992 will increase Agriculture Research Service hydrologic work on a regional scale.

TABLE 3.1 METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH COSTS, BY AGENCY  
(Thousands of Dollars)

AGENCY	Operations			Supporting Research			Total		
	FY91	FY92	%CHG	FY91	FY92	%CHG	FY91	FY92	%CHG
Agriculture	9220	9740	5.6	20000	31060	55.3	29220	40800	39.6
Commerce/NOAA	722456	940707	30.2	56118	48436	-13.7	778574	989143	27.0
Defense(Subtot)	686087	676317	-1.4	128271	111303	-13.2	814358	787620	-3.3
Air Force	350145	363820	3.9	17653	18212	3.2	367798	382032	3.9
DMSP*	221693	187343	-15.5	48484	28478	-41.3	270177	215821	-20.1
Navy	88531	88176	-0.4	33890	33890	0.0	122421	122066	-0.3
Army	25718	36978	43.8	28244	30723	8.8	53962	67701	25.5
Interior/BLM	870	870	0.0	0	0	0.0	870	870	0.0
Transp/CG	2577	2577	0.0	0	0	0.0	2577	2577	0.0
Transp/FAA	469675	410745	-12.5	14615	33828	131.5	484290	444573	-8.2
EPA	0	0	0.0	7150	7150	0.0	7150	7150	0.0
NASA	8291	8841	6.6	149400	153200	2.5	157691	162041	2.8
NRC	200	200	0.0	150	150	0.0	350	350	0.0
TOTAL	1899376	2049997	7.9	375704	385127	2.5	2275080	2435124	7.0
% of FY TOTAL	83.5	84.2		16.5	15.8		100.0	100.0	

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

## DEPARTMENT OF COMMERCE (DOC)

All reported DOC meteorological activities are within the National Oceanic and Atmospheric Administration (NOAA). The NOAA FY 1992 total congressional request of \$989.1 million for meteorological programs is 27 percent more than the FY 1991 appropriated funds. Changes in NOAA's operations and supporting research for FY 1992 are presented below, subdivided by activities.

Weather Services. Increases in the subactivity for FY 1992 include the following: NWS requests an increase of \$1.8 million and 160 positions for the Modernization and Associated Restructuring Demonstration and Implementation (MARDI) program. Funding is necessary to prepare for the multi-site operational demonstration as well as implementing the modernization program nationwide. NWS also requests an increase of \$3.3 million to fund its share of the tri-agency NEXRAD program. The increase is necessary to augment funding the production phase facilities and logistics support activities. An increase of \$1.4 million is needed for the Automated Surface Observation Systems (ASOS) to continue the full-scale production phase. Plans also include an increase of \$34.5 million for the AWIPS/NOAAPort program. The requested level will allow initiation of the Development Phase, continuation of risk reduction activities, and provision for remapping of GOES data at NESDIS. Plans also include an increase of \$15.9 million to acquire a Class VII supercomputer system. Aviation weather increased \$868,000 as an adjustment due to inflation.

Proposed FY 1992 decreases include the following: Reduce staff forecast services at eight WSFOs for a savings of \$782,000 and 35 positions. Consolidate the Pacific and Alaska region headquarters for a savings of \$383,000 and 11 positions. Eliminate contractual data buoy system engineering and tests for \$536,000. Discontinue maintenance of four moored buoys surrounding Hawaii for \$561,000. Eliminate agriculture weather services for \$2.4 million and 37 positions. Reduce fire weather services for \$467,000 and 8 positions. Discontinue the operation support for the Susquehanna and the Colorado River Basin Flood Warning System for a total of \$1.0 million. Savings of \$200,000 will be achieved by canceling contract observations at Stampede Pass, Washington; Sexton Summit, Oregon; and Blue Canyon, California. A decrease of \$2.0 million is requested for equipment maintenance. NOAA proposes to streamline NWS management by consolidating six of the National Weather Service (NWS) regions into four, saving a net of \$1.2 million and eliminating 29 positions.

Environmental Satellite, Data, and Information Services. Proposed funding for FY 1992 includes an increase in the polar-orbiting satellite program of \$99.5 million and an increase in the geostationary satellite program of \$51.2 million. These changes will 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 1991 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.

A reprogramming of \$7.0 million in FY 1991 and an increase of \$5.6 million in FY 1992 is proposed to initiate the Earth System Data and Information Management Program. The key elements of this program are the rescue of critical data that are presently at risk of being lost due to deterioration of storage media and outmoded data handling equipment, and improved access to NOAA's environmental data and information.

Funds are also included to provide basic mission services including maintenance and operation of satellite ground facilities; provision of satellite-derived products; conduct of research to improve

the use of satellite data; and the archiving and dissemination of climatic, oceanographic and geophysical data.

Weather Research. Under the Weather Research line item, including Solar Environmental Research, there will be a net programmatic decrease of \$8.301 million due to the funding profile for operation and assessment of the 25-site/16-state Wind Profiler Demonstration Network (WPDN). This funding profile reflects the availability of carryover funds to operate the program.

In addition, the Program for Regional Observing and Forecasting Systems (PROFS) will be decreased. The cooperative five-state Weather Modification Research Program will also be terminated. The Program supports studies of the physical mechanisms of cloud and precipitation formation.

Offsetting these decreases will be an increase of \$500,000 to improve solar forecast data handling and processing capabilities.

#### DEPARTMENT OF DEFENSE (DOD)

The DOD total budget request for FY 1992 is \$787.6 million which is 3.3 percent less than the total funding level for FY 1991. Details are given below.

#### U.S. Air Force

U.S. Air Force resources for meteorological support for both operations and research can be divided into two distinct and major categories: General Operations and Defense Meteorological Satellite Program Operations ("DMSP" in the tables). Both of these have supporting research components.

General Operations. The operations part of this budget request for FY 1992 is \$363.8 million. Since last year's Federal Plan submission the operations budget was reduced over \$7.0 million in FY 1991; of this, \$4.5 million was cut by the Congress in the FY 1991 appropriation for contract savings on the Automated Weather Distribution System (AWDS). The remaining reduction was "fair share" of across-the-board Air Force operations and maintenance cuts. Because the AWDS contract savings had already been reprogrammed to procure systems meeting other Air Force requirements, the cut was absorbed in the AWDS line forcing a 40 percent reduction in the planned procurement of the Transportable (tactical version of) AWDS. Considering inflation, \$363.8 million in general operating budget represents a program decline of 4 percent since FY 1991.

The \$363.8 million, in the budget request, will pay for weather and space environmental support to the entire USAF (active force, national guard, and reserves), the entire US Army, six of the eight unified commands, both specified commands, and other executive agencies as directed by the Chief of Staff of the Air Force. The support is conducted by over 6200 people from over 260 weather units. These 6200 include active military reservists, weather members of the Air Force National Guard, weather reconnaissance specialists ("Hurricane Hunters"), weather communications and computer specialists, and civilians; all people in the Air Force dedicated to the weather mission. The funds pay the salaries of all these people and the operations and maintenance costs for support they provide.

The funds also pay for weather communications. The main weather communications hub at Carswell AFB processes over 250,000 weather messages per day to and from nearly 10,000 world-

wide weather stations over Air Force long haul circuitry and over some 1400 leased circuits. This function is required 24 hours per day, 365 days per year.

The FY 1992 request includes \$59 million for procurement of systems which will enhance the Air Force weather community's ability to support the needs of the Air Force, the Army and other DOD agencies. Although \$59 million falls \$5.5 million short of funds needed to meet requirements, there is still progress being made. Installations of AWDS reach full swing. AWDS allows weather forecasters to store, process, graphically display, and distribute weather information. Two other programs will be funded partially in FY 1992: the Trans-ionospheric Sensing System (TISS) and the Solar Electro-Optical Network (SEON) Upgrade and Replacement, increase the capability to support DOD communications and space operations. At the Air Force Global Weather Central (AFGWC), an effort begins to modify components of the Satellite Data Handling System (SDHS) to ingest and display additional required weather satellite data. Deployed weather teams to areas such as Desert Shield will benefit from two FY 1992 programs to buy tactical meteorological equipment. Finally, these funds continue the Air Force share of DOD payments to the Department of Commerce toward the Next Generation Weather Radar (NEXRAD) full scale production.

DMSP Operations. The Defense Meteorological Satellite Program (DMSP) is the primary DOD environmental satellite program. Though funding for DMSP comes from the Air Force, the system is the major source of space-borne meteorological data to the four military services. DMSP is also a national resource. Through the shared processing network, environmental data from all DMSP sensors is also provided outside the DOD to the National Weather Service.

The operations part of the FY 1992 budget request for DMSP is \$187.3 million. This is a 15.5 percent reduction from the FY 1991 budget. The substantial portion of this funding is for procurement of spacecraft and their associated environmental sensors. The reduction between FY 1991 and FY 1992 is due to the lower level of procurement of these items. Also included in the DMSP line is funding for 364 military and civilian personnel associated with the operation of, and to a much smaller extent the procurement of, the DMSP system. The funds also pay operations costs for two dedicated command and control facilities. In addition, \$17 million of the request is for procurement of Mark IVB tactical terminals for worldwide deployment.

General Supporting Research. The FY 1992 requested budget for Air Force supporting research is \$18.2 million which is a 3.2 percent increase (before inflation) over FY 1991. Research in weather systems development includes efforts to refine NEXRAD algorithms, enhancements to the AWDS through pre-planned product improvements, efforts to further refine and automate Electro-optical Tactical Decision Aids (EOTDAs) which provide battlefield commanders weapons performance indicators, development of a new sensor for the Air Force Radio Solar Telescope Network (RSTN), development of new weather computer models to improve space environmental specification and forecasting, and the development of new automated weather observing sensors. The Air Force continues to monitor the Department of Commerce's prototype development of the Automated Surface Observing System.

DMSP Supporting Research. The FY 1992 budget request for research and development funds for the Defense Meteorological Satellite Program is \$28.4 million which is a 41 percent decrease from FY 1991. This reduction is due to the completion of three major development efforts in FY 1991: the first 5D-3 satellite, the special sensor microwave imager/sounder, and the Mark IVB tactical terminal. Most of the developmental funding is for initial development of the next generation satellite system, DMSP Block 6. Block 6 satellites are scheduled to replace the Block 5D-3 production spacecraft in 2003. Block 6 spacecraft will offer improved avionics, and exploit

advanced hardware and software technologies to produce a more reliable, longer-lived spacecraft, with greater mission capability. The remaining funds are for continued calibration/validation efforts for new/modified sensors, development efforts for a new smaller tactical terminal, and modification of data application algorithms.

### U.S. Navy

The U.S. Navy FY 1992 funding request of \$122.06 million for meteorological programs is approximately the same as the planned funding for FY 1991. The request includes \$88.17 million for operational programs and \$33.89 million for supporting research.

Operations Support. Operations Support for Navy includes the day-to-day provision of meteorological products and services, as it does for other agencies. Navy also provides specific and unique services such as acoustic propagation models and products, environmentally-sensitive tactical decision aids, and global ice analysis and forecast products. Communication costs are significant for an organization with global responsibilities, and the uniqueness of forces at sea drives requirements for specific products and communications capabilities.

Systems Acquisition. Major systems undergoing procurement in FY 1991 and FY 1992 are identified below (see Appendix B for more detail):

- ▶ Tactical Environmental Support System (TESS)
- ▶ Primary Oceanographic Prediction System (POPS)
- ▶ SMQ-II Environmental Satellite Receiver/Recorder
- ▶ Automated Surface Observing System (ASOS)
- ▶ Shipboard Meteorological and Oceanographic Observation System (SMOOS)
- ▶ NEXRAD Principal User Processors (PUPs)
- ▶ Naval Oceanographic Data Distribution and Expansion System (NODDES)

Research and Development. This equates to basic or exploratory research, usually conducted by a government or university laboratory. This research is not generally system-specific, but may have applications to one or more meteorological, oceanographic or tactical systems. Navy's tabulation of these data includes R&D funding for Exploratory Development initiatives.

### U.S. Army

The U.S. Army is requesting \$67.70 million for FY 1992. This is a 25.5 percent increase over the comparable FY 1991 spending. The request includes \$36.98 million for operations and \$30.72 million for supporting research.

This increase was caused by two opposing trends - an increase in procurement and continued decrement in Met Team support. Army will start procurement of a light weight upper air sounding system for artillery support in FY 1992. This will add approximately \$9 million for the engineering development, overhead start-up costs, and initial procurement. Forces Command (FORSCOM) will spend about \$3.75 million to upgrade the GOLDWING system used by the USAF Weather Teams for tactical weather communications. In the opposite trend, the TECOM will cut the Met Teams by about \$2 million to continue the trend started in FY 1990. The new and upgraded equipment will enhance operational capabilities of combat forces, but operational weather support to R&TE facilities will continue to decline. The lost TECOM funding will delay scheduled upgrades and replacement in hardware and software, make significant cuts in training and off-site support, limit augmentation of Met Teams for specific tests, or limit other on-site testing support. Within Training

and Doctrine Command, the Aviation Center will spend about \$500,000 to buy automated surface observing equipment for training locations and closed circuit television capabilities for local dissemination of weather information.

Within Army Materiel Command (AMC), following the transfer of the Met Teams to TECOM, ASL will sustain a further reduction of \$2.4 million from FY 1991 to \$20.9 million in FY 1992. This will reduce basic research into advancing the understanding of atmospheric behavior and phenomena affecting Army systems and operations. Communications-Electronics Command (CECOM) Center for Electronic Warfare/Reconnaissance, Surveillance, and Target Acquisition (CEW/RSTA) will increase funding from \$275,000 in FY 1991 to \$900,000 in FY 1992 to provide added technical assistance to the program managers for the artillery upper air systems and the Integrated Meteorological System (IMETS). The Research and Development on IMETS will begin in FY 1992 at a cost of approximately \$4.5 million. Other efforts in AMC, the Corps of Engineers, and the Medical Research and Development Command are expected to be about the same level in FY 1991.

The FY 1991 expenditures of \$25.7 million reported here for operational support differ from the FY 1991 requested funding of \$12 million reported in the Federal Plan for FY 1991. This difference was caused in large part by a change in reporting procedures. The Met Teams were transferred from Laboratory Command's (LABCOM) Atmospheric Sciences Laboratory to the Test and Evaluation Command's (TECOM) Atmospheric Sciences Division. The transfer removed the Met Teams budget (approximately \$13.9 million) from the R&D budget of ASL. In this Plan for FY 1992, the Met Team function is described as operational support rather than R&D support. In conjunction with the move, the Met Teams budget was cut by \$3.5 million. The remaining \$10.4 million was transferred to the FY 1991 operational funds. Personnel in operational support also increased from the 160 spaces transferred from ASL to TECOM. The increased cost of consumable supplies for artillery upper air soundings also raised FY 1991 operational costs reported in this Plan.

#### DEPARTMENT OF THE INTERIOR (DOI)

The DOI FY 1992 funding request of \$870,000 is for meteorological operations within the Bureau of Land Management (BLM). This request is the same as for FY 1991. In FY 1987, the funding and implementation for the Bureau-wide Initial Attack Management System (IAMS) and the Remote Automated Weather Station (RAWS) programs were re-emphasized with a planned FY 1991 program completion. This established changes in the operational and maintenance (O&M) funding required and the procurement funding needed to complete the total system. Annual increases in program costs are attributed to the increased requirements of personnel, travel, and operations to cover the added stations and network expansion to full implementation. After full implementation is reached, procurement costs will be reduced to systems life cycle change-out and O&M costs will normally plateau.

#### DEPARTMENT OF TRANSPORTATION (DOT)

Within DOT, the U.S. Coast Guard and the Federal Aviation Administration have reported on meteorological programs in FY 1991 and FY 1992.

##### U.S. Coast Guard (USCG)

All of USCG's funding for meteorological programs is for operations support. In FY 1992, the requested funding level is \$2.58 million. This is unchanged from the planned funding for FY 1991. Among the Coast Guard's activities is the collection and dissemination of meteorological information

TABLE 3.2 AGENCY OPERATIONAL COSTS, BY BUDGET CATEGORY  
(Thousands of Dollars)

AGENCY	Operations Support		Systems Acquisition		Special Programs		Total		% of FY92 TOTAL
	FY91	FY92	FY91	FY92	FY91	FY92	FY91	FY92	
Agriculture	9220	9740	0	0	0	0	9220	9740	5.6 0.5
Commerce/NOAA	404272	415933	313898	520160	4286	4614	722456	940707	30.2 45.9
Defense (Subtot)	462627	462722	223419	213552	41	43	686087	676317	-1.4 33.0
Air Force	298614	297843	51531	65977	0	0	350145	363820	3.9 17.7
DMSP*	54100	54357	167593	132986	0	0	221693	187343	-15.5 9.1
Navy	85141	86313	3390	1863	0	0	88531	88176	-0.4 4.3
Army	24772	24209	905	12726	41	43	25718	36978	43.8 1.8
Interior/BLM	870	870	0	0	0	0	870	870	0.0 0.0
Transp/CG	2577	2577	0	0	0	0	2577	2577	0.0 0.1
Transp/FAA	238210	264672	228130	142584	3335	3489	469675	410745	-12.5 20.0
EPA	----- Not Applicable -----								
NASA	6489	6971	1005	840	797	1030	8291	8841	6.6 0.4
NRC	200	200	0	0	0	0	200	200	0.0 0.0
TOTAL	1124465	1163685	766452	877136	8459	9176	1899376	2049997	7.9 100.0
% of FY TOTAL	59.2	56.8	40.4	42.8	0.4	0.4	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.

for the benefit of the marine community. The Coast Guard provides this information to NOAA's National Weather Service and provides use of facilities to the National Data Buoy Center.

### Federal Aviation Administration (FAA)

The Federal Aviation Administration's (FAA) involvement in meteorological programs is principally concerned with aviation weather. The FAA's role is limited to the observation and dissemination of aviation weather information and to very short range automated warnings and forecasts. FAA's aviation weather programs are aimed to improve the timeliness and accuracy of weather information to the aviation user. The FAA also supports research in those areas that involve improvements to the observation, dissemination and forecasting of aviation weather data to the end user including pilots, dispatchers, and air traffic controllers.

Total FAA funding for aviation weather in FY 1991 is \$484.3 million for both operations and supporting research. FAA's proposed FY 1992 budget for aviation weather is \$444.6 million -- a decrease of 8.2 percent from FY 1991. Most of the decrease is in the Systems Acquisition category which drops 37 percent from \$228.1 million to \$142.6 million. The Operations Support category will increase by 11 percent from \$238.2 million to \$264.6 million. Funding for supporting research will more than double, going from \$14.6 million to \$33.8 million.

Most of the FY 1992 decrease in Systems Acquisition is due to programs that are reaching maturity in terms of appropriations. Programs with decreases in excess of \$2 million are listed below.

<u>Program</u>	<u>Decrease</u> <u>(\$millions)</u>
Terminal Doppler Weather Radar (TDWR)	62.5
Direct Users Access Terminal (DUATS)	13.1
Flight Service Station Automation (FSSA)	8.2
Automated Weather Observing System (AWOS)	5.8
Automated Surface Observing System (ASOS)	2.9
New Generation Runway Visual Range (RVR)	2.5
National Graphic Weather Display System (GWDS)	2.1

Partially offsetting these decreases are FY 1992 increases in excess of \$2 million for three programs. These include the Real-time Weather Processor (RWP), the Low Level Wind Shear Alert System Enhancement (LLWAS), and the New Denver Airport with increases of \$6.4 million, \$4.1 million, and \$3.4 million, respectively.

In the area of Operations Support, most programs are flat or marginally up, due to cost inflation, from FY 1991 to FY 1992. There are two exceptions. Contract Weather Observations Program costs increase from \$18.4 million to \$24.2 million in FY 1992 due largely to a projected increase in contract sites from 157 in FY 1991 to 185 in FY 1992. Leased telecommunication costs increased from \$18.1 million to \$31.2 million in FY 1992 due to the operating costs of Direct User Access Terminals (DUATS) which is now operational.

Funding for supporting research programs increases significantly between FY 1991 and 1992. The majority of the increased funding is committed to programs which support systems research. Significant increases in funds for FY 1992 are programmed for Terminal Doppler Weather Radar, the Integrated Terminal Weather Information System, and the Aviation Weather Products Generator. The FAA is continuing its icing and airborne windshear research programs at approximately the same levels.

TABLE 3.3 AGENCY SUPPORTING RESEARCH COSTS, BY BUDGET CATEGORY  
(Thousands of Dollars)

AGENCY	Research & Development		Systems Development		Special Programs		Total		% of FY92 TOTAL	
	FY91	FY92	FY91	FY92	FY91	FY92	FY91	FY92		
Agriculture	20000	31060	0	0	0	0	20000	31060	55.3	8.1
Commerce/NOAA	43883	45096	3776	1870	8459	1470	56118	48436	-13.7	12.6
Defense(Subtot)	121522	100683	6749	10620	0	0	128271	111303	-13.2	28.9
Air Force	12292	12871	5361	5341	0	0	17653	18212	3.2	4.7
DMSP*	48484	28478	0	0	0	0	48484	28478	-41.3	7.4
Navy	33890	33890	0	0	0	0	33890	33890	0.0	8.8
Army	26856	25444	1388	5279	0	0	28244	30723	8.8	8.0
Interior/BLM	----- Not Applicable -----									
Transp/CG	----- Not Applicable -----									
Transp/FAA	4114	4401	10501	29427	0	0	14615	33828	131.5	8.8
EPA	7150	7150	0	0	0	0	7150	7150	0.0	1.9
NASA	81800	90400	67600	62800	0	0	149400	153200	2.5	39.8
NRC	150	150	0	0	0	0	150	150	0.0	0.0
TOTAL	278619	278940	88626	104717	8459	1470	375704	385127	2.5	100.0
% of FY TOTAL	74.2	72.4	23.6	27.2	2.3	0.4	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.

The number of personnel engaged in FAA's aviation weather program remains virtually unchanged at 3829 for FY 1991 and FY 1992. However, if one were to compare the FY 1991 personnel figure in this year's report with the FY 1991 personnel figure in last year's report, a discontinuity would be seen in the personnel figures. In this report, for the first time, FAA has included personnel assigned to maintenance of aviation weather systems. This one-time accounting change increases aviation weather personnel from 2898 to 3829 for FY 1991, an increase of about 32 percent.

Also included in this year's report for the first time are automated surface (land) observations stations. FAA will have about 140 such stations operational by the end of FY 1991. Many of these sites are at remote locations where weather observations have never been taken on a regular basis before.

#### ENVIRONMENTAL PROTECTION AGENCY (EPA)

All of EPA funding of meteorological programs is for supporting research. The anticipated funding level for FY 1992 is \$7.15 million, which is the same as the FY 1991 level. The funding level for general air quality model development under the Clean Air Act decreased from FY 1991 due to a Congressional reduction of funds for the EPA Office of Research and Development. However, this reduction was offset by a Congressional appropriation targeted specifically for the Southern Oxidant Study.

The EPA is continuing its development and validation of air quality dispersion models for pollutants on all temporal and spatial scales as mandated by the Clean Air Act. The research will focus on indoor, urban, mesoscale and regional models, and will be used to develop pollution control and exposure assessment strategies. Increased emphasis will be placed on meteorological research into regional ozone transport, global climate change, and acid aerosol formation, while research into acid deposition model development and evaluation has decreased due to completion of the field study to validate the Regional Acid Deposition Model.

#### NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Much of NASA's funding in meteorology is for supporting research. The requested funding for this supporting research in FY 1992 is \$153.2 million, an increase of 2.5 percent from the revised FY 1991 funding level. The FY 1991 funding level was revised downwards by nearly \$50 million primarily because of refocusing of NASA priorities and increased research emphasis on basic climatology. The FY 1992 level reflects increased funding for all of the supporting research and analysis programs, the development of several research instruments for flight in space, Earth Probes and the Earth Observing System related activities. Request for the Upper Atmosphere Research Satellite declined from \$66.0 in FY 1991 to \$18.5 million in FY 1992 due to its maturity and launch readiness.

#### NUCLEAR REGULATORY COMMISSION (NRC)

The NRC is requesting funding of \$200,000 for meteorological operations and \$150,000 for supporting research. The FY 1992 request is essentially unchanged from the FY 1991 request.

The meteorological support program in the U.S. Nuclear Regulatory Commission is primarily focused on obtaining and analyzing meteorological data and information to be utilized in atmospheric dispersion models used in the determination of concentration and dose projections, and plume pathway characterizations related to the safe operation of nuclear facilities and the protection of the

TABLE 3.4 AGENCY OPERATIONAL COSTS, BY SERVICE  
(Thousands of Dollars)

AGENCY	Basic		Aviation		Marine		Agriculture & Forestry		General Military		Other		Total	
	FY91	FY92	FY91	FY92	FY91	FY92	FY91	FY92	FY91	FY92	FY91	FY92	FY91	FY92
Agriculture	0	0	0	0	0	0	9220	9740	0	0	0	0	9220	9740
Commerce/NOAA	665304	884533	32580	35389	19265	17885	2407	0	0	0	2900	2900	722456	940707
Defense(Subtot)	300860	291450	193910	191946	25504	24692	0	0	132447	136158	33366	32071	686087	676317
Air Force	175072	181910	122551	127337	0	0	0	0	35015	36382	17507	18191	350145	363820
DMSp*	110847	93671	44338	37469	0	0	0	0	55423	46836	11085	9367	221693	187343
Navy	14941	15869	26626	27140	25504	24692	0	0	16686	15962	4774	4513	88531	88176
Army	0	0	395	0	0	0	0	0	25323	36978	0	0	25718	36978
Interior/BLM	0	0	0	0	0	0	0	0	0	0	870	870	870	870
Transp/CG	1777	1777	0	0	800	800	0	0	0	0	0	0	2577	2577
Transp/FAA	0	0	469675	410745	0	0	0	0	0	0	0	0	469675	410745
EPA	----- Not Applicable -----													
NASA	0	0	0	0	0	0	0	0	0	0	8291	8841	8291	8841
NRC	70	70	0	0	0	0	0	0	0	0	130	130	200	200
TOTAL	968011	1177830	696165	638080	45569	43377	11627	9740	132447	136158	45557	44812	1899376	2049997
% of FY TOTAL	51.0	57.5	36.7	31.1	2.4	2.1	0.6	0.5	7.0	6.6	2.4	2.2	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.

health and safety of the public and the environment. Obtaining current, accurate, and relevant meteorological information on a real-time basis for use if needed during emergencies is a prime consideration. The NRC budget in this area reflects these priorities.

### AGENCY FUNDING BY BUDGET CATEGORY

Table 3.2 (page 3-8) shows how the agencies plan to obligate their funds for meteorological operations broken down by budget category. The funding levels for each agency were discussed above. Table 3.3 (page 3-10) shows how the agencies plan to obligate their funds for meteorological supporting research according to the budget categories.

In earlier years, the agencies' operational budgets were subdivided into "functional" categories-- Observations, Analyses and Forecasts, Communications, Dissemination, and Management Support. Advancing technology and increasing integration of components have blurred the meaning of these functions and have made identification more difficult. The new categories were chosen to align more closely with agency budgets or, at least, to simplify the relationship between agency budgets and the new categories. As a result, the new categories are referred to as "budget categories". The two major new categories are "Operations Support" and "Systems Acquisition". To a large degree, these correspond to hardware costs (Systems Acquisition) and non-hardware costs (Operations Support). For agency convenience in identifying small components that do not fit into the above two major categories, a third category, is added, "Special Programs". Also for agency convenience, special programs such as the Air Force's Defense Meteorological Satellite Program can be listed on a separate line. The agencies supporting research budgets are subdivided along similar lines -- Systems Development (hardware), Research and Development (non-hardware), and again Special Programs for small items that do not easily fit into the first two 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 indicates the corresponding data for supporting research. Table 3.4 shows that "Basic" services require approximately 51 percent of the total operational costs while Aviation Services require about 36 percent. The remaining 13 percent is used to support the other specialized services. The definitions of specialized and basic services are provided below.

#### Specialized Services

Aviation Meteorological Services. Those services and facilities established to meet the requirements of general, commercial and military aviation. Civil programs are included that are directly related to services in support of rotary wing aircraft and medium or long-range missile operations.

Marine Meteorological Services. Those services and facilities established to meet the requirements of Commerce and Defense on the high seas, 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 Meteorological 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.

TABLE 3.5 AGENCY SUPPORTING RESEARCH COSTS, BY SERVICE  
(Thousands of Dollars)

AGENCY	Basic		Aviation		Marine		Agriculture & Forestry		General Military		Other		Total	
	FY91	FY92	FY91	FY92	FY91	FY92	FY91	FY92	FY91	FY92	FY91	FY92	FY91	FY92
Agriculture	0	0	0	0	0	0	20000	31060	0	0	0	0	20000	31060
Commerce/NOAA	51451	43769	1767	1767	0	0	0	0	0	0	2900	2900	56118	48436
Defense(Subtot)	10898	11421	0	0	33890	33890	0	0	83483	65992	0	0	128271	111303
Air Force	8826	9106	0	0	0	0	0	0	8827	9106	0	0	17653	18212
DMSP*	0	0	0	0	0	0	0	0	48484	28478	0	0	48484	28478
Navy	0	0	0	0	33890	33890	0	0	0	0	0	0	33890	33890
Army	2072	2315	0	0	0	0	0	0	26172	28408	0	0	28244	30723
Interior/BLM	----- Not Applicable -----													
Transp/CG	----- Not Applicable -----													
Transp/FAA	0	0	14615	33828	0	0	0	0	0	0	0	0	14615	33828
EPA	0	0	0	0	0	0	0	0	0	0	7150	7150	7150	7150
NASA	149400	153200	0	0	0	0	0	0	0	0	0	0	149400	153200
NRC	150	150	0	0	0	0	0	0	0	0	0	0	150	150
TOTAL	211899	208540	16382	35595	33890	33890	20000	31060	83483	65992	10050	10050	375704	385127
% of FY TOTAL	56.4	54.1	4.4	9.2	9.0	8.8	5.3	8.1	22.2	17.1	2.7	2.6	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.

General Military Meteorological 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 here.

Other Specialized Meteorological Services. Those services and facilities established to meet requirements of user agencies or groups not included in the preceding categories, such as support to civil and military programs involving space operations and support to Federal, state and local governmental agencies responsible for dealing with urban air pollution.

Basic Services

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

PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS

Table 3.6 shows agency staff resources in meteorological operations. Overall, agency staff resources for FY 1992 total 17,748, which is a decrease of 2.6 percent from FY 1991.

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

<u>AGENCY</u>	<u>FY 91</u>	<u>FY92</u>	<u>%CHG</u>	<u>% of FY92 TOTAL</u>
Agriculture	98	98	0.0	0.6
Commerce/NOAA	4607	4264	-7.4	24.0
Reimbursed**	635	635	0.0	3.6
Defense (Subtotal)	8953	8821	-1.5	49.7
Air Force	6312	6210	-1.6	35.0
DMSP	364	364	0.0	2.1
Navy	1694	1659	-2.1	9.3
Army	583	588	0.9	3.3
Interior/BLM	16	16	0.0	0.1
Reimbursed**	4	4	0.0	0.0
Transp/CG	79	79	0.0	0.4
Transp/FAA	3829	3829	0.0	21.6
EPA	0	0	0.0	0.0
NASA	0	0	0.0	0.0
NRC	2	2	0.0	0.0
<b>TOTAL</b>	<b>18223</b>	<b>17748</b>	<b>-2.6</b>	<b>100.0</b>

\* 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

<u>Agency Funds Transferred from:</u>	<u>Agency Funds Transferred to:</u>	<u>FY 1991 Funds (\$K)</u> <u>Estimated or Planned</u>		
		<u>Operations</u>	<u>Supporting Research</u>	
Commerce/NOAA	DOT/FAA	\$486		
	DOT/USCG	693		
	NASA	125		
	DOI/MMS	151		
Defense: Army	DOC/NOAA	690	\$578	
	Navy	DOC	895	
	Air Force	DOC	295	
	Air Force	DOT		350
	Air Force	USGS	176	
Transportation/FAA	DOC/NOAA	17,888	2,925	
	NSF		6,975	
	DOD/USAF		1,100	
NASA	DOD/USAF	460		
	DOC/NOAA/NWS	1,670		
	DOC/NOAA/NDBC	76		
	DOC/NOAA/NCC	110		
EPA	DOC/NOAA/ARL		3,800	
DOE	DOC/NOAA/NWS	2,246		
NRC	DOC/NOAA/ARL	45		
	DOE/PNL		150	
USDA	DOC/NOAA/NCPO	30		

## INTERAGENCY FUND TRANSFERS

Table 3.7 summarizes interagency fund transfers for FY 1991 to other agencies to pay for services that the receiving agencies can perform more efficiently and effectively. While specific amounts may vary from year-to-year, depending upon agency needs, the pattern shown in this table is essentially stable and reflects a significant level of interagency cooperation.

Department of Commerce (DOC). The FAA will be reimbursed \$486,000 for facilities support; the USCG \$693,000 for support to the Data Buoy Center; NASA \$125,000 for support at Wallops Island; and DOI's Minerals Management Service \$151,000 for continued operation of moored buoys off the California coast.

Department of Defense (DOD). The Army reimbursements include: DOC \$578,000 for supporting research relating to Lidar development, horizontal path profilers, UHF wind profiler, radio acoustic sounder, radar support, icing model evaluation, mini Sodar, expendables, and \$690,000 to maintain weather reporting stations. The Navy will reimburse DOC a total of \$895,000 of which \$800,000 is for climatological analysis and forecasting and \$95,000 for training in satellite applications and forecasting. The Air Force will reimburse DOC a total of \$295,000 for climate data (\$165,000), and general support (\$130,000). The Air Force will transfer \$350,000 to DOT to complete a contract helping develop automated observation sensors and \$176,000 to USGS for magnetometer data.

Department of Transportation. The FAA will reimburse DOC/NOAA a total of about \$17.888 million for operations -- \$6.57 million for meteorological support at Center Weather Service Units (located with most Air Route Traffic Control Centers and the National Aviation Weather Unit in Kansas City); \$11.30 million for contract weather observations; and \$18,000 for high altitude facsimile charts. FAA will also reimburse NOAA \$2.925 million for supporting research. The National Science Foundation will be provided \$6.975 million to have the National Center for Atmospheric Research run TDWR/LLWAS field tests, and related work. The Air Force will be reimbursed \$1.1 million for Lincoln Laboratory's Orlando TDWR prototype field work.

National Aeronautics and Space Administration. The Air Force will be reimbursed \$460,000 for data acquisition; NOAA/NWS will be reimbursed \$1.67 million principally for meteorological support to the space-shuttle operations; NOAA/NDBC \$76,000 for operation of data buoys; and NOAA/NCC \$110,000 for climatological data.

Environmental Protection Agency. NOAA's Air Resources Laboratory will be reimbursed \$3.8 million for research related to air quality dispersion models, and guidance for EPA policy development.

Department of Energy. The NOAA/NWS will be reimbursed \$2.246 million to support the Weather Service Support Office at the Nevada Nuclear Test Site.

Nuclear Regulatory Commission. NOAA's Air Resources Laboratory will be reimbursed \$45,000 for technical assistance; and DOE's PNL will be reimbursed \$150,000 for technical assistance.

## LOCATIONS BY TYPE OF OBSERVATION

Table 3.8 indicates the number of locations or platforms at which the Federal agencies carry out (or supervise) the various types of weather observations. Both the type and the number of platforms change little from year to year.

TABLE 3.8 LOCATIONS BY TYPE OF OBSERVATION

<u>Type of Observation</u>	<u>Agency</u>	<u>No. of Locations (FY 1991)</u>
Surface, land	Commerce (WSO, WSFO, WSMO)	233
	Commerce (WSCMO)	27
	Commerce (Marine Reporting/CG Station)	146
	Commerce (AMOS, RAMOS, AUTOB, DARDC)	127
	Commerce (Supplem. Aviation Wea. Reportg Station)	450
	Defense (U.S.)	173
	Defense (Overseas)	92
	Transportation (Flight Service Station)	137
	Transportation (Limited Aviation Wea. Rprtng Station)	152
	Transportation (FAA Contract Wea. Obs. Station)	123
	Transportation (Automated Wea. Obs. Station)	140
	Transportation (USCG Coastal)	110
	Interior	214
	Agriculture	840
	NASA	2
	Surface, marine	Commerce (Merchant Ship Coop Program)
Commerce (Merch Ship Coop - Foreign Assisted)		314
Commerce (SEAS-equipped ships)		120
Commerce (Coastal-Marine Automated Network)		52
Commerce (Moored Buoy)		50
Commerce (Large Navigation Buoy)		9
Defense (Ships with met personnel)		39
Defense (Ships without met personnel; based on record archivals during CY 1989)		283
Transportation (Coast Guard Ships)		93
Upper air, balloon	Commerce (U.S.)	98
	Commerce (Foreign, cooperative)	33
	Defense Fixed (U.S. & Overseas)	69
	Defense (Ships)	33
	Defense Mobile (U.S. & Overseas)	70
	NASA (U.S.)	2
Upper air, rocket	NASA	1
	Defense	2
Weather radar	Commerce (NWS)	129
	Commerce (At FAA Sites)	27
	Defense (U.S. & Overseas)	125
	Defense (Remote displays)	49
	Transportation (Remote display)	131
	NASA	1
Weather reconn. (No. of aircraft)	Commerce (NOAA)	2
	Defense (USAFRES)	10

## SECTION 4

### SOME RECENT DEVELOPMENTS IN LIGHTNING MAPPING SYSTEMS\*

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#### INTRODUCTION

Since their first implementation in the 1970's, systems that automatically map lightning flashes have helped federal agencies address wide ranging weather-related problems. In some federal operations, such as rocket launches, munitions handling, mining, forest fire prevention, and airport operations, lightning itself is a primary threat. In others, lightning mapping systems provide a valuable tool to identify and track storms for thunderstorm warnings and forecasts. Applications of mapping systems have grown rapidly in recent years and continue to grow. These applications have saved the government millions of dollars in reduced property damage, operating expenses, and down time. Present users include agencies in DOD, DOC, DOI, DOE, DOT, USDA, and NASA.

This article emphasizes the development of lightning mapping systems. For information on agency operational systems including lightning detection systems, the reader should refer to the report "Preliminary National Plan for Lightning Detection Systems" (FCM-P22-1988). This report is available from the Office of the Federal Coordinator.

Before 1970, remote sensing techniques for locating lightning required cumbersome manual analysis and provided little information about the structure of lightning channels inside storms. Since then, several technologies have been developed by private companies to locate lightning automatically out to ranges of 100 miles or more. Different scientific insights have been important in developing each of the technologies, but a critical development for all the technologies has been the radical advances in data communication and in computer power that were made in the 1970's and 1980's.

One of the first of these technologies, a system for mapping where lightning strikes ground, was installed by the Bureau of Land Management in the late 1970's to detect lightning-ignited forest and range fires. These data were also supplied to the Western Region of the National Weather Service (NWS) for use in detecting thunderstorms in regions with little if any radar coverage. A short time later, both NOAA and the State University of New York at Albany installed systems primarily for use in storm research.

In September 1983, the Office of the Inspector General, Department of Commerce, issued a report describing the situation then developing, in which several government agencies were using, or planned to use, lightning detection systems to increase the efficiency of their operations. The report noted that independent actions by multiple agencies probably would lead to duplicate efforts and to voids and extensive overlap in coverage of the lightning mapping systems. As a result of recommendations in the report, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) was requested to coordinate the efforts of federal agencies.

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\*This is a paper requested by the Office of the Federal Coordinator for Meteorology. It reflects some of the findings of a review initiated and supported by the Office of the Federal Coordinator.

To spearhead the coordination, the Interdepartmental Committee on Meteorological Services and Supporting Research (ICMSSR) of the OFCM formed the Ad Hoc Group for Lightning Detection Systems, which became, a year later, the Working Group for Lightning Detection Systems (WG/LDS). The WG/LDS conducted preliminary studies of existing and planned lightning detection systems and related government agency activities. In 1985, the WG/LDS decided that it was premature to develop a comprehensive national plan, because few agencies had enough experience with lightning mapping systems to assess requirements. In order to gain the necessary practical experience, agencies provided funds through the OFCM to combine three existing lightning strike mapping networks in a demonstration experiment, which lasted from April 1987 through March 1991. As a result of experience during the demonstration experiment, NWS plans to procure lightning strike data from a commercial national network for use by federal agencies for the next five years.

This paper describes some of the recent experience with lightning mapping systems. The aim is to provide enough basic background that a reader can understand developments in government use of lightning data over the next few years. The remainder of the paper will have three sections. The first will briefly describe various technologies now available for mapping lightning remotely. The second will examine the experience of one government unit, the National Severe Storm Forecast Center (NSSFC) of the National Weather Service (NWS), in using data from the National Demonstration Lightning Strike Detection Network in its operations. The third will examine examples of early research results that point to possible additional applications of lightning mapping systems.

Lightning Terminology. This subsection describes specialized lightning terminology that will be used in the rest of the paper. Lightning can be classified into two types: (1) Cloud-to-ground lightning is lightning that has at least one channel spanning from the cloud to the ground. (2) Intracloud lightning is any lightning that does not have a channel to ground and includes in-cloud, cloud-to-air, and cloud-to-cloud lightning. Cloud-to-ground lightning can be further classified by the polarity of charge that it effectively lowers to ground: Positive cloud-to-ground lightning lowers positive charge; negative cloud-to-ground lightning lowers negative charge. Most cloud-to-ground flashes are negative.

A cloud-to-ground lightning flash usually begins inside the cloud and is first apparent when a faint channel, called the stepped leader, moves from the cloud to the ground in jumps roughly 50-100 meters long. When the stepped leader connects with the ground, a bright pulse moves back up the lightning channel in a process called a return stroke. After a pause of roughly 0.02-0.15 seconds, another leader can travel back down the already established lightning channel, followed by another return stroke. The combination of a leader and return stroke is called a stroke. All strokes going through essentially the same channel to ground make up a single cloud-to-ground flash. There can be anywhere from one to a few tens of strokes in a flash.

## LIGHTNING MAPPING TECHNOLOGY

Several technologies are now used to map where lightning occurs. This section will introduce the basic concepts of the technologies that are expected to be used for meteorological operations. It begins with technologies for mapping the ground strike point of cloud-to-ground lightning, because they are most likely to be used in a national network in the next few years. Additional information about ground strike mapping systems can be found in an evaluation of ground strike mapping systems sponsored by the OFCM (MacGorman and Rust, 1988). The section concludes by discussing two technologies for mapping all lightning.

## Direction-Finder System

The present direction-finder system is an outgrowth of a technology that is decades old. The basic sensor is a crossed-loop antenna that consists of two vertical loops mounted perpendicular to each other, one oriented north-south, the other east-west. If a lightning channel is vertical, the signal induced in each loop depends on the electric current in the lightning channel and on the angle between the plane of the loop and the bearing to the lightning channel. By using the ratio of the signals induced in two perpendicular loops, the dependence on current is eliminated; the ratio depends only on the bearing to the lightning channel. When the bearing is measured by two or more direction finders, the location of the channel can be calculated by triangulation, as shown in Figure 4.1.

A major improvement of direction-finder technology was introduced by Lightning Location and Protection, Inc. (LLP) in the 1970's. Direction-finder systems work properly only for vertical lightning channels, so LLP designed direction-finder systems that use only the part of a lightning signal generated by the cloud-to-ground lightning channel within roughly 100 meters of ground. Since lightning channels are predominantly vertical near ground, the errors caused by departures from vertical orientation are small.

To use the signal from a lightning channel near ground, it is necessary first to make sure that the signal is generated by a cloud-to-ground flash. The LLP system uses signals in the radio frequency band below about 100 kHz, where cloud-to-ground flashes radiate much more energy than intracloud flashes. LLP also has developed several tests for the shape of signal waveforms in this band to identify signals from cloud-to-ground flashes and reject signals from intracloud flashes.

The largest sources of location error are terrain features and man-made structures that reradiate lightning signals. Errors from these sources are called site errors. They are different for lightning in different directions from a station, but are the same for all lightning flashes in the same direction, and they usually are reasonably constant in time. Therefore, once site errors are determined, measured bearings to flashes can be corrected in real time.

An LLP direction-finder network consists of several direction-finder stations that send lightning data to a central analyzer, called a position analyzer. If the position analyzer receives data from two or more direction-finder stations within a preset time window (typically 0.02 seconds or less), it assumes that the stations detected the same flash and calculates a strike location.

There have been several evaluations of the LLP direction-finder system. These have found that the system detects 60-90 percent of the cloud-to-ground flashes that occur. At least part of this spread of values is caused by variations in lightning characteristics from one geographical region to another. Based on published evaluations and on additional analyses by MacGorman and Rust (1988), a national network of direction-finder stations is expected to have location errors of 3-6 miles within most of the contiguous United States. Outside the contiguous United States, errors are expected to be less than 7 miles within 125 miles of the network and will increase to roughly 13 miles at a distance of 200 miles. These estimates assume that site errors larger than 1° have been removed from the data, so stations must have been established long enough (one thunderstorm season for most locations) to determine site errors.

## Time-of-Arrival System

Lightning Position and Tracking System (LPATS) for mapping lightning was first developed and manufactured in the early 1980's by Atlantic Scientific Corp., which later became Atmospheric Research Systems, Inc. (ARSI). This system detects lightning with a simple whip antenna and uses a time-of-arrival technique: each station identifies the time of a peak in a lightning signal that it receives, and a central processor determines the differences in the times the lightning signal arrives

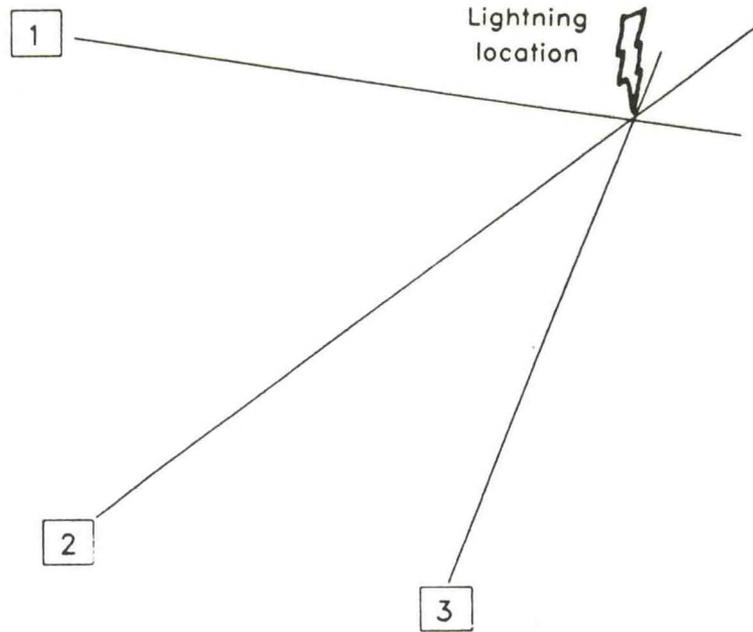


Figure 4.1 Locating lightning by triangulation. The bearings from the stations (numbered squares) intersect at the location of the lightning channel.

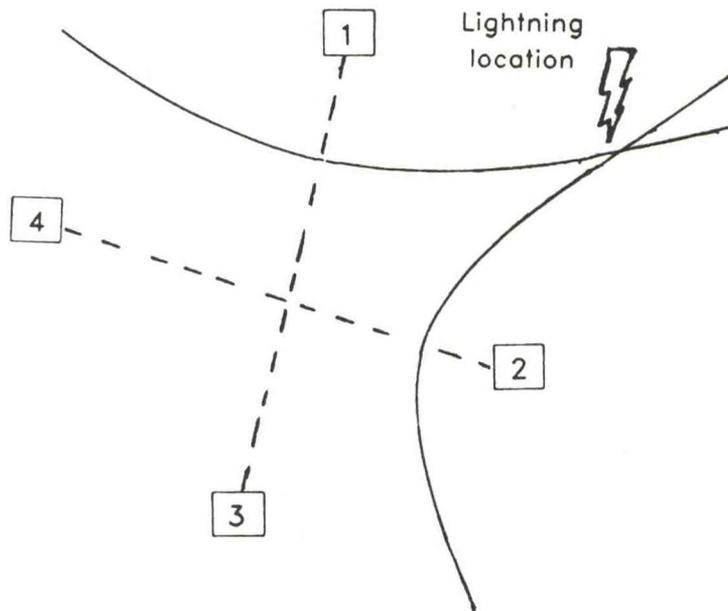


Figure 4.2 Locating lightning by the time-of-arrival technique. The difference in times that a lightning signal arrives at two stations (numbered squares) defines a hyperbola on which the lightning channel is located. The hyperbolas from different pairs of stations intersect at the location of the lightning channel.

at four to six stations. For a given time difference between a pair of stations, the lightning channel that generated the signal can be located anywhere along a hyperbola that passes between the stations (see Figure 4.2). The location of the lightning is found by solving for the intersection of two hyperbolas, each determined by a time difference between a different pair of stations.

Unlike the LLP system, LPATS does not use waveform criteria to evaluate whether a signal is from a cloud-to-ground flash. Although cloud-to-ground lightning generates the largest signals in the radio frequency band of LPATS, an individual LPATS station can accept signals from both cloud-to-ground and intracloud lightning. If stations are only a few tens of miles apart, many of the nearby lightning channels that LPATS locates likely will be from intracloud flashes. However, as the distance between stations becomes larger, it becomes less likely that a signal received at multiple stations is from an intracloud flash, because intracloud signals do not usually travel as far as signals from cloud-to-ground flashes. If the distance between stations is at least 125-150 miles, most lightning flashes mapped by the system will be cloud-to-ground flashes.

The critical task for a time-of-arrival system is to accurately time the arrival of the same part of a lightning signal at four or more stations. When stations are more than 100 miles apart, the specified performance of an LPATS network can be maintained by synchronizing time between stations within less than a millionth of a second. ARSI has developed two techniques for synchronizing stations, one using the signal from a single LORAN-C navigational transmitter and the other using synchronization pulses from television broadcasts.

Identifying the same return stroke signal at four stations is not usually difficult, because the propagation time of the signal between stations is much smaller than the time interval between return strokes, even in a multistroke flash. When there is too much local radio noise at a site, however, the LPATS station's processing capacity is overloaded. Noise problems can be caused either by man-made noise or by frequent radio impulses from nearby intracloud lightning. Sites can be chosen to eliminate most problems with man-made noise, but thunderstorms can occur near any site. LPATS turns a station off if the number of signals detected by the station is large enough that thunderstorms are likely to be nearby.

Aside from possible problems with noise, errors in lightning locations from LPATS are caused by anything that affects the determinations of the time of the peak in a lightning signal. The largest errors occur when one of the stations chooses the wrong peak or has its time synchronized incorrectly. However, these errors can be detected by newer models of LPATS (models after Series 2), so resulting strike locations can be discarded. The next largest errors are caused by changes in a lightning signal as it propagates from a flash to a station. The effect of propagation on location errors usually decreases with distance outside the network and is largest within the boundary of the network.

A national LPATS network probably will consist of several independent networks that communicate with a central computer. Results from the most extensive evaluation of LPATS (MacGorman and Rust, 1988) suggest that such a linkage of LPATS networks will locate 40-55% of the cloud-to-ground flashes. Typical location errors will be 6-13 miles near and inside the boundary of each individual LPATS network. Outside each network, the location accuracy is expected to improve, with errors typically less than 6 miles at a range of 125-200 miles from the center of the nearest four stations.

#### Arrival-Time-Difference System

The arrival-time-difference (ATD) system was developed by the British Meteorological Service to replace the manual direction-finder system that it had used for decades. Like LPATS, the ATD system determines the difference in times at which a lightning signal arrives at different pairs

of stations and uses the time differences to calculate the location of lightning. Instead of timing only the peak of the signal waveform, however, the entire waveform and the time it arrived are transmitted back to a central analyzer. The central analyzer then analyzes the whole waveform to determine the time differences between stations.

The British Meteorological Service had a specific set of requirements that dictated the parameters of the system they developed. The primary concern was to develop an automatic system for accurately locating lightning, and hence, thunderstorms, over ranges of thousands of miles, much of which was over oceans. Having a high detection efficiency was not a requirement, so the system was designed to analyze only about 500 flashes per hour. The Very Low Frequency (VLF) radio band (300-3000 Hz) was chosen because cloud-to-ground lightning radiates strong signals in that band, and because VLF signals can propagate thousands of miles. Distances between neighboring stations were set at 150-2100 miles to provide the necessary accuracy in the computed lightning locations.

Most evaluations of the ATD system have been statistical analyses of ATD data alone. Published estimates indicate that typical location errors are less than about 2 miles in Great Britain and increase to roughly 15 miles at the western limit of the system's service area, about 1500 miles away.

### SAFIR Interferometric System

Although American scientists were the first to adapt interferometry from radio astronomy in order to map lightning channels, another adaptation of the technique was developed independently in France beginning in 1979 and was subsequently commercialized as the SAFIR system by the French company Dimensions. SAFIR is used in meteorological operations for the European space program and is the only commercial system now available that is designed to map both intracloud and cloud-to-ground lightning. (Several research systems have been developed.) A typical SAFIR system has three interferometric stations separated by 20-60 miles. Each station in the system uses interferometry to determine the bearing to a lightning channel inside a cloud and sends that information to a central processor. The central processor uses triangulation from two or more stations to calculate the location of the channel.

SAFIR uses a higher radio frequency band than is used by systems designed primarily to detect cloud-to-ground lightning. Ground-based radio receivers in this higher frequency band usually receive signals from lightning no more than roughly 100 miles away. At this range, a SAFIR system with a 60 mile baseline between stations will have a typical error of 3-5 miles in the location of lightning channels that it maps. Within the network, typical errors are approximately 1 mile.

### Satellite Lightning Mapper

NASA and NOAA plan to launch a satellite lightning mapper on one of the present series of GOES weather satellites in the late 1990's, although plans are not yet finalized. The sensor, which was developed by NASA, is a charge-coupled-diode optical array with electronics capable of detecting transient light from lightning, even during the day. This sensor has been packaged with lenses to provide coverage of much of North America, including all of the contiguous United States, with resolution of about 6 miles in both the east-west and north-south coordinates. From work with prototypes, NASA estimates that the system will detect 90 percent of the flashes that occur in daylight.

When this system is launched, it will provide a new capability to map both cloud-to-ground and intracloud lightning continuously over continental distance scales. No means have yet been found to reliably distinguish between cloud-to-ground and intracloud lightning with the satellite's

optical sensor, but identification of flash type can be provided by combining satellite data with data from a ground-based network, such as those described above. These data are expected to be extremely valuable for thunderstorm and climate research and for lightning and thunderstorm detection and warning.

#### NSSFC EXPERIENCE WITH NATIONAL LIGHTNING STRIKE DATA

The networks combined for the demonstration experiment mentioned in the Introduction were operated by three different organizations: the National Severe Storms Laboratory (NSSL), the Bureau of Land Management (BLM), and the State University of New York at Albany (SUNYA) (listed from smallest to largest coverage). The SUNYA network had substantial support from the Electric Power Research Institute, the National Science Foundation, and NASA. All three networks used LLP direction-finder stations.

For this experiment, data from the NSSL and BLM networks were transmitted to SUNYA and combined with SUNYA data in real time. SUNYA then transmitted lightning strike locations for the entire region of coverage to users via satellite links. When the demonstration experiment began in 1987, coverage by the networks encompassed approximately 80 percent of the area of the contiguous United States. By the summer of 1989, SUNYA had expanded coverage of its network to fill in almost all voids.

The National Severe Storms Forecast Center (NSSFC) was chosen as the primary NWS office to evaluate the utility of national lightning strike data for NWS operations because it had advanced interactive displays with rapid access to satellite data, radar data, and standard weather observations, and it had many of the capabilities that NWS forecast offices will have in the future. A primary reason for the evaluation was a concern that lightning data would provide little new information, but would contribute to a flood of data sources that might overwhelm forecasters. It had been argued, for example, that lightning data are primarily useful where radar data are not available, such as in much of the western United States. Since the NSSFC had computer access to several meteorological data sources, it was well suited to testing the utility of lightning strike data in the presence of other data.

In April 1988, the NSSFC installed SUNYA display systems for lightning strike data at its offices in Kansas City. Independent displays were installed in two of the NSSFC forecast units, with each having a slave display in an adjacent unit. The lightning display program ran on a personal computer using SUNYA software and plotted a strike location for each cloud-to-ground flash in essentially real time. Flashes were color coded to indicate the time interval in which they occurred. The software allowed the user to select either a continuously updated static display of strike points in real time or a dynamic looping of time-lapse sequences up to the current time. A zoom feature allowed the user to focus on any region of concern.

Four units at the NSSFC, each with differing forecast responsibilities, had access to real-time lightning mapping data: (1) The Severe Local Storms unit (SELS) is responsible for issuing severe thunderstorm and tornado watches for the continental U.S., and for providing one and two day advance outlooks for general and severe thunderstorms. (2) The Mesoscale Division (MD) is responsible for providing guidance to NWS offices about significant mesoscale weather features expected to occur during the next three hours. (3) The Convective SIGMET unit is responsible for issuing SIGMET forecasts to aviation interests for thunderstorms that aircraft should avoid. (4) The In-Flight Advisory and Area Forecast (FA) Unit is responsible for forecasts of other weather hazards to aviation, such as turbulence, icing, low ceiling, reduced visibility, dust, and wind shear.

## Evaluation Results

The NSSFC began formal documentation of its evaluation of the lightning data in November 1988. At the end of every shift, forecasters in each unit were asked to complete a one-page questionnaire designed to give some insight into the applications and value of real-time lightning data in forecasting convective activity. Between November 1988 and August 1989, 1344 evaluations were collected from shifts in which convective activity occurred in the forecaster's area of concern when lightning data were available. Additional information about evaluation results is available in Lewis (1989).

Added Knowledge. On each questionnaire, forecasters were asked to classify thunderstorm activity during their shift as weak, moderate, or strong, and to evaluate whether lightning data added anything to their knowledge of the convective situation that could not be perceived from either satellite images or radar data. Of the 1344 responses, 461 categorized thunderstorm activity as strong, 512 as moderate, and 371 as weak. The forecasters indicated that lightning data contributed unique information about 60 percent of the time when convection was either weak or strong and 50 percent of the time when convection was moderate. An analysis of the responses from individual NSSFC units shows that the contribution of the lightning data depends, as expected, on the forecast responsibility of the unit. The SELS, SIGMET, and MD units found unique information 68-74 percent of the time; the FA unit, with forecast products that encompass weather elements other than storms, found unique information only 25 percent of the time.

Frequency of Use. With the availability of other, more familiar resources, such as satellite images, radar, and surface observations, and with the advent of the AWIPS-90 communication network, which will send data in packets at set intervals rather than in real time, there is a need to know how often the lightning data were being used. More specifically, how frequently did a forecaster refer to lightning data during busy periods of his shift. Overall, the median time interval between references to lightning data was about 10 minutes. As storm strength increased, there was a shift to more frequent use of lightning data, increasing from a median of about 13 minute intervals during weak and moderate convection to about 8-minute intervals during strong convection.

Utility of Lightning Data. Finally, forecasters were asked to evaluate the utility of lightning data in depicting eight aspects of thunderstorm activity: existence, initiation, movement, dissipation, configuration, coverage, intensity, and redevelopment. (These will be discussed in more depth in the next section.) For each aspect that was applicable to a shift's forecast situation, the forecaster on duty rated the utility on a scale from 1.00 to 4.00 with 4.00 signifying most useful. Overall, lightning utility was rated highest for existence and initiation, with mean scores of 3.25 and 3.04, respectively, while it was rated lowest for intensity, with a mean score of 2.17. The mean scores for the remaining five aspects were about the same -- approximately 2.7 overall. The utility of lightning data increased for most aspects as convection became stronger; the utility for all aspects except intensity was rated 3.0 or better when convection was strong.

## Uses of Real Time Lightning Strike Data

The NSSFC evaluation showed that lightning data were useful for many meteorological situations. This section describes how lightning strike data were used to examine each of the eight aspects of thunderstorm activity. These applications are described in more detail by Mosher and Lewis (1990).

Existence. When forecasting thunderstorms, which by definition generate lightning, the existence of lightning is a useful piece of information, particularly in regions with poor radar coverage. Much of the area in the western United States and out to 200 miles in coastal waters lacks

adequate radar coverage, but is covered by the lightning network. In these areas, lightning data are used with satellite data to monitor convection, much as a forecaster would use satellite and radar data to detect active thunderstorms. Lightning data also are used as a radar substitute if radar data are unavailable.

Lightning strike data have been especially useful in determining the existence of shallow convection. Occasionally, winter storms will have tops of 20,000 feet or less and yet will produce lightning. These storms are a hazard to aircraft. Furthermore, they can be embedded within areas of widespread precipitation, which makes them very difficult to detect with radar and satellite data.

Another application is in monitoring situations in which the forecast is uncertain. For severe weather to develop, a number of atmospheric conditions must occur simultaneously. In a typical case, some factors are favorable for the development of severe weather, but others are not; a forecaster must determine whether favorable factors dominate the situation. If lightning is present in a storm, it provides the valuable information that nature is allowing deep convection to occur. There have been a number of situations in which the existence or absence of lightning has influenced decisions made by SELS forecasters in issuing severe weather watches during marginal situations, when other meteorological data provided contradictory information.

Initiation. The NSSFC forecasters have observed that lightning data frequently provide the first indication that convection has started. This can be attributed to two factors. First, lightning strikes are displayed within a few seconds of occurrence. All other types of data are provided to the NSSFC on a fixed delivery schedule. Surface observations are generally available hourly, remote radar displays are available no more often than every 15 minutes, and satellite data are available every 30, 15, or 5 minutes, depending on the scanning mode of the satellite. Because lightning data are available continuously in real time, they often can show the beginning of convection before data from other sources.

The second factor is related to the way in which storms produce lightning. The electric charge that is the source of lightning is generated as the updraft of the storm causes moisture to condense and grow into the precipitation that radar detects. Eventually the precipitation falls out of the cloud, but it takes several minutes for the precipitation to reach ground level. Since present radar systems are generally operated only at low elevation angles, they pick up the rainfall near ground level, but not at higher elevations. Therefore, lightning systems frequently will detect convective activity ten minutes or more before low level radar scans detect precipitation.

Movement. To determine storm motion, a forecaster sometimes animates a sequence of periodically scheduled satellite and radar images. Because storms evolve between scheduled images, it is often difficult to follow the movement of individual thunderstorm cells, particularly if there is much convective activity. The looping option of the lightning display animates a continual time-lapse sequence of lightning strike activity. The better continuity of lightning data makes it easier for forecasters to monitor cell movement.

Dissipation. Forecasting the end of convection is one of the most challenging tasks of a meteorologist. Lightning data have become a primary tool to determine when convection is dissipating because diminishing lightning activity is usually closely related to dissipation of the storm updraft. A decrease in lightning rates often precedes a decrease in the power of signals reflected to a radar (radar reflectivity) from low regions of a storm by 10-30 minutes and precedes the warming of cloud tops shown on satellite images by 30-90 minutes. Hence, lightning data can be very effective in separating active convection from storm debris.

Another aid in detecting thunderstorm dissipation is a transition from predominately negative to predominately positive cloud-to-ground flashes. Although positive cloud-to-ground flashes are

generally much less common than negative cloud-to-ground flashes, as mentioned previously, they tend to occur in several specific situations. Positive flashes are usually limited mainly to upper outflow regions and to the area of widespread rain behind an active thunderstorm cell. However, as an isolated weak-to-moderate thunderstorm begins to dissipate, it often begins to produce predominately positive ground flashes. When this transition occurs, radar reflectivity at low heights generally will start to diminish within 30 minutes. While this signature is frequently useful, it must be used with caution, because positive cloud-to-ground flashes can be produced in other situations, as will be discussed later. Lightning data should be used in conjunction with other data sets, especially when used for severe storm forecasting, to provide a more complete indication of trends.

Configuration. Convection can take the form of an isolated cell, a line, a supercell, or a combination of these. Meteorologists traditionally have used the configuration of heavy precipitation on radar displays to infer information about the severity of a storm. For instance, a bowed line of storms, in which thunderstorms at the center of the bow move faster than thunderstorms at the edges, frequently produces severe damaging winds. Lightning data clearly show the horizontal structure of convection, and so can be used to infer information about the severity of the storm.

Lightning data also are useful in detecting the transition from scattered storms to organized lines of convection. Lines of convection are more disruptive to air traffic than scattered storms because flight paths around lines are generally much longer. Changes in storm configuration are apparent in lightning data up to an hour before becoming visible on radar and satellite images. As a result, Convective SIGMET meteorologists have been able to improve their product by reducing the areas covered by SIGMETS and by delineating threatened areas more accurately.

Coverage. Satellite images of cloud tops and Manually Digitized Radar (MDR) observations have traditionally been used by NSSFC forecasters to determine storm coverage. However, MDR observations have coarse resolution (about 27 miles), and areas of active convection are often obscured on satellite images by higher cloud shields. Lightning data resolve convective activity better than MDR observations and are useful in determining the location of active convection within the cloud mass shown on satellite images.

Intensity. The main concern of NSSFC's forecasters with respect to storm intensity is to forecast and detect severe storms, including tornadic storms. Unfortunately, cloud-to-ground lightning characteristics have been difficult to correlate with severe weather, because apparent relationships have considerable variability. Research results show some signs of promise for this application, as will be discussed in a later section, but relationships are not yet understood well enough to be applied in operations. Consequently NSSFC forecasters have been cautious in using lightning flash rates to infer severe weather.

Although lightning flash rates vary considerably from storm to storm, trends in lightning flash rates can be a useful tool in determining if a storm has reached its full convective potential. Increasing or decreasing flash rates usually indicate that the storm is growing or dissipating, respectively. (One exception that can be readily identified during forecasting operations is described in the section on research results.)

Redevelopment. While decreasing lightning activity can often be a good indication that a thunderstorm system is dissipating, an increase in negative flashes behind a storm that has started to dissipate is a very good indication that redevelopment is taking place. This early signal of redevelopment is useful for forecasters who are trying to decide if a watch should be cleared after storms have passed through an area.

## Summary of the Evaluation

Analysis of the NSSFC's evaluation shows that real-time lightning strike data are a significant new tool for the operational forecasting environment. The data have proven valuable as a supplement to conventional data sets, such as satellite and radar data, in defining, locating, and monitoring convective activity for a variety of forecast products. They also have supplied critical information when other data sources were unavailable. The NSSFC's evaluation has established that data from a national lightning mapping system should be an integral data set in weather forecasting operations.

## LIGHTNING RESEARCH

Without further research, lightning mapping systems already can be used to warn of lightning hazards and to detect and track thunderstorms. However, mapping systems also have opened up new vistas of research. Even the early research results now available suggest that considerable information is contained in the lightning data, and that this information can be exploited to improve thunderstorm forecasting and warning.

This section covers three areas of research that hold promise for future application to forecasting and warning. This is in no way a complete listing of all areas of lightning research having promise, but is only a selection of examples. In all of the applications we will discuss, lightning mapping systems are not envisioned as stand alone systems, but as an important addition to the suite of sensors available to a forecaster.

### Convective Tendencies and Microbursts

Although the evolution of lightning varies considerably from storm to storm, some patterns seem to recur frequently. It is well established, for example, that the first lightning flash in a storm is almost always an intracloud flash. Cloud-to-ground flashes typically begin to occur later, as a storm begins to have downdrafts and large ice particles near the freezing level. Usually lightning flashes do not begin to occur frequently until vigorous convective growth of the storm extends to heights that are colder than  $-30^{\circ}\text{C}$ .

These patterns led some scientists to examine whether intracloud and cloud-to-ground lightning flash rates might be useful, in combination with data from other sensors, to detect the formation of microbursts, those transient thunderstorm downdrafts that create hazards for aircraft at low altitudes. Although the above trends in lightning evolution are not unique to storms that produce microbursts, it was suggested that the lightning trends might help warn of microburst formation when environmental conditions appear favorable for microbursts. Initial studies have found that intracloud lightning flash rates typically peak 4-8 minutes before microbursts occur in moist environments, such as in southeastern states. Cloud-to-ground flashes tend to occur closer in time to microbursts. An example of these relationships is shown in Figure 4.3, which shows intracloud flash rates increasing first, as the height of moderate precipitation particles grows to its maximum value (indicated by the height of the 30 dBZ radar reflectivity contour). Cloud-to-ground flashes begin as the height of moderate precipitation reaches a peak and begins to decrease, followed a few minutes later by the microburst.

### Tornadic Storms and Hail Storms

Lightning flash rates in tornadic storms were extensively studied in the 1960's and early 1970's by examining the radio noise emitted by lightning. Those studies suggested that total lightning flash rates increase to unusually high values in at least 80 percent of tornadic storms, while cloud-to-ground flash rates often decreased near the time of the tornado. More recent studies using mapping

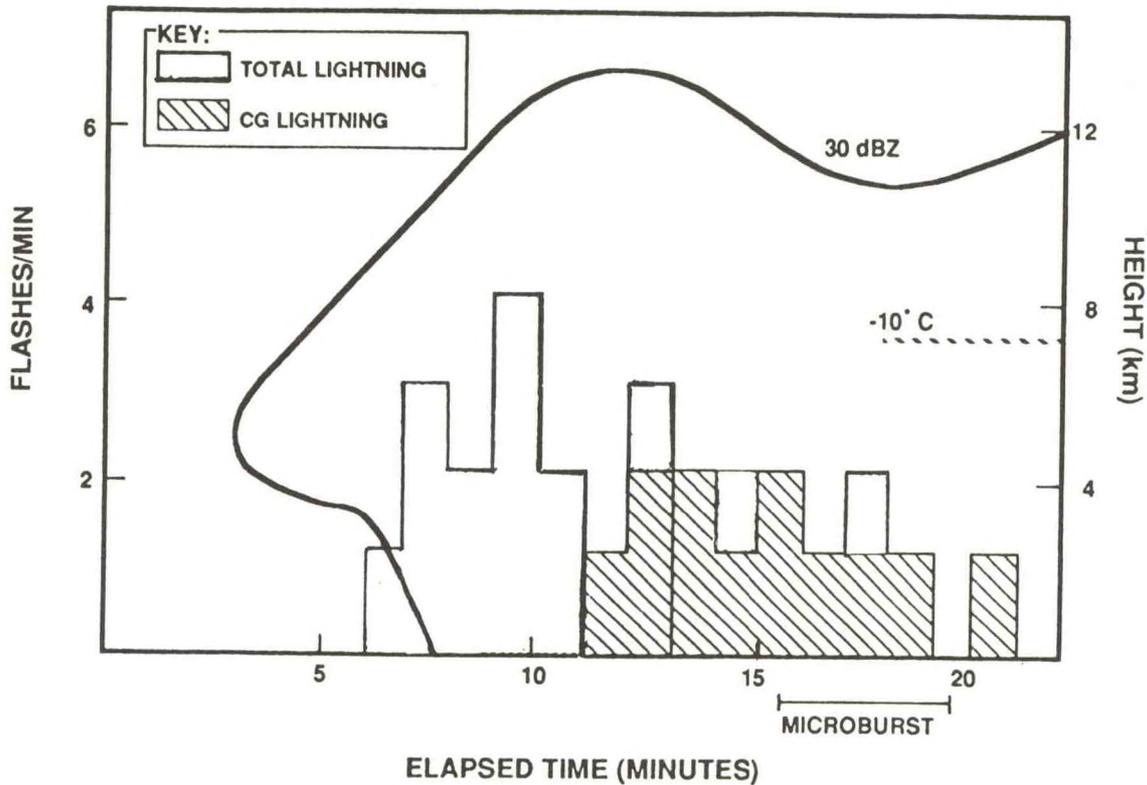


Figure 4.3 A time history of the maximum and minimum heights of 30 dBZ radar reflectivity (generally corresponding to moderate precipitation), cloud-to-ground and total lightning flash rates, and microburst occurrence. Intracloud flash rates are the difference between total and cloud-to-ground flash rates (i.e., the unshaded area between the two lightning histograms.) This is a conceptual composite from cases presented by Williams et al. (1989).

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 systems have suggested that cloud-to-ground flash rates are suppressed primarily in tornadic storms that are unusually strong and well organized. In weaker, less well organized storms, cloud-to-ground flashes can become more frequent and more concentrated around the tornadic region when a tornado occurs (see, for example, Figure 4.4). These relationships may eventually be useful in helping a forecaster to diagnose the severity and evolution of tornadic storms, but too few storms have been studied to characterize the relationships very well now.

Severe storms also appear to exhibit a potentially useful relationship with positive cloud-to-ground flashes. Scattered or infrequent positive flashes can occur in a couple of storm situations, as discussed previously. However, severe storms that produce large hail, sometimes accompanied by tornadoes, often also produce clustered positive cloud-to-ground flashes, and the positive flash rate can be much higher than in other types of storms. Only two cases of severe storms with positive cloud-to-ground lightning have been analyzed comprehensively, but several meteorologists who have monitored lightning strike activity extensively during storms have noticed the relationship. Although not all hail storms and tornadic storms have this lightning signature, it occurs frequently enough in the central United States so that some forecasters are beginning to look for the signature as one way to detect that a storm is producing hail. Research is underway at the NSSL to determine how generally relationships with severe storms apply.

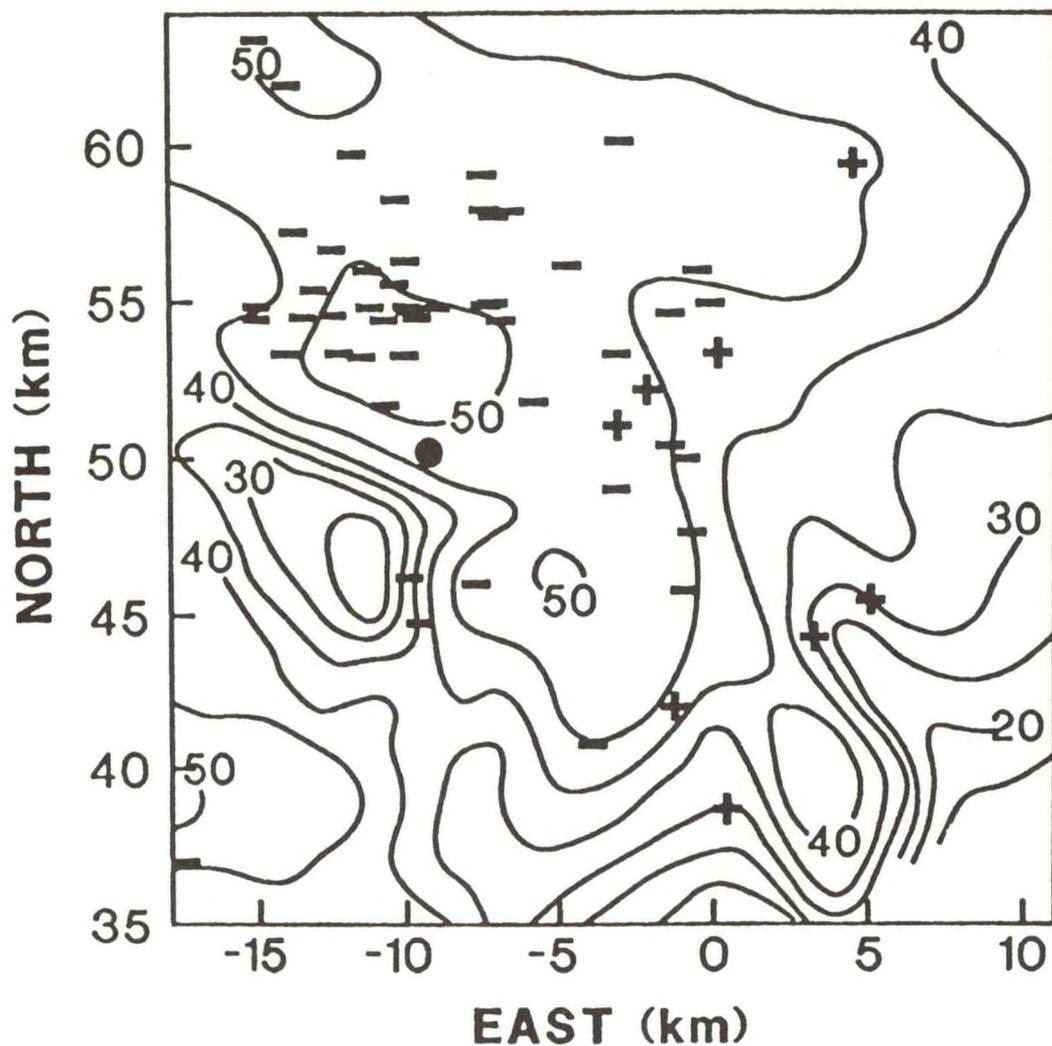


Figure 4.4 A plot of cloud-to-cloud lightning strikes superimposed on radar reflectivity from a height of 3 km at 1824-1827 CST on 8 May 1986 (from MacGorman and Nielsen, 1991). Minuses indicate strike points of negative flashes; pluses, strike points of positive flashes. The large dot marks the center of the vortex in the storm that is the parent for the tornado vortex. Contours of radar reflectivity are labelled in dBZ. Increasing reflectivity indicates larger and/or more precipitation particles. Distances east and north of NSSL are labelled in kilometers.

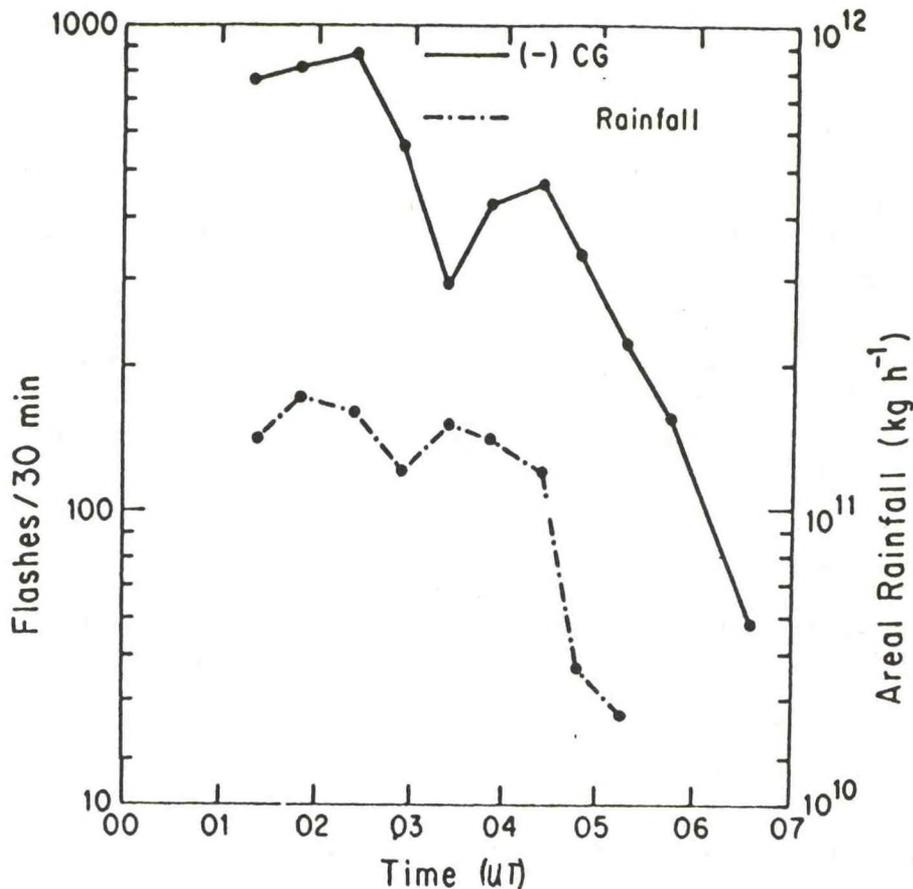


Figure 4.5 A time history of negative cloud-to-ground flash rates and of rainfall from a line of strong convection in a large storm system (adapted from Rutledge and MacGorman, 1988).

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### Large Storm Systems

Many regions of the United States receive much of their rainfall and lightning from a few long-lived, large storm systems. Because lightning data are easier to collect, distribute, and plot from large areas in real time than composite radar images from multiple radars, lightning data have considerable promise for improving a forecaster's ability to monitor storm systems that have dimensions of hundreds of miles. Lightning data can easily be combined with data from other sources, such as radars and satellites, to provide continuous updating of weather products that are available otherwise only once every 15-30 minutes.

In early studies of the evolution of lightning in large systems, several scientists found that the spatial distribution of lightning strikes is often similar to that of intense rainfall. Furthermore, the timing of trends and maxima in negative ground flash rates is often similar to the timing of trends and maxima in the total rainfall rate from the region of intense convection, as shown in Figure 4.5.

In storm systems that form a large area of light precipitation behind the intense convection, scattered positive cloud-to-ground flashes usually begin to occur as the region of trailing precipitation forms, and the initial increase in positive ground flash rates corresponds to increasing rainfall rates in this region. Also, there sometimes are long-lived small clusters of infrequent positive ground flashes behind the region of intense convection, suggestive of high-based convective cells. However, analysis of these phenomena is in its early stages, and more work is needed before reliable inferences about the properties of storm systems can be made from positive ground flashes.

## Status of DOD Systems

The Department of Defense has volunteered information on the status and use of their operational systems for inclusion in this section. No requests were made to other agencies for similar status reports. For information on the operational lightning detection systems of all agencies, the reader should refer to the "Preliminary National Plan" listed in the references.

The U.S. Air Force's Air Weather Service uses a combination of stand-alone lightning mapping systems and access to lightning mapping networks to provide a wide range of support to both the Air Force and the Army. The exploitation of lightning mapping technology is primarily funded by the supported organizations. Data from the stand-alone systems and networks are used as a forecasting tool for protection of personnel and equipment.

Lightning mapping system data are used to protect space vehicle ground processing and pre-launch activities, and to determine launch constraints. Other applications include determining potential for satellite ground contact interference, and tracking potential communications outages. Lightning mapping system data are used to warn and advise on lightning safety hazards to ground activities such as aircraft refueling, munitions handling, cargo and passenger loading on aircraft, and facility construction. Computer installations, including a high-value flight simulator, are also protected from the harmful electrical effects of lightning through warnings and advisories based on lightning mapping system data.

The U.S. Navy has currently fielded their LPATS Lightning Detection and Tracking System (LDATS) with hubs located at Cape Canaveral, FL; Pensacola, FL; and Charleston, SC. Additional networks will be installed during 1991 to complete coverage of the east, gulf, and west coasts.

## CONCLUSION

Lightning mapping systems are being used by more and more government agencies to improve performance of their missions. The usefulness of the systems for hazard avoidance and weather forecasting has been clearly manifested during a trial sponsored by the OFCM. This has led the NWS to begin procurement of data from a national lightning strike mapping network for a five year period. New mapping systems now being developed, such as the satellite lightning mapper, promise additional capabilities in five to ten years. Although lightning mapping systems are useful simply for detecting and tracking thunderstorms, as in most present applications, early research results suggest that lightning data provide considerably more information about storms. Research is continuing to study this information to develop applications for thunderstorm forecasting and warning.

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## 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

##### MISSION

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 awareness 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.

##### ENABLING LEGISLATION

The basic enabling legislation and authority for weather services are listed below:

- ▶ 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

NOAA 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 Meteorological Center (NMC). The NWS core mission also depends on the study, development, and testing of new methods for improving basic warning and forecast capabilities through research.

### Local Warnings and Forecasts

Local weather services are provided through a national network of 52 Weather Service Forecast Offices (WSFOs), 220 more localized Weather Service Offices (WSOs) and 13 River Forecast Centers (RFCs).

Weather Warnings and Forecasts. Both WSFOs and WSOs issue local warnings of severe weather such as hurricanes, tornadoes, severe thunderstorms, flash floods, and extreme winter weather. WSFOs prepare forecasts for zones which are comprised of several 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; a generalized statewide forecast twice daily; and a more general, 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.

To prepare local warnings and forecasts, WSFOs use forecast guidance prepared by the National Meteorological Center (NMC) that is based on worldwide meteorological observations. The National Severe Storms Forecast Center (NSSFC) and the National Hurricane Center (NHC) also provide central support for the local warning program.

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

River and Flood Warnings and Forecasts. RFCs 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. NMC 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 NMC, 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 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). This Center provides real-time operations, data acquisition and data processing, and distribution of meteorological/oceanographic data from moored and drifting buoys and automated observing stations at selected coastal locations. The 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.

Agricultural Weather Services. NWS provides the Nation with generalized agricultural weather services, including observations, and forecasts that improve agricultural efficiency, conserve energy, and protect the environment. At the direction of Congress, NWS issues warnings of low temperatures injurious to winter and spring crops, particularly in citrus and deciduous fruit-growing areas as well as specialized forecasts similar to those available from the private sector. The FY 1992 budget proposes that users of these specialized services purchase them directly from the private sector.

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 and suppression activities. Localized weather forecasts are issued, as required, during a fire. 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. The FY 1992 budget proposes that state and local users of these specialized services purchase them directly from the private sector.

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.

## Central Forecast Guidance

Over the last several decades, NOAA has made major improvements in forecasting synoptic-scale (large-scale, slowly evolving) weather. NOAA can implement significant improvements in the severe weather and flood warnings program as a result of several developments: (1) continuing improvements in larger scale, centrally prepared weather guidance products for day 2 and beyond, (2) implementation of NWS systems upgrades, (3) advanced observations from the planned geostationary and polar-orbiting satellites, and (4) the development of mesoscale predictive techniques for NWS field operations.

General Weather Guidance. The National Meteorological Center (NMC) provides centralized processing of data, analyses, forecasts, and outlooks required by field forecasters as a basis for local forecasting. The Center, using numerical forecasting techniques run on large computers, provides the NWS, other government agencies, private industry, and foreign users with guidance forecasts covering periods out to 10 days. When needed NMC provides guidance in tracking hurricanes (to 72 hours) and in forecasting the movement of large storms that cause significant precipitation.

In the course of its 24-hour-per-day, year-round operation, NMC receives approximately 50,000 surface observation reports daily, from land stations, 3,000 reports from ships, 4,100 upper air observations, and 3,000-4,000 reports from aircraft. Weather satellites provide cloud images, atmospheric temperature soundings, and sea-surface temperatures. Ocean buoys provide additional information on sea temperatures, ocean currents, and air-sea interactions. These data are processed, catalogued, used in the various forecast guidance model runs, and distributed widely to field offices, other government agencies, private subscribers, and overseas users.

NOAA will continue to incorporate improvements in general weather guidance by:

- ▶ Implementing second generation Regional Analysis and Forecast Systems (RAFS) models with higher resolution and improved physics to forecast severe thunderstorms, heavy rain, and snow more accurately;
- ▶ Implementing second generation hurricane models to predict the development and movement of hurricanes more accurately; and
- ▶ Continuing improvements in 1 to 2 day and 3 to 10 day forecasts as much as possible pending the availability of increased computer capacity to handle state-of-the-art physics, increasing resolution, and analysis.

Severe Storm Guidance. The National Severe Storms Forecast Center (NSSFC), Kansas City, MO, prepares and releases messages of expected severe local storms, including tornadoes. These Tornado or Severe Thunderstorm Watches, include information for public use and aviation services. NSSFC meteorologists continuously monitor weather developments and issue watches when needed. NOAA will continue to develop systems application programs designed to streamline use of the satellite and numerical weather prediction data by forecasters to improve severe storm guidance.

Hurricane Guidance. Two Hurricane Forecast Centers forecast the path and intensity of hurricanes, other tropical disturbances, and associated sea conditions. These two centers are the National Hurricane Center (NHC) in Miami, FL, and the Central Pacific Hurricane Center (CPHC) in Honolulu, HI. A portion of NHC's responsibility for public warnings rests with the Hurricane Warning Office at San Juan, PR. NMC provides forecast guidance on the track and intensity of hurricanes based on numerical models.

Special hurricane forecasting staff at NHC base their predictions, advisories, and warnings on subjective and objective methods. The hurricane forecasting functions at the NHC and CPHC are integrated with the regular forecasting functions of the Weather Service Forecast Offices where these Centers are located. NOAA will continue to improve hurricane guidance through development of techniques and programs that maximize use of satellite data and through implementation and calibration of storm surge models.

Climate Guidance. The Climate Analysis Center prepares monthly and seasonal (90-day) outlooks; collects and analyzes data to depict current anomalies of climate. To improve the accuracy of climate outlooks, the Center develops predictive techniques, performs diagnostic studies of large-scale climate anomalies, and conducts stratospheric research. NOAA will continue to incorporate improvements into long-range climate guidance.

### Atmospheric and Hydrological Research

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. NWS will conduct 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 NEXRAD (Next Generation Weather Radar) with doppler capability, and GOES-NEXT (geostationary satellites with higher resolution);
- ▶ 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. NWS will develop 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 National Weather Service River Forecast System;
- ▶ Specialized flood and flash flood forecasting procedures using linked hydrological and meteorological models;
- ▶ Algorithms to combine NEXRAD precipitation estimates with data from satellites and other ground-based observation systems.

## MODERNIZATION

A Strategic Plan for the Modernization and Associated Restructuring of the National Weather Service 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 100-685 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 2 and beyond through advanced forecasting models and the requested increased computer processing capability are essential to successful implementation of mesoscale forecasting in NWS field operation, where field forecasters will concentrate on the small-scale, short-lived processes that occur in the zero to 36 hour time-scale.

The National Implementation Plan, that will be submitted to Congress each fiscal year, will provide a planning framework and general strategies for accomplishing the transition. The interrelationships of all of the activities--facilities preparation, staffing augmentation, training, commissioning of systems, and realigning operations and services--have been planned so that the demonstration can begin in FY 1995. In addition to preparations for the demonstration, nationwide planning and implementation have begun: facilities preparation is on-going; training schedules for field personnel are being planned with necessary backup personnel to cover operational shifts; software development continues; new communications are being established; and all NWS offices are working on 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 and flood warnings and forecasts through the acquisition of the following new, technologically advanced systems:

- ▶ Automated Surface Observation Systems (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;
- ▶ Class VII computer power at the NOAA Central Computer facility 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 warnings.

## NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE

The National Environmental Satellite, Data and Information Service (NESDIS) manages U.S. civil operational Earth-observing satellite systems, as well as global data bases for meteorology, oceanography, solid-earth geophysics, and solar-terrestrial sciences. From these sources it 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 the development and management of natural resources.

An agency of the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), NESDIS was established 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 that monitor daily weather and surface conditions over the globe. It is also responsible for operating two geostationary weather satellites -- one that monitors the Atlantic Ocean and U.S. East and Gulf Coasts, and one that monitors the Pacific Ocean and West Coast. However, on January 21, 1989, the Western satellite, GOES-6, failed. The Eastern satellite, GOES-7, was moved to a centralized location on February 21, 1989. The location is adjusted between 108°W and 98°W to provide maximum coverage during the Pacific and Atlantic storm seasons.

The second major area of NESDIS' responsibility is environmental data and information management and dissemination. NOAA gathers global data about the oceans, earth, atmosphere, space, and Sun and their interactions to describe and predict the state of the physical environment. Many other agencies, organizations, and individuals, both domestic and foreign, collect similar data for particular uses and missions. Once the original collection purposes have been served, selected data flow to NESDIS data centers, which incorporate them into national environmental data bases that document the physical environment and its processes.

### Environmental Satellite Service

#### SATELLITE OFFICES

The Office of Satellite Operations 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) facilities that command and control, track, and acquire data from these environmental satellites.

The Office of Satellite Data Processing and Distribution 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 and other domestic and foreign users. A system for the display and animation of satellite imagery from the GOES-TAP system has been installed in all Weather Service Forecast Offices (WSFO). The system, called the Satellite Weather Information System (SWIS), automatically acquires, stores, displays, and animates GOES imagery and superimposes guidance products from the National Meteorological Center with the imagery. WEFAX (Weather Facsimile) direct readout systems on NOAA's weather satellites enable users to receive, on relatively low-cost equipment, images and weather charts directly from the satellites.

National Weather Service's Satellite Field Services Stations (SFSSs) distribute processed geostationary satellite products to regional National Weather Service offices and other Federal

agencies. The products also are made available to private groups at their expense. SFSSs are located in Washington, DC; Miami, FL; Kansas City, MO; Honolulu, HI; San Francisco, CA; and Anchorage, AK. The Anchorage, Washington, and San Francisco SFSSs distribute data from both the polar-orbiting and geostationary systems. The San Francisco SFSS also has the capability of receiving data from the polar orbiting satellites.

The Office of Research and Applications provides guidance and direction for NESDIS research and application activities. It coordinates the efforts of the Satellite Research Laboratory and Satellite Applications Laboratory. In addition, it assesses the requirements and goals of NESDIS research and applications programs, and evaluates their progress.

## POLAR ORBITING SYSTEMS

The NOAA series of environmental polar-orbiting satellites replaced the ITOS system in July 1979. TIROS-N, the NASA prototype, was launched on October 13, 1978; and NOAA-6, the first NOAA-funded operational satellite of this series, was launched on June 27, 1979. In the years following, a series of NOAA polar orbiting satellites were launched. Currently, the primary operational spacecraft are NOAA-10 and NOAA-11. NOAA-9 also provides data from operational sensors.

NOAA-funded satellites retain the NOAA name and are numbered consecutively beginning with the number immediately following that last used in the ITOS series. These satellites increase the accuracy of weather forecasting by providing quantitative data required for improved numerical weather forecast models. They carry advanced instruments to provide improved temperature soundings and microwave channels to facilitate sounding retrieval in cloudy areas. They also provide advanced multi-channel images and carry a data collection and platform location system. During the lifetime of the NOAA system, new instruments may be added or substituted for others. The first Advanced TIROS-N (ATN) satellite, NOAA-8, carried a search and rescue capability in addition to its standard instruments. NOAA-9 carries sensors to measure the Earth's radiation budget and ozone. The projected launch schedule and associated instruments for polar-orbiting satellites are shown in Table A.1.

NOAA spacecraft are five-sided, box-like structures that are 3.71 m long, 1.88 m in diameter, and 1,409 kg in weight, including expendables. NOAA-11, NOAA-10, and NOAA-9 operate in near-polar, sun-synchronous orbits of 849, 814 and 852 km, respectively, and provide environmental observations of the entire Earth four times each day. NOAA-11 crosses the Equator in a northward direction at 1354 local time. NOAA-10 crosses the Equator in a southward direction at 0730 local time and NOAA-9 crosses the Equator in a northward direction at 1702 local time. The orbital period of the satellites ranges from 101.23 to 102.2 minutes which produces approximately 14.2 orbits per day.

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. Thus, the AVHRR instrument improves satellite services in stored and direct readout radiometer data for day and night cloud cover, sea-surface temperatures, and snow mapping. AVHRR read-out is accomplished by the following:

- ▶ Direct readout to ground stations of the APT class worldwide, at 4-km resolution, of the visible and infrared data; panoramic distortion is removed;

- ▶ Direct readout to ground stations of the HRPT class worldwide, at 1.1-km resolution, of all spectral channels;
- ▶ Global onboard recording of 4-km resolution data from all spectral channels; global area coverage for commanded readout for processing in the NOAA central computer facility at Suitland, MD;
- ▶ Onboard recording of data from selected portions of each orbit at 1.1-km resolution of all spectral channels, with local area coverage for central processing and sea-surface temperature measurements.

The TIROS 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). The primary instrument providing tropospheric data, HIRS/2, is sensitive to energy from the visible to the carbon dioxide region of the infrared spectrum. This instrument is designed to provide data that permit calculation of temperature profiles from the surface to 10 mb, water vapor content at three levels of the atmosphere, and total ozone content. The SSU instrument, which is sensitive to energy in the carbon dioxide 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 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 and Location System (DCLS) is provided by the Centre National d'Etudes Spatiales of France and is called the ARGOS DCLS. The ARGOS DCLS provides a means to locate and collect data from fixed and moving platforms. It provides two services not available in the geostationary meteorological satellite data collection system. First, it has the capability to determine platform location, using an inverse Doppler technique. Second, it is able to acquire data from any place in the world, but more particularly in the polar regions, beyond transmission range of the geostationary satellites.

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 three detectors included within this instrument are the Total Energy Detector, Medium Energy Proton and Electron Detector, and High Energy Proton and Alpha Detector. This instrument augments the measurements made by NOAA's geostationary satellites. The data from the SEM are processed at Suitland, MD, and transmitted over a dedicated data link to NOAA's Space Environment Laboratory at Boulder, CO, within one hour of the spacecraft readout. The NOAA series data, as well as the geostationary series data, are used to monitor the state of solar activity, which has a significant effect on terrestrial communications, electrical power distribution, and high-altitude aircraft flight.

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

The Earth Radiation Budget (ERBE) has two components. One is a non-scanner instrument with four earth-viewing radiometers, two of which are wide angle (limb to limb of the Earth), while the other two are medium angle (10° Earth central angle). A fifth radiometer is a shuttered, sun-viewing monitor. The wide and medium angle radiometers each have a total channel (0.2 to 50  $\mu\text{m}$ ), and a shortwave channel (0.2 to 5  $\mu\text{m}$ ). The sun-viewing radiometer measures the total solar spectrum (0.2 to 50  $\mu\text{m}$ ). A second component of ERBE is a cross-track scanner instrument with three earth-viewing radiometers having a 3° by 4.5° field-of-view. The spectral intervals of the radiometer are shortwave (0.2 to 5  $\mu\text{m}$ ), longwave (5 to 50  $\mu\text{m}$ ), and total (0.2 to 50  $\mu\text{m}$ ).

NOAA-9 and future polar satellites carry instruments for the operational monitoring of atmospheric ozone (the SBUV/2 is only carried on the afternoon or PM satellite) and will contribute to experimental monitoring of the Earth's radiation budget with the ERBE on NOAA-9 and NOAA-10 only. NOAA-8 and future polar satellites carry search and rescue (SAR) transponders, used to improve the detection and location of distress signals. This project is an international effort committed to global coverage for the search and rescue mission. The United States operates and maintains the SAR Mission Control Center and three ground stations. The ground stations receive Doppler signals directly from the satellite and process the information to provide the location of distress transmissions.

The ground system, required to receive large volumes of digital data from NOAA satellites, consists of two major subsystems -- the Data Acquisition and Control Subsystem (DACS) and the Data Processing and Services Subsystem (DPSS). The DACS includes components at the Wallops, VA, and Fairbanks, AK, Command and Data Acquisition (CDA) stations; the Satellite Operations Control Center (SOCC) at Suitland, MD; and the Western European Station at Lannion, France. All the DPSS components are in the NOAA facility at Suitland.

DACS is used to command and control the spacecraft, monitor its health via housekeeping telemetry, and retrieve and transmit the spacecraft environmental data to the DPSS processing and data handling facility. The delivery of NOAA system data from the CDAs to Suitland is accomplished by General Electric using the 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 DPSS subsystem for initial processing.

The DPSS ingests the raw satellite data and pre-processes and stores them along with appended auxiliary information, such as Earth location and quality control parameters.

## GEOSTATIONARY SATELLITE PROGRAM

The geostationary satellite program began in 1966 as an operational experiment in which the imaging capability and weather broadcast system of the NASA Applications Technology Satellites 1 and 3 were used. This program became an operational reality following the launch of NASA's Synchronous Meteorological Satellites (SMS) 1 and 2 in 1974 and 1975. These satellites were the prototypes for NOAA's Geostationary Operational Environmental Satellites (GOES).

Since GOES-1 was launched on October 16, 1975, seven more GOES satellites have been put into orbit. GOES-7, launched in March 1987, is currently positioned at 107.1°W. The next launch of a geostationary satellite, GOES-I, is currently scheduled for late 1992. At that time, NOAA will locate one spacecraft at 75°W and another at 135°W. This will provide overlapping or concurrent

TABLE A.1 PROJECTED SATELLITE LAUNCH SCHEDULE

POLAR-ORBITING SYSTEM

<u>Satellite Designator</u>	<u>Planned Launch Date*</u>
NOAA D <sup>+</sup>	CY 1991
NOAA I	CY 1991
NOAA J	CY 1993
NOAA K	CY 1994
NOAA L	CY 1995
NOAA M	CY 1996

Instruments for Advanced TIROS N Series

AVHRR	Advanced Very High Resolution Radiometer
SEM	Space Environment Monitor
SBUV	Solar Backscatter Ultraviolet Radiometer
SAR	Search and Rescue Instrument
ERBE	Earth Radiation Budget Experiment
HIRS	High Resolution Infrared Sounder
SSU	Stratospheric Sounder Unit
MSU	Microwave Sounder Unit
DCLS	ARGOS Data Collection and Location System

GEOSTATIONARY SYSTEM

<u>Satellite Designator</u>	<u>Planned Launch Date*</u>
GOES I	CY 1992
GOES J	CY 1993
GOES K	CY 1996
GOES L	CY 1997
GOES M	CY 2001

Instruments for GOES Series

SEM	Space Environment Monitor
DCS	Data Collection System
GIS	GOES Imager and Sounder
SAR	Search and Rescue

\*Launch date depends on performance of prior spacecraft.

<sup>+</sup>NOAA D does not carry the SBUV, SAR, or ERBE.

viewing of the development and movement of destructive weather systems, such as thunderstorms, hurricanes and major mid-latitude storms over much of North and South America and adjacent oceans. The projected launch schedule and associated instruments for geostationary satellites are shown in Table A.1.

The VISSR Atmospheric Sounder (VAS) is the principal instrument on the geostationary satellites starting with GOES-4. The VAS has both imaging and sounding capability. The VAS provides near-continuous cloud viewing with resolutions of 1, 2, 4 and 8 km in the visible wavelengths and 8 km and 16 km in the infrared wavelength. Full Earth disc pictures are available at 30-minute intervals throughout the day and night; partial disc pictures can be obtained at more frequent intervals to meet special requirements such as viewing development and movement of severe storms.

The concept of obtaining atmospheric soundings from geostationary satellites is being tested. GOES 6 and 7 are being used in an operational demonstration program to determine the capability of the VAS. Results have been excellent, and an operational demonstration of a ground system to use the VAS data to improve NOAA's operational weather analysis and forecasting programs is underway. The additional capabilities of the VAS are the multi-spectral imaging. The VAS has 12 infrared channels which are used to derive temperature and moisture profiles over selected areas. Sounding from a geostationary satellite affords several advantages over sounding from a polar-orbiting satellite. They are: (1) constant surveillance, (2) constant viewing geometry, (3) better determination of temporal and spatial gradients, (4) easier comparisons with radiosondes, and (5) synoptic large-area coverage. Starting with GOES-I, the systems will be capable of simultaneous imaging and soundings.

The VAS demonstration program has resulted in a VAS Data Utilization Center (VDUC) interconnecting the NWS's three major centers with NESDIS. Future development and direction of operational meso-meteorological systems will be influenced by the outcome of this VAS demonstration. The GOES also carry a Data Collection System 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. These satellites rebroadcast imagery, meteorological analyses, and other environmental data to remote locations using the weather facsimile (WEFAX) system. Data are collected for warnings of solar activity using the Space Environment Monitor. This instrument is similar to the SEM on board the NOAA series S/C and consists of a Magnetometer, a Solar X-Ray Telescope, and an energetic particle monitor.

Beginning in calendar year 1991, NESDIS will send a limited set of remapped GOES image data products to the first two National Weather Service modernization "risk reduction" sites. Weather Service Forecast Offices at Norman, Oklahoma, and Denver, Colorado, will be equipped with work stations that will capture satellite images and other NOAA data, emulating modernized Weather Service capabilities. This dedicated-line transmission of remapped GOES data will be upgraded to a point-to-multipoint broadcast service in 1992 with the initial deployment of AWIPS-90. After acceptance, this service, to be known as NOAAPORT, will be used to distribute other NOAA environmental data and satellite products to various users.

#### 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 which consists of the Satellite Operations Control Center (SOCC) and two Command and Data Acquisition Stations at Wallops, VA, and Fairbanks,

AK. The Office of Satellite Operations is responsible for the operation and safety of NOAA polar and geostationary satellites and for providing satellite data to the Office of Satellite Data Processing and Distribution in Suitland, MD.

Another major component is the Central Data Distribution Facility (CDDF) in Camp Springs, MD. The CDDF is connected in turn with the Fairbanks CDA station, and the six Satellite Field Services Stations. The Fairbanks CDA station also relays satellite data by land line and microwave circuits to the Anchorage SFSS and the NWS WSFOs at Anchorage and Fairbanks. The WSFO at Juneau, AK, receives satellite data from the Anchorage SFSS. By the end of FY 1988, SATCOM consisted of over 60 data links required for the operation of the satellite data processing and distribution system.

#### SUPPORTING RESEARCH PROGRAM FOR FY 1992

The requirements and goals addressed by NESDIS Supporting Research in FY 1992 include:

- ▶ NOAA's role in the national effort on the study of climate and global change (as detailed in the interagency report of the Committee on Earth and Environmental Sciences);
- ▶ The modernization effort of the National Weather Service (per P.L.100-685);
- ▶ The improvement of the monitoring of the global ocean and the management of resources in the coastal zones;
- ▶ The management of data that will be needed to support the above;
- ▶ The evaluation, validation and implementation of new products and services from GOES-I; these will support the NWS modernization;
- ▶ The continuation of products and services from the polar orbiting satellite system.

Research and the development of applications of environmental satellite data are devoted to the improvement and development of improved techniques for quantitative and qualitative products and services. These serve national and international programs in weather analysis and forecasting; climate diagnosis; programs for agriculture, fisheries, coastal zone management, energy; and other weather, land and environmental applications. The data from current NOAA operational satellites in both polar and geostationary orbits, and research satellites operated by other nations and by NASA and DOD are used to develop improved techniques and algorithms for the definition of the global, three-dimensional structure of the atmosphere (both temperature and moisture structure) that is essential for numerical weather analysis and forecasting.

The geostationary environmental satellites provide nearly continuous imagery and multi-spectral data in the visible and infrared for study and applications. These studies lead to the understanding of the genesis and life cycles of severe storms (from thunderstorms to hurricanes and winter snow storms) and the morphology and evolution of the mesoscale systems (small time and space scales) in which they form. This research leads to the application of data from GOES-I, its analysis and application with the other modernization tools of NEXRAD, Profiler, ASOS, AWIPS, etc.

Climate analysis, diagnosis and monitoring performed by the National Meteorological Center's Climate Analysis Center depend upon global satellite observations of the incoming and outgoing radiation. Knowledge of this "heat" or "radiation-budget" of the earth-atmosphere system is essential to the national and international research on the Earth's climate and environment. Research with satellite data is the key to understanding the effects of clouds as regulators of incoming and outgoing

radiation that may lead to long term net warming of the globe. Applications research continues to improve estimates of the global distribution of atmospheric aerosols, their effect on climate, and on other satellite measurements. Satellites provide the only global measurement of ozone. Monitoring its distribution and concentration is critical to understanding the fate of this important atmospheric compound.

Monitoring sea surface temperature with satellites will continue to be a focus of research for climate diagnosis and other applications. The passive microwave and other multispectral data from DOD's meteorological satellites and international satellites contribute to improvements in the measurement of this important parameter. Research and development on the use of satellite data in coastal marine areas continues. This includes algorithms for estimating temperature, turbidity, and productivity for bays and estuaries. These satellite observations combined with aircraft and in-situ oceanic data contribute to development of dynamic models of coastal processes.

Improvement in the methods for estimating precipitation from satellite data is important for flash floods on the local scale, and, on the global scale, important to the understanding of the effects of the release of latent heat of condensation in both numerical weather forecasts and in numerical climate models. Other measurements from satellites requiring continued study and improvements are solar insolation, the "vegetation-index" of biomass concentration, and winds derived from cloud motions. These contribute to understanding of the hydrologic and biogeochemical cycles.

The scientists at NESDIS continue to provide expertise and advice for the specification of sensors, processing systems and technical requirements for the development of future satellite systems.

### Environmental Data Bases

#### NATIONAL CLIMATIC DATA CENTER

The National Climatic Data Center has the principal responsibility to manage the national climatological data program, including data and information services. To meet the responsibility, the Center:

- ▶ Performs all data management functions regarding data acquisition, archiving, retrieval, indexing quality assessments, evaluations, synthesis, dissemination, and publication of data from global and national observation networks that have enduring value to the Nation and are sufficient to describe the climate;
- ▶ As a designated agency Federal Records Center, operates the Center for NOAA for processing, storage, and servicing of retrospective meteorological 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 data bases 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 programs. In this capacity, NCDC operates the World Data Center-A for Meteorology under the auspices of the International Committee of Scientific Unions.

The modernization of observing networks with the use of new technology and the increased concern on global climate change throughout the world have increased the challenge of managing climate data and serving the research community. To meet this challenge, NCDC will be focusing on the development and implementation of new data processing systems for data from new observing equipment; and to prepare and structure baseline data sets to meet the national needs for monitoring climate change.

### Climate Data Management

The management of climatic data has become increasingly complex as new automated high volume observing systems replace traditional manual systems. First, these new systems have necessitated a change in the concept of processing data for the climate data base. New automated observing systems have made it possible to effectively quality control data for random errors on site, leaving the more complex quality control to identify systematic errors and biases to the NCDC. Second, the data from the new systems must be integrated with the historical data, and third, the requirements for accurate homogeneous long series data sets on a national, regional and global scale is placing an additional demand on data management and user services that may require the reprocessing of entire long-series data bases.

In FY 1992, the NCDC plans to:

- ▶ Continue technology upgrade (i.e., computers, on-line storage, communication, etc.) to meet the data management and services through the 1990's;
- ▶ Implement new processing systems to account for the changed concept in processing data from automated systems and to accept new data streams;
- ▶ Study the characteristics of data collected with automated systems versus manually observed data and continue the development of techniques to treat data to form homogeneous long series data bases;
- ▶ Working with the World Meteorological Organization, participate in the preparation of a high priority global data set to monitor climate change;
- ▶ Prepare climate perspectives studies to place contemporary climate into historical perspective;
- ▶ Reanalyze and/or reprocess long-series data sets and produce global/regional baseline data sets;
- ▶ Enhance the operation of the World Data Center to concentrate on the collection and exchange of international historic climate data needed to complete long series data sets;
- ▶ Participate in NOAA data management programs as required to support global change;
- ▶ Develop CD-ROM based systems to describe the climate of the United States and to present data and information from around the world;

### Climate Services

The demand for the basic climatic data and information services has been increasing annually. The recent concern for climate change has placed an increased need to readily identify the availability of data bases and to service large volumes of data. NOAA has implemented a NOAA Master Directory and will be expanding the capabilities of this directory that will help users access data. The NCDC plans to develop an interface between the NCDC data inventory system and the NOAA directory to provide more information to users. An automated system to allow users to

browse (review available data products), to order and for cost accounting will be implemented. Expanded on-line access to data bases is planned.

## NATIONAL OCEANOGRAPHIC DATA CENTER

The National Oceanographic Data Center (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 Tropical Ocean-Global Atmosphere (TOGA) program, the World Ocean Circulation Experiment (WOCE), and the Joint Global Ocean Flux Study (JGOFS). The 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, shipping industry).

### Data Management

The NODC is working closely with the academic community to provide data management for global change research programs. Three joint centers have been established with university groups to focus on different aspects of data management for global change:

- ▶ Joint Environmental Data Analysis (JEDA) Center with the Scripps Institution of Oceanography, University of California at San Diego;
- ▶ Joint Archive for Sea Level (JASL) with the University of Hawaii;
- ▶ Joint Center for Research in the Management of Ocean Data (JCRMOD) with the University of Delaware.

The JEDA Center is providing management of subsurface thermal data in support of TOGA. Initially this activity covered only data from the tropical Pacific Ocean, but it has extended its task of intake, quality control, and analysis of available upper ocean thermal data to include the entire Pacific Ocean (November 1988), the Indian Ocean (August 1989), and the North Atlantic Ocean (in 1990). As of December 1990, the TOGA tropical Pacific thermal database assembled by the JEDA Center contained 86,343 temperature profiles (see Table A.2).

Through the creation of the Joint Archive for Sea Level, the NODC is assisting researchers at the University of Hawaii in the acquisition, processing, quality assurance, archiving, and dissemination of sea level data from a network of island-based and coastal tide gages. The network consists of stations in the Pacific Ocean Sea Level Network originally established as part of the North Pacific Experiment (NORPAX), which began in 1974, as well as stations operated by many national and foreign agencies. As of November 1990, the archive of sea level at the NODC included hourly, daily, and monthly sea level values for 94 stations in the Pacific Ocean and 40 stations in the Indian Ocean. NODC expects to receive the first submission of sea level data from stations in the Atlantic Ocean in 1991.

Activities at JCRMOD have revolved around data management for WOCE, in particular the design of a WOCE data management system. This is an NSF-funded project with the College of Marine Studies at the University of Delaware. An online information system called "Oceanic" is now providing WOCE program information to principal investigators and other researchers.

The National Science Foundation agreed to support NODC's proposed U.S. Joint Global Ocean Flux Study data management responsibilities. The NODC Northeast Liaison Officer stationed at Woods Hole Oceanographic Institution (WHOI) has been designated as the U.S. JGOFS Data Manager. A PC-based data management system has been designed to allow for inventorying,

tracking, quality control, processing, documentation, and archiving of U.S. JGOFS data. Ongoing field programs from which data are being received include the JGOFS/WOCE Bermuda Atlantic Time-series Station and the JGOFS/WOCE Hawaii Ocean Time-series Station. During 1990 a data report for the JGOFS North Atlantic Bloom Experiment was also prepared.

### Data Services

In FY 1990, the NODC fulfilled a total of 6,782 user requests and disseminated a total of 76 gigabytes of digital data to customers. As of December 1990, NODC has distributed 412 copies of CD-ROM NODC-01, its first compact disc that contains over 1.3 million temperature-depth and salinity-depth profiles taken in the Pacific Ocean between 1900 and 1988. It is accompanied by menu-driven data access and display software provided on a single high density floppy disk. Developed as an experimental prototype CD-ROM NODC-01 was provided to researchers who agreed to test it and to provide their evaluation to the NODC. As a result of comments and suggestions already received, an upgrade (Version 1.1) of the access/display software was prepared and released. In early 1991, the NODC plans to release a companion disc of temperature-salinity profile data for the other ocean basins (Atlantic, Indian, Arctic). Late in 1991, an updated version of the Pacific disc will be issued.

Although a failing power supply terminated the mission of the U.S. Navy Geodetic Satellite (GEOSAT) in December 1989, the NODC continues to provide users with copies of the GEOSAT Exact Repeat Mission (ERM) data set that is held on 32 high density magnetic tapes. The NODC also received and is now disseminating a special data set of GEOSAT data for the Southern Ocean collected during the 18-month Geodetic Mission (GM) that lasted from April 1, 1985 to September 30, 1986. This data set, declassified in 1990, consists of the GEOSAT GM data acquired between 60 degrees and 72 degrees south latitude around Antarctica. During 1991, the NODC will receive the final tapes from the 36-tape set of GEOSAT Crossover Difference Data from the Geodetic Mission and begin disseminating this data set. Although the complete set of sea level data from the Geodetic Mission is classified, the crossover differences (sea level difference at ground track intersections) computed from these data can be released because they contain no geodetic information.

With assistance from WDC-A, Oceanography, NODC has compiled inventories of ocean measurement (oceanographic station data and salinity, temperature, density) programs that have repetitive sampling at the same locations for long time periods. A total of 27 time-series data sets ranging in minimum duration from five years for North Pacific Ocean Weather Stations and related sections to more than 30 years for the CALCOFI sections have been identified and researched. A total of 56 North Atlantic sections have also been fully inventoried. Final manuscript has now been completed for both inventories. A third inventory covering the remainder of the World Oceans is currently in progress. Each data set constitutes the basis for a new data product that will be available on magnetic tape from NODC and WDC-A.

The NODC has management responsibility for the NOAA Library and Information Network (NLIN) consisting of:

- ▶ the NOAA Central Library in Rockville, MD;
- ▶ regional libraries at major NOAA facilities in Miami, FL. and Seattle, WA.;
- ▶ more than 30 field libraries and information centers at other NOAA locations throughout the United States.

Among the Central Library's valuable holdings is an extensive collection of manuscript volumes of foreign meteorological data. To evaluate the proper disposition and use of these data, the NLIN received a planning grant from the Interagency Working Group on Data Management for Climate and Global Change. The funds were used with assemble a group of experts to evaluate the collection, compare it with similar data in other collections, and to provide guidance on its use in support of global change research.

### Technology Enhancements

In November 1990, the NODC's in-house computer resources were upgraded through installation of a new Digital Equipment Corporation VAX 6000/410 computer. This new computer will replace NODC VAX 1100/750 and be used in conjunction with NODC's VAX 1100/785 as part of an upgraded ocean data management system.

During November 1990, a WORM Optical Disk Autochanger or "jukebox" was installed and made operational at the NODC. The "jukebox" can store over 300 gigabytes of data. It will provide online access to users of the Coastal Ocean Program's satellite imagery and other coastal data. It is also planned to be used in the transfer of archived satellite data from magnetic tapes onto optical platters as part of the Pathfinder data rescue project.

## NATIONAL GEOPHYSICAL DATA CENTER

### Program Description

The National Geophysical Data Center (NGDC) carries out a number of programs which provide data for research in meteorology and climatology. Of particular interest is NGDC's program to assemble global information on paleoclimate and cooperate in research projects to employ the combined global paleoclimate data base for climate model verification and climate change studies. Support for this program from the NOAA Climate and Global Change Program (CGCP) is continuing.

NGDC has actively sought and acquired many paleoclimate data bases derived from tree-rings, lake and bog sediments, marine sediments, ice cores, and other geological and biological sources. Digital data sets have been enhanced with custom display and search capabilities. These research tools are currently being distributed to the paleoclimate community. Catalogues and inventories of paleoclimate data contained in ice cores, lake varves, and marine varves, have been published. Objectives of the program are to cooperate with other NOAA and academia researchers to better describe the global effects of annual to century scale climate change; to identify and better understand the causes of this climate change; and to improve the ability of separating man-induced climate change from the natural variability in order to predict global climate change for the next several centuries.

Long-term, global records of solar variability archived at NGDC are the principal record of past conditions that document the impact of changing solar energy output affecting Earth. Continued older types of observation of solar activity provide continuity with the past and provide a means to calibrate new types of measurements made using modern instruments on Earth and in space. Drawings and counts of sunspots from visual observations exist since the early 17th century, and show the persistence of the well-known 11-year solar cycle. This cycle has been correlated with changing climatic conditions. From early in the 20th century, systematic telescopic observations were made of solar flares in visible light and other wavelengths. NGDC holds Space Environment Monitor data

from NOAA geostationary satellites since the early 1970s, including X-ray flare records from above the shielding atmosphere. For the past 11 years, satellites have carried absolute instruments above the atmosphere to record significant changes in the "solar constant," the total luminous output of the sun. These data are studied at NGDC, combined with complementary geomagnetic and ionospheric databases, and made available to the research community in publications and on computer media that include magnetic tapes, floppy diskettes, and Compact Disc-Read Only Memory (CD-ROMs).

NGDC, through its affiliated contract data center, the National Snow and Ice Data Center (NSIDC) maintains several cryosphere-related datasets 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 DOD-NOAA sea ice chart digitizing programs. In addition, NSIDC provides data management services for the Coordinated Eastern Arctic Experiment and the Second Greenland Ice Sheet Program (GISP II) and 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-ROMs. Under NOAA Climate and Global Change Program (CGCP) sponsorship, NSIDC is studying ways to utilize the ingest and output data streams from the Naval Polar Oceanography Center's Digital Ice Forecast and Analysis System for climate research. NSIDC is also developing an improved global snow cover model for the Air Force Global Weather Central.

In addition, NGDC has had a long history of compiling various digital global databases including land topography, geomagnetic and gravity anomalies, heatflow, historical volcanic activity, and ocean bottom samples, drilling data, and bathymetry. These databases will be improved and enhanced and new global baseline and thematic databases (e.g. vegetation indices, ecosystem classifications, land use, terrain characteristics, soils, permanent ice cover, seasonal snow cover) will be acquired and compiled. Models of the global climate use these databases for model parameterization and data-model intercomparisons. In support of these data bases, graphic browse and visualization software is being developed. It is expected that these data bases and the associated supportive access software will play an important role in the NOAA CGCP.

## OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH

### Environmental Research Laboratories

Environmental Research Laboratories (ERL) R&D programs support NOAA meteorological 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 forecasts and warnings. 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. ERL laboratories will continue to conduct both inhouse and cooperative research with other NOAA components, joint institutes, and universities.

## Observing Technology

The Profiler Program Office of ERL, located in the Forecast Systems Laboratory, is deploying the wind profilers that will make up the 25 station demonstration network in the central United States. Installation of the systems will be completed in late 1991. Wind data from this network will be used to assess the operational impact of this new technology.

The Wave Propagation Laboratory (WPL) continued to operate three automatic tropospheric wind profiling radars and total water (i.e., vapor and precipitation) measuring radiometers in Colorado during FY 1991. Only two of the wind profiling radars are co-located with radiometers. Observations from the systems of WPL and Profiler Program Office contribute to development and test methods for effective use of continuous profile data to improve NWS short-range, local forecasts. The data will continue to be used in real time by the Denver National Weather Service and surrounding Forecast Offices, and for research by ERL, the National Center for Atmospheric Research, and university researchers.

WPL will continue studies to improve the accuracy and height resolution of wind, temperature, and humidity profiles. Low-altitude vertical temperature profiles comparable to those of the radiosonde are currently being produced by the Radio Acoustic Sounding System (RASS). The altitude is extended by combining the RASS measurements with TIROS N satellite data. Development of both the RASS and the thermodynamic (temperature/moisture) remote sensing profilers will continue in FY 1992. The development of a high resolution interferometric sounder (HIS) began in FY 1990 and will continue into FY 1992. The remote sounder will provide ground based measurements of atmospheric temperature and humidity profiles and trace constituents.

Profiler radars can also detect precipitation and large cloud particles. From the time-continuous records of Doppler spectra as a function of height, the size distribution of precipitation particles, their temporal evolution, and their change with altitude can be monitored. Several case studies have been made that illustrate how the profiler can observe the morphology of drop size distributions in liquid precipitation. This work will continue in 1992.

The technology of infrared Doppler lidar and multifrequency radars will be advanced by continued application to wind, aerosol, and turbulence studies, as well as to convective storms.

## Severe Weather Analysis and Forecasting Research

The National Severe Storms Laboratory (NSSL) in Norman, OK, focuses its research to understand and forecast severe convective storms and their associated weather hazards such as hail, high winds, heavy rain, lightning and turbulence. The parameters of storm development and intensification are identified by incorporating observations from Doppler weather radar, satellites, remote-sensing wind profilers, instrumented aircraft, and lightning location networks. NSSL provides significant technical and scientific support, including research and development, for the NOAA/USAF/FAA NEXRAD program.

NSSL will continue to develop techniques, in cooperation with the National Weather Service, to identify and warn of lightning hazards to aviation and the general public. Immediate technology transfer will be effected by close association with the National Weather Service Forecast Office in Norman, OK.

In FY 1991, ERL continued to transfer knowledge of Doppler radar applications, convective 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 new training programs such as the Cooperative program for Operational Meteorology, Education and Training (COMET) in Boulder and the NEXRAD Operational Support Facility in Norman. This level of activity will be continued in FY 1992.

The Program for Regional Observing and Forecasting Service (PROFS) in Boulder, CO, is continuing to improve the effectiveness of short range, locally specific, weather services. The improvements are achieved through a program of applied forecasting research and development based on new understanding of storm development as determined by the research community. PROFS integrates these advances with emerging technologies, advanced observational systems (such as NEXRAD, VAS, and the Profiler), and conventional data. These quasi-operational systems are specific hardware/software configurations of the highly flexible PROFS Exploratory Development Facility, with extensions into Denver and Norman WSFOs under the NWS AWIPS program. These advanced capabilities will be evaluated to reduce the risks of AWIPS procurement, to improve forecasts and operations, and as a prototype of the NWS forecaster work-station of the 1990s.

PROFS will continue its emphasis on data application from the GOES VISSR Atmospheric Sounder (VAS), Doppler radar, and the Profiler as inputs to its quantitative mesoscale analysis and prediction model, thus expanding service improvement efforts to include nonsevere as well as severe weather, to assist NWS modernization and restructuring, and to upgrade National Meteorological Center operations.

#### Mesometeorology and Precipitation Forecasting and Warning Research

The NSSL and FSL develop techniques to improve short-term forecasts of significant weather events. Through detailed case studies and regional climatologies, ERL scientists have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storms complexes. Activities underway include studies of the precipitation structure of mesoscale convective systems, of interactions between mesoconvective systems and the larger environment, of satellites to infer storm development and rainfall, and of winter storm forecasting procedures.

#### Hurricane Analysis and Prediction Research

The Hurricane Research Division (HRD) of the Atlantic Oceanographic and Meteorological Laboratory performs research to improve operational hurricane forecasts and warnings. HRD's hurricane field program uses highly instrumented NOAA P-3 research aircraft to acquire unique data which are analyzed to describe and understand the dynamics and energetics of the hurricane's inner intense core.

HRD purchased and installed a computer work station on one of NOAA's P-3 research aircraft. The new work station, together with appropriate software developed by HRD scientists, will enable HRD to conduct airborne real-time processing and analysis of fields such as radar data, omega dropwindsonde data, stepped frequency microwave radiometer data, and in-situ flight level data. The results will be transmitted to the National Hurricane Center in real time via the GOES satellite. The system was subjected to a partial test in Tropical Cyclone Marco during 1990. A similar work station will be installed on the other NOAA P-3 and HRD will continue development and testing of these systems in FY 1992.

In addition to the HRD research, the Geophysical Fluid Dynamics Laboratory (GFDL) at Princeton, NJ, models the genesis, development, and decay of tropical storms, including small-scale

features within hurricane systems, using multi-nested models of the storm system and its environment. FY 1992 plans of GFDL and HRD include research to:

- ▶ Improve understanding of the genesis, development, and decay of tropical depressions by investigating the thermo-hydrodynamical processes using numerical simulation models;
- ▶ Study small-scale features of hurricane systems, such as the collective role of deep convection, the exchange of physical quantities at the lower boundary, and the formation of organized spiral bands;
- ▶ Investigate the capability of numerical models in the prediction of hurricane movement and intensity;
- ▶ Develop a next generation operational hurricane prediction model.

### Numerical Analysis and Prediction Modeling

GFDL conducts long lead-time research to understand the predictability of weather on both large and small scales and carries out experimental applications of this understanding to NOAA missions. Two main areas of weather research are covered by the GFDL program -- Experimental Prediction and Mesoscale Dynamics.

Experimental prediction research is carried out with the National Meteorological Center to determine the predictability of global atmospheric circulation on extended time scales. FY 1992 research plans are to:

- ▶ Develop more accurate and efficient atmospheric and oceanic Global Circulation Models (GCM's) suitable for monthly and seasonal forecasts;
- ▶ Identify important external forcing mechanisms for the forecast range of several weeks to several months; accurately specify initial states of the atmosphere, oceans, soil, and snow/ice cover;
- ▶ Investigate the influence of additional internal processes such as orography, cloud-radiation interaction, and cumulus convection upon atmospheric variability on the seasonal time scale;
- ▶ Study the mechanisms of various atmospheric phenomena such as blocking, orographic cyclogenesis, equatorial ocean-atmosphere interaction, tropical circulations, and teleconnections.

Mesoscale dynamics research seeks to understand the practical limits of mesoscale predictability and the interaction of mesoscale phenomena with the larger and smaller scales.

The Wave Propagation Laboratory, through cooperative agreements with the National Center for Atmospheric Research, continues to apply four-dimensional data assimilation modeling techniques to simulate Profiler Network observations. Results have demonstrated the importance of co-locating RASS temperature capabilities with wind profilers and will provide information for determining the necessary density of an operational wind profiler network.

ARL's Atmospheric Sciences Modeling Division (Research Triangle Park, NC) conducts intramural and extramural research programs to develop predictive models on local, regional, and global scales for assessing changes in air quality and air pollutant exposures, as affected by changes in ecosystem management and regulatory decisions. The Division provides technical guidance on applying and evaluating air quality simulation models that are used to assess, develop, or revise air pollution control strategies for attainment/maintenance of ambient air quality standards.

## Air Quality Research

The Air Resources Laboratory (ARL) carries out research on processes that affect the quality of the atmosphere, primarily in the contexts of air pollution, global climate change, and emergency preparedness. Various field divisions of ARL focus on specific issues related to the development of predictive models. The Atmospheric Turbulence and Diffusion Division (Oak Ridge, TN) carries out an integrated program of theoretical and experimental research on atmospheric turbulence and diffusion in the lower atmosphere. This includes dispersion and planetary boundary layer studies in non-stationary and non-homogeneous conditions, air-surface exchanges of properties and trace gases (especially over and within vegetation canopies), and emergency preparedness efforts.

ARL's Field Research Division (Idaho Falls, ID) conducts research on the transport, dispersion and removal of those materials in the atmosphere usually regarded as pollutants. Progress toward this goal is sought by studies of the mean and turbulent atmospheric flow characteristics on all scales of motion and by studies of the history of a wide variety of tracers accidentally or purposefully introduced into the atmosphere.

## Space Environment Services

The National Oceanic and Atmospheric Administration and the USAF Air Weather Service jointly operate the National Space Environment Services Center in the Space Environment Laboratory (SEL) in Boulder, CO. The Center 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: (1) to optimize the operation of technical systems that are adversely affected by disturbances in the space environment, and (2) 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 space and on high altitude aircraft, degradation of surveillance and monitoring systems for defense, errors in navigation systems, and perturbations of satellite orbits.

The Center serves as the International World Warning Agency for the solar-terrestrial environment. It collects international data in real time, provides Ursigram and World Days Service, and meets additional specific needs of other Government agencies. The Center distributes data to other countries and issues a consensus set of daily forecasts for international use.

The Center operates with observations received from agencies that make their data available in real time and, in return, receive the services to meet their own needs. Agencies making major contributions of data include DOD, NASA, DOC, NSF, DOE, and DOI. The Space Environment Laboratory cooperates directly with NOAA/NESDIS to receive solar x-ray, particle, in situ magnetic field, and plasma data from the Space Environment Monitors on GOES and polar-orbiting NOAA satellites.

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

Planned FY 1992 research will continue development of solar prediction techniques using data which simulate those expected from the Solar X-ray Imager, to be flown on GOES-NEXT. Research will continue to insure full utilization of imager data in operational forecasts during the GOES-NEXT era. Additionally, research will begin on interplanetary scintillation maps and their use as a forecasting tool.

## 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 development of national policy for oceans and their users. NOS coordinates and supports marine activities pursued by other NOAA components (National Weather Service, National Marine Fisheries Service, Office of Oceanic and Atmospheric Research, and National Environmental Satellite, Data, and Information Service), and provides products and services that support meteorological, climatic, and environmental programs.

The objective of the NOS Ocean Services Program is to improve the Nation's ability to observe and predict physical changes in the global and coastal ocean environment on all temporal and spatial scales. To accomplish this mission, NOS manages a broad program to: modernize and enhance ocean data collection; provide timely quality assurance for operational marine data sets; develop techniques and interactive systems to analyze and predict marine processes; issue analyses and forecast guidance products of the marine environment; and distribute data and products to a wide range of Government and private sector users.

The ocean observing program provides an end-to-end data management approach. User requirements for operational and research applications are routinely solicited, reviewed, and coordinated in an attempt to establish consensus and identify cost-effective solutions. NOS maintains an inventory of all available long-term observing systems; the development and deployment of new ocean observing platforms are leveraged against the existing observing capabilities. Quality assurance is provided on the data sets through automated procedures onboard the platforms and interactive procedures at data processing facilities. Real-time data are disseminated on a variety of communications networks operated by NOS, NWS, and NMFS.

The Ocean Services Program provides operational marine analyses and forecast guidance material in support of NOS, NWS, and NMFS field offices. Analyses, interactive guidance products, and numerical model output are produced at and disseminated from three National Centers: the NOAA Ocean Products Center (Camp Springs, MD) which provides marine weather and physical oceanographic products; the Navy-NOAA Joint Ice Center (Suitland, MD) which provides global, regional, and local sea and Great Lakes ice products; and the NOAA Center for Ocean Analysis and Prediction (Monterey, CA) which provides analyses, assessments, and forecast guidance of biochemical and ocean climate processes.

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 Miami International Airport in 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 obtained 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 upgrade forecasting models of hurricane track/intensity. The AOC aircraft have primary responsibility for reconnaissance of tropical storms and hurricanes over foreign airspace that may be restricted for military operations. AOC augments USAF operational aircraft reconnaissance with high-density, high-accuracy data when storms are within 24 hours of landfall of the continental United States and whenever DOC needs exceed DOD resources. AOC also provides a quick response capability for investigation of storm activity east of 80°W longitude from August 1 through September 30 each year.

## APPENDIX B

### DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates a military environmental service system to provide specialized worldwide meteorological and oceanographic prediction services in support of military forces. This service directly supports all phases of military operations, from strategic planning to tactical operations. The U.S. Navy's Naval Oceanography Command and the U.S. Air Force's Air Weather Service are the primary military support agencies. The Army and Marine Corps each have a small specialized weather support capability, but depend upon the primary weather services for most support. The military weather services contribute to the national and international weather observing capability by making conventional observations on land and at sea where there is no other conventional weather observing capability and where the observations are most needed to meet military requirements. In addition, DOD maintains special observing capabilities such as the Defense Meteorological Satellite Program 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

Recently the Air Force established the Directorate of Weather within the Deputy Chief of Staff for Plans and Operations (HQ USAF/XOW), located in the Pentagon. AWS was realigned as a field operating agency under the Directorate of Weather. The Directorate of Weather is responsible for overseeing the development and implementation of weather concepts, doctrine, policies, plans and programs, and integration and interoperability standards to ensure effective weather support for the Air Force, Army and other agencies as directed by the Chief of Staff, United States Air Force. The Directorate of Weather also interfaces with the other military services, DOD, other Federal Departments, and international organizations concerning coordination, cooperation, and standardization/interoperability of weather services.

The Air Weather Service (AWS) is tasked by Joint Chief of Staff Publication No. 2 (JCS Pub 2) and Air Force Regulation (AFR) 23-31 to provide or arrange for staff and operational weather services to active and reserve United States Air Force (USAF) and Army units, designated unified or specified commands, and other agencies as directed by the Chief of Staff, USAF. The primary AWS mission is to support Air Force and Army combat operations in wartime. During peacetime, AWS prepares for this role by practicing special wartime support procedures and by providing or arranging daily weather support to its military customers. AFR 23-31 also defines certain related environmental and scientific support requirements to other DOD and U.S. Government agencies, foreign governments, or individuals. Collection, processing, and dissemination of atmospheric and space environmental data are intrinsic to such support.

The Office of Management and Budget Circular A-62, 13 November 1963, divides meteorological services into two types--basic and specialized. Although involved in both services, AWS is more heavily oriented toward specialized services. The general functions involved in providing meteorological services include:

- ▶ Observing weather conditions;
- ▶ Communicating meteorological data and information;

- ▶ Preparing analyses and forecasts;
- ▶ Issuing and disseminating forecasts and warnings;
- ▶ Providing specialized support.

## Observations

Meteorological observations are frequently 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 AWS personnel in support of military operations and analysis and forecasting. Observations at both Air Force and Army locations (fixed and tactical) are manually prepared with some atmospheric elements being sensed by instruments and some directly by the observer. These observations are made available to local users and are also collected by the Automated Weather Network (AWN) for transmission to the Air Force Global Weather Central (AFGWC) and to other military and civil locations throughout the world. There are 165 AWS surface observing locations or facilities in the continental United States (CONUS) and overseas.

Upper air observations provide a major input for numerical analysis and forecasting. Most of this information is obtained from U.S. civil and foreign sources, as well as rawinsonde (fixed and mobile) facilities operated by AWS. Additional upper air information from data-void areas is obtained from in-flight pilot reports from both military and civil aircraft.

Weather radar is a principal source of information for making short term warnings of severe weather. AWS operates 91 fixed weather radar sets (21 at overseas locations) and five tactical weather radar sets. Two of the CONUS sets are a part of the U.S. basic weather radar network; nine are used in a backup capacity. Also, fifteen of the AWS weather radars are used to support the National Hurricane Operations Plan. The tactical weather radar sets are used to support contingency operations.

The DOD meteorological satellite system provides a large volume of cloud, upper air and space environmental data for strategic and tactical support and is the most important single source of global weather data. The Defense Meteorological Satellite Program (DMSP) is the DOD operational environmental satellite system managed by the Air Force to support worldwide military requirements. On-board sensors provide to the AFGWC and FNOC visible and infrared (IR) images of the entire globe, temperature soundings, auroral electron counts, and other specialized environmental data. DMSP also supplies direct, real time readout of regional cloud-cover information (visible and IR) to selected military terminals located around the world.

The present DMSP satellite series (Block 5D-2) uses an Operational Line-scan System (OLS). Beginning with the fourth (Block 5D-1) series satellite the infrared spectral window was narrowed to 10.5 to 12.5 micrometers to reduce the amount of absorption by ozone and water vapor. The visible detectors were selected to optimize distinction among clouds, ground, 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 sounder (SSM/T) which provides vertical temperature and height profiles of the atmosphere. Satellite F-8, launched in June 1987, carried the first microwave imager (SSM/I) providing new capabilities to observe rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data.

## Communications

The utility of observations of meteorological elements depends on an effective communications network. The USAF global weather communications system provides for the collection of alphanumeric meteorological data, delivers these data to weather centrals and forecast facilities, and distributes centrally-produced products to the user. The Air Force communications system consists of conventional weather teletype networks; high-speed automated digital facilities; long-haul, point-to-point teletype data circuits; facsimile networks; and radio and teletype intercept facilities.

The Automated Weather Network (AWN) is the backbone of military weather communications. High-speed computers interconnected with 2400 baud -56 Kbps circuitry are used to deliver foreign and domestic weather data to designated users. Weather intercept sites in key overseas areas obtain weather data from foreign weather broadcasts for AWN delivery to the AFGWC. The AWN also delivers these data to the Navy's Fleet Numerical Oceanography Center and to NOAA's National Meteorological Center. Overseas collection and dissemination teletype networks are driven by the AWN Automatic Digital Weather Switch (ADWS) computers at Hickam AFB, HI, and RAF Croughton, UK. The CONUS ADWS at Carswell AFB, TX, drives the CONUS Meteorological Data System (COMEDS) and special teletype systems within the CONUS, an integral part of the weather collection and dissemination function. COMEDS serves as the prime communications system for the collection and dissemination of military Notice to Airmen (NOTAM) message traffic to all DOD CONUS users.

The Communications Front-End Processor (CFEP) at Offutt AFB, NE, is the hub of the facsimile system, providing graphic data to worldwide military users. CFEP drives the separate networks serving the CONUS, Alaska, Europe, Central America, and the Pacific, using computers to store and forward required products.

## Preparation of Analyses and Forecasts

The primary center for providing weather analyses and forecasts for Air Force and Army operations is the AFGWC at Offutt AFB, NE. The AFGWC employs over 700 scientists and technicians (military and civilian). AFGWC uses seven mainframe production computers, a cluster of three super minicomputers for computer flight plan generation, and an interactive graphics and imagery system. The computer-based operation of AFGWC uses a "build-and-apply" concept. Worldwide weather data are relayed to AFGWC via the AWN and blended with civil and military meteorological satellite data to construct a real time, integrated environmental data base. Scientific computer programs further digest the data to construct models of the atmosphere and to forecast its future behavior. Final tailoring of the data is accomplished for application to the specific problem of the decisionmaker. The interaction between forecaster and machine is accomplished with the Satellite Data Handling System (SDHS). SDHS consists of 35 interactive workstations capable of high-speed interaction with satellite and conventional meteorological data to prepare forecasts and other environmental products. SDHS provides man-machine interactive computer support to virtually all tasks formerly performed manually within AFGWC. The Federal Plan for Mutual Support and Cooperative Backup Among Operational Processing Centers designates AFGWC as backup for the NWS's facsimile network, and NWS's National Severe Storms Forecast Center.

In support of tactical military operations, AWS operates centralized units consisting of AFGWC, USAF Environmental Technical Applications Center (USAFETAC), fixed theater Forecast Units (FUs), deployed Tactical Forecast Units (TFUs), and fixed Weather Support Units (WSUs). Normally weather support is a mix of centrally and locally produced meteorological products. AFGWC is generally responsible for forecaster aids (analyses and prognoses) and other

operational support products for general purpose use by meteorologists who apply the information to specific areas or 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 Tactical Forecast Unit provides the same services as a theater FU; however, it is activated and deployed to support a specific contingency, activity, or exercise which is not or cannot be supported by theater FUs. FU/TFU forecasts may be direct applications of AFGWC or theater FU products or may be refined based on information available locally at the FU/TFU. AFGWC directly supports deployed weather teams whenever the theater FU lacks support responsibilities, a TFU is not established, or during the period when the deployed TFU is not yet operational.

### Dissemination of Forecasts and Warnings

The Air Force and Army require worldwide meteorological services to support 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; training and deployment of military forces; and contingency operations.

AWS contributes to the unique global needs of military aviation and makes its information available to civil aviation. AWS provides flight weather briefings, air/ground radio services, tailored observations, forecasts, watches, and warnings for unique military requirements.

An aspect of special emphasis in military weather support is the need to provide adequate decision-assistance to commanders and resource managers. To fulfill this requirement, designated AWS personnel serve as part of the working staff of supported Air Force and Army units. In this capacity, AWS identifies all weather sensitive areas of the supported operation, monitors the weather service provided in these areas, and provides expert advice when weather threatens to restrict training or combat operations. This AWS effort helps ensure that Air Force and Army units are able to fulfill their missions in spite of adverse weather, and it results in efficient use of weather resources by gearing them to mission essential support needs.

Deployed weather teams are the basic units supporting customers in a tactical theater. These teams provide surface and upper air observations often by using tactical weather observing equipment, staff weather officer services, and forecasting support. The Tactical Weather 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 system that will transmit alphanumeric and facsimile products to the theater weather support force is planned. This system will consist of a number of regional broadcast stations. The system at Elkhorn AFB, NE has been fully operational since 1988. Systems are being installed at other sites and will become operational over the next several years.

### Specialized Support

The USAF Environmental Technical Applications Center (USAFETAC), Scott AFB, IL, provides environmental data and specialized studies to support the USAF, U.S. Army, and other Government agencies. Typical support satisfies requirements for assessments of natural environmental effects on military plans, weapon systems, facilities, and intelligence activities. USAFETAC collects environmental data from its parent organization (AFGWC), then sorts, checks, stores and employs these data to produce tailored products. USAFETAC also operates a facility collocated with the National Climatic Data Center in Asheville, NC, that exchanges data and shares

some facilities with that civil agency. USAFETAC typically collects, quality assures and applies worldwide surface and upper air observations; a three-dimensional cloud analyses extracted from meteorological satellite imagery (Realtime Nephanalysis); a global analysis of snow cover; solar, geomagnetic and space observations and indices; and many other specialized environmental data sets.

In addition to the specialized support provided by USAFETAC, the AWS supports an array of specialized requirements of the Air Force and Army. Some of these are described below.

AWS integrates Army weather support into its overall support concept. AWS personnel are trained and oriented on applicable Army organizations, concepts of operations, and weather sensitivities of Army operations and equipment. AWS support units are aligned and integrated with the Army intelligence organization. Support products are in a form which is directly usable and understandable by Army personnel and are integrated into Army communications systems. Mobile and fixed meteorological equipment for use in Army support is programmed by AWS. In a tactical environment, direct forecast support is normally provided down to corps, divisions, separate brigades, regiments, echelon-above-corps, aviation brigades, armored cavalry regiments, ranger regiments, and special forces groups (as well as subordinate battalions deployed at forward operating bases). Observer support is provided to all levels identified above.

AWS provides meteorological support to the Nation's space and missile programs. This includes a wide range of weather observing services at the Air Force Eastern Space and Missile Center and the Kennedy Space Center. AWS also provides launch forecasting service for NASA's manned and unmanned launches and for commercial launches from the Kennedy Space Center.

AWS provides specialized meteorological services for the Air Force Western Space and Missile Center at Vandenberg AFB, CA, and the Pacific Missile Range which includes Pt. Mugu and San Nicholas Island, CA, and Barking Sands, HI. AWS also supports the White Sands Missile Range, NM, the Kwajalein Missile Range, and other DOD research and test facilities.

The Air Force and the Navy operate the Joint Typhoon Warning Center on Guam under the Naval Oceanography Command Center, Guam. The Center provides tropical cyclone warning services to DOD units and other US subscribers in the area west of 180 degrees to the east coast of Africa in both hemispheres.

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

Through the AFGWC, AWS 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.

### Planned Enhancements

USAF and Army operational requirements for environmental support are the basis for all AWS actions to improve existing or acquire new capabilities. AWS assesses these requirements and attempts to satisfy them through either hardware acquisitions or technique development.

AWS plans to modernize its base-level weather support systems. This includes an Automated Weather Distribution System (AWDS) and the Next Generation Weather Radar (NEXRAD). Both of these systems have funds programmed for their R&D and acquisition phases.

The AWDS will automate the handling of weather data by incorporating the latest state-of-the-art data processing, communications, and display technologies. The data-handling function will maximize forecaster capability. A modular design will permit AWDS to be operated in a fixed or mobile environment and minimize staffing requirements. Initial installation was completed at McGuire AFB, NJ in 1990. Additional stateside installations are in progress; overseas and tactical installations will be completed by 1995. AWDS receives information from the National Weather Service through the AFGWC via the AFOS at the AFGWC. (AFOS is the NWS system also known as "Automation of Field Operations and Services").

To enhance AWDS in base weather stations and to expand the capabilities of forecasters in a tactical wartime environment, the AWDS Pre-Planned Product Improvement (AWDSP<sup>3</sup>I) will provide the following capabilities: inter-system interoperability, High Frequency radio for transportable AWDS, increased local graphic distribution, multiple software improvements, improved meteorological satellite ingest, and forecaster assistance through advanced processing techniques and command post Staff Weather Officer (SWO) terminals.

AWS plans to significantly enhance its tactical warfare weather support capability through employment of the Battlefield Weather Observation and Forecast System (BWOFS). BWOFS involves the development of two capabilities: 1) Electro-Optical Tactical Decision Aids (EOTDA) to provide weather support for electro-optical target acquisition, weapons guidance, and reconnaissance systems, and 2) the Pre-Strike Surveillance/Reconnaissance System (PRESSURS) to acquire weather observations in uncontrolled or enemy controlled areas of the battlefield. PRESSURS capabilities are linked to advances within the DMSP, especially the Mark IV-B Tactical Terminal, scheduled for first deployment 30 June 1992. The Mark IV-B will put full DMSP capabilities in the hands of the tactical user.

The NEXRAD radar, WSR-88D, is being procured under the auspices of the NEXRAD Joint System Program Office. The WSR-88D is an automated, digitized, S-band Doppler system that was jointly developed and procured. It will be operated and maintained by DOD, NOAA, and FAA within the CONUS and by the USAF and Navy overseas. The system incorporates the latest technological advances in Doppler radar, data processing, communications, and display. The CONUS NEXRAD network will satisfy weather radar requirements in support of the general public, the military, and the entire spectrum of the aviation community. Installations of the WSR-88D are in progress and are expected to be completed by 1994.

The Improved Weather Reconnaissance System (IWRS) became operational in 1989. This system incorporates the new USAF inertial navigation system for improved positioning. It automatically gathers data, provides improved flight level winds, and has a windsounding capability. Increased volumes of highly accurate data are relayed by satellites from reconnaissance aircraft to agencies for use in hurricane prediction models. IWRS equipment is also used on the NOAA WP-3D research aircraft.

The Centralized Data Management System is a related series of distinct acquisition, development and integration efforts to transition AFGWC from a multiple copy data base environment to a centralized data base environment. The system replaced two Sperry computers during FY 1990 with one computer for both unclassified and classified production as well as backup and development capacity. A Centralized Data Base Computer was also acquired in FY 1990 which will be integrated with improved software from the AFGWC Software Improvement Program (ASIP). Additional AFGWC hardware/software systems will be transitioned to the centralized data base environment until final operational capability is achieved in approximately FY 1997.

The final model acquired under AFGWC's Advanced Weather Analysis and Prediction System (AWAPS) is the Relocatable Window Model (RWM), a regional and relocatable analysis and forecast model suite designed for military application. Limited operational use of the RWM has already been made. The model will provide non-cloud fields to the Battlefield Weather Observation and Forecast System (BWOFS).

An Improved Point Analysis Model (IPAM) was implemented at AFGWC in FY 1990. Implementation at USAFETAC and final operational capability will occur in FY 1991. The IPAM will construct gridded cloud depictions and vertical profiles of atmospheric pressure, temperature, density, absolute humidity, precipitable water and winds. In addition, IPAM will construct pseudo-surface weather observations, a 24-hour surface weather history, and the aerosol parameters needed as inputs to atmospheric transmission models. IPAM will take advantage of new data sources and updated or new climatological data and models. Improvements to IPAM will be made through FY 1994 by means of the Improved Point Analysis Model Technology Transition (IPAMT<sup>2</sup>) Program.

The Advanced Computer Flight Plan (ACFP) System will replace a leased optimized computer flight plan system and an existing USAF-owned flight simulation model. The ACFP system will satisfy requirements beyond the capabilities of current systems with enhanced flight planning and optimization features, and increased responsiveness to the needs of all Major Air Commands. The system will meet initial operational capability in FY 1993.

Changes will be made to models and applications at AFGWC to take advantage of the promising, new Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Water Vapor Profiler (SSM/T-2) and a new Upper Atmospheric Sounder associated with the DMSP Special Sensor Microwave Imager and Sounder (SSMIS). The SSMIS Upper Atmospheric Sounder will produce credible temperature soundings to approximately 70 km.

The Air Weather Service upgraded its support to Air Force base disaster preparedness personnel by fielding the Geophysics Laboratory's Air Force Toxic Chemical Dispersion Model (AFTOX). Support to electronic warfare was improved by fielding the Naval Ocean Systems Center's Integrated Refractive Effects Prediction System (IREPS).

The MARK IVB Tactical Terminal program will procure a total of sixteen terminals to replace the aging MARK IIAs, IIIs, and IVs. Four of the MARK IVB terminals will be mobile, the other twelve will be fixed. In addition to providing satellite imagery, the MARK IVB terminals will be able to accept and use data from the DMSP Microwave Imager, Microwave Temperature Sounder, Microwave Water Vapor Profiler, and the TIROS Advanced Microwave Sounding Units A and B to produce both uniform gridded data fields and traditional meteorological products. The MARK IVB contract was awarded to Lockheed Corporation in October 1988.

In January 1988, the Air Force awarded four competitive concept studies for Block 6, the follow-on to the Block 5D-2/5D-3 satellites. The objectives include lowering DMSP system life cycle cost, and assessing cost effective options for increased survivability, interoperability, and remote sensing capability. The Navy (oceanography) and Army (tactical support) are participating in the Block 6 studies.

## SPACE ENVIRONMENTAL SERVICES

Many DOD systems operate in, or are affected by, conditions above 50 kilometers. The space environment includes the near-Earth regions of the thermosphere, ionosphere, and magnetosphere,

as well as the regions that influence them such as the heliosphere (solar) and interplanetary space. The AWS provides basic and specialized space environmental support to military electromagnetic communications, surveillance, and warning systems which operate in this environment. AWS provides environmental forecasting and specialized services for: (1) ionospheric conditions, (2) neutral atmospheric conditions, (3) the magnetosphere, (4) solar flare and solar particle events, and (5) providing geomagnetic and solar indices to users for determining upper atmospheric density variability.

The current hub of the AWS space environmental forecasting program is the AFGWC Space Environmental Support Branch which provides the only operational space environmental support within the DOD. The AWS is now moving space environmental support functions and manpower positions to a new facility, the Space Forecast Center (SFC). Initial operational capability of the SFC will occur in January 1992 with final operational capability in June 1992. Ionospheric conditions have a profound effect on radio wave propagation. The SFC will have the capability to give real-time reports on ionospheric conditions and the capability to forecast and predict ionospheric disturbances. Ionospheric models under development will be ready for customer use after the SFC becomes operational. Magnetospheric, and Neutral Atmospheric models are also being developed.

The Air Weather Service also participates with NOAA in the joint operation of the National Space Environment Services Center (SESC) in Boulder, CO. The SESC provides basic solar-geophysical analyses and forecasts to AFGWC and serves as a contingency backup for AFGWC space environmental support.

#### Data Sources

USAF operates and funds a variety of ground-based and space-based solar-geophysical sensors. The Solar Observing Optical Network (SOON) is comprised of AN/FMQ-7 solar optical telescopes located in Puerto Rico, New Mexico, Hawaii, Australia, and Italy. The Radio Solar Telescope Network (RSTN) is comprised of AN/FRR-95 solar radio telescopes in Massachusetts, Hawaii, Australia, and Italy. USAF operates, or provides funding for, numerous other geophysical sensors as shown in Table B.1.

#### Data Provided

Space environmental support encompasses the present state and forecasts of the Sun, the interplanetary medium, the near-Earth space environment, and the ionosphere.

Solar Flares. The SOON (AN/FMQ-7) was specifically designed to provide consistent, rapid flare observations and data for reliable, short-term forecasting of solar flares and their effects. Currently, the actual work on exploitation of SOON data by applying advanced modeling techniques is being accomplished by the Air Force's Phillips Laboratory, Hanscom AFB, MA, and NOAA's Space Environment Laboratory (SEL) located at Boulder, CO. SOON optical data are complemented by radio frequency measurements via the Radio Solar Telescope Network (RSTN). Radio data provide flare observations despite cloud cover and permit tracking of solar disturbances through the solar atmosphere.

Geomagnetic Index. AFGWC monitors variation of the Earth's magnetic field through the use of ground-based magnetometers. Data from these sensors are processed at AFGWC to develop a geomagnetic index which is transmitted to users for real-time use in density models. Recently, AFGWC expanded its magnetospheric monitoring by using real-time high energy particle data from operational DOD geostationary spacecraft as well as magnetospheric observations from the GOES satellites.

Ionospheric Variability. AFGWC forecasters monitor the state of the ionosphere, the Sun, and the magnetosphere in order to provide notifications and forecasts of ionospheric irregularities. Short term forecasts for high frequency communications systems can be provided in real-time as can specification and forecasts of electron density profiles and total electron content. The primary long-range forecast requirements are for HF radio propagation.

Event Notification. Since the state-of-the-art in accurately forecasting solar and geophysical events is limited, AWS has concentrated on providing rapid notification to system operators of actual solar events which could degrade the performance of their systems. Rapid event notification is provided for decision assistance to all levels within the military chain of command. The Proton Prediction System model upgrade has enhanced AWS forecasts of solar proton events. AFGWC notifications of these events are provided within minutes of detection of a disturbance and are specifically tailored for each system operator.

### Planned Enhancements

AWS plans to upgrade the Space Environmental Support System in several areas: ground-based observing, space-based observing, and forecast capability.

Ionospheric measurements will be improved by replacing five analog ionosondes with digital systems and adding 14 digisondes to the AWS Network. A new ionospheric height analysis model will be installed in the 19 digisondes. Ionosonde data will be added from southern hemispheric sources. Seventeen Transitionospheric Sensing System (TISS) units will use signals from the Global Positioning System (GPS) to calculate total electron content and scintillation parameters. The Solar Electro-Optical Network (SEON) of optical and radio telescopes will be upgraded and given new capabilities -- an ability to locate solar flares on the Sun by radio wavelength means and enhanced magnetograph capabilities. The SEON will be consolidated from six sites to five sites, and possibly to four if technology permits. New space environment sensors will fly on future Defense Meteorological Satellite Program (DMSP) satellites. A Solar X-Ray Imager (SXI) will be flown on the GOES Next series. 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 National Space Environment Services Center in Boulder, CO and transmitted to the Space Forecast Center (SFC) in real time. Initiatives continue to be considered to obtain solar wind and interplanetary magnetic field data from sensors located outside the magnetosphere.

The Space Forecast Center (SFC) will be the focal point of space environmental support to the DOD. Located at Falcon AFB, CO, the SFC will consist of a 37-person team dedicated to providing support to a variety of customers. Real-time data will be received at the SFC from a number of sources: DMSP, GOES, and other satellite systems; SEON sites; and ground-based magnetometers, the TISS, and ionosondes. The SFC teams will use those data and new space environmental models and forecast techniques to produce alerts, warnings, and other products for elements of the DOD (USSPACECOM, SAC, NORAD, etc). New space environmental models will run on state-of-the-art computer systems: global Ionospheric Models, Neutral Atmospheric Models, a Magnetospheric Model, and Integrated Space Environmental Models.

The Ionospheric Models will consist of a specification and a forecast component. The specification component will be the Parameterized Real-time Ionospheric Specification Model (PRISM) which includes high-latitude and southern hemispheric enhancements and has the capability to use data from the Defense Meteorological Satellite Program space environmental sensors and other real-time data sources.

Table B.1 Geophysical Sensors of Space Environment

<u>Sensor</u>	<u>Purpose</u>	<u>Locations</u>
Polarimeters	Measure total electron content of ionosphere	Eleven, N. Hemisphere
Ionosondes	Measure ionospheric electron density profiles	Eleven, N. Hemisphere
Magnetometers	Measure changes in geomagnetic field	Six, mid-high latitude
Defense Meteorological Satellite Program	Measure precipitating electron flux, ion flux, ion density, electron and ion temperature, and provide optical auroral pictures	Polar orbit
DOD Spacecraft	Measure high-energy and low-energy electrons and protons	Geostationary orbit
Solar X-ray Imager (USAF funds for FY91)	Locate positions of solar flares, measure solar x-ray and extreme ultraviolet fluxes	Geostationary orbit

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The Neutral Atmospheric Models consist of a parameterized forecast model and a more detailed specification model. The forecast model is the University of Michigan Vector Spherical Harmonics (VSH) parameterization of the Thermospheric Ionospheric General Circulation Model (TIGCM). The specification model is the TIGCM itself. The neutral atmospheric models will specify and predict global neutral densities, winds, and temperatures from 90 to 1500 km in the atmosphere. The models will incorporate measurements of neutral density, solar extreme ultraviolet radiation, interplanetary magnetic field orientation, and high-latitude ion convection and auroral zone energy measurements from DMSP sensors.

The Magnetospheric Model has completed advanced development and will provide specification of magnetospheric particle fluxes and geomagnetic activity levels. The model is a parameterization of the Rice University Convection Model. The model incorporates geomagnetic index inputs, available solar wind and interplanetary measurements, geostationary energetic particle measurements and ion convection and low-latitude auroral boundary inferences from Defense Meteorological Satellite Program DMSP sensors. An upgrade to this model is underway and will provide a forecasting capability.

The Integrated Space Environmental Models, now in the planning stage, will provide an interplanetary model to carry shocks in the solar wind plasma from the Sun's corona to the Earth's magnetopause. An energy transfer model will be used to convey interplanetary energetics to the Magnetospheric Model and other space environmental models, based on interplanetary magnetic field conditions. A coupling model will be used to provide output fields from one space environmental model as inputs to the other models, and feedbacks will be provided among the models so they act as a single system. Solar models will not be ready for operational use until the mid- to late-1990s.

## SUPPORTING RESEARCH

The objective of the Air Force meteorological research program is to develop equipment and techniques for observing and predicting meteorological conditions that affect military systems and operations. Requirements for research and technology in meteorology are expressed in Air Force Technology Planning Objectives, Mission Area Analyses, and Statements of Operational Needs. In addition, the Air Weather Service provides guidance in the form of documented geophysical requirements. The Phillips Laboratory, Geophysics Directorate (GP) at Hanscom AFB, MA, has the mission responsibility within the Air Force to conduct both in-house and contractual basic research, exploratory development, and advanced technology development in the environmental sciences, including meteorology. Its exploratory development program in meteorology emphasizes moisture and cloud numerical weather prediction, ground-based and satellite remote sensing, climatological studies, boundary layer meteorology, cloud physics, atmospheric density, and battlefield weather observing and forecasting. Research and development for the Defense Meteorological Satellite Program (DMSP) is also conducted.

In the area of moisture and cloud forecasting, research is being conducted on global and regional scales. Research with a mesoscale cloud model focuses on improved boundary conditions and accounting for local forcing. New moisture-to-cloud algorithms are being developed based on a comparison of global model cloud forecast errors with Air Force Global Weather Central (AFGWC) operational cloud forecasts. New physical parameterization schemes for cumulus convection, boundary layer processes, and radiation (including input from satellite sensors) have been developed and are being tested on the global model. The initial regional model was completed and is undergoing testing and modification. Forecaster effectiveness in an automated operational environment, such as the Automated Weather Distribution System (AWDS), is being evaluated using GP's Advanced Interactive Meteorological System (AIMS). More work is planned to evaluate how continuous wind measurements from a vertically pointing very high frequency (VHF) radar will contribute to numerical modeling and real-time monitoring of developing mesoscale weather systems. An assessment of the utility of "expert system" techniques in short-range weather forecasting is being pursued. A new effort called the Advanced Meteorological Processing System (AMPS) is underway. AMPS will incorporate "expert system" techniques and numerically-based approaches to receiving and processing copious amounts of weather data from new observing systems. New procedures will be used to process and combine weather radar and satellite imagery to automatically estimate cloud motions. These motions can then be integrated to allow mapping cloud and precipitation systems in three dimensions. Research efforts will remain constant in this area.

In the ground-based remote sensing area, automated doppler weather radar techniques are being developed for identifying regions of potential hazardous clear air turbulence and aircraft icing. Doppler techniques are also being developed for precise short-term forecasts of thunderstorm precursor phenomena. These techniques will be incorporated into the jointly-procured (DOD, DOC, and DOT) WSR-88D Doppler Weather Radar (also known as NEXRAD). Coherent polarization diversity weather radar techniques to derive hydrometeor characteristics, such as particle size distribution, orientation, and thermodynamic phase, are being tested. A new task is underway to evaluate the potential of ground-based remote sensing techniques including a VHF wind profiler, a microwave doppler weather radar, and a loransonde system to provide accurate and continuous vertical profiles of the horizontal winds in clear and cloudy air and for all seasons of the year.

To support satellite meteorological requirements, improved inversion algorithms are being developed to compute more accurate vertical temperature and water vapor profiles from satellite measurements at far-infrared and microwave wavelengths. An additional effort is planned to

establish a versatile cloud-truth data field which is essential for evaluating new cloud algorithms that use satellite observations. A study will evaluate the use of microwave imagery information for mapping meteorological parameters such as rain rate, ocean surface wind speed, and soil moisture. Techniques will be developed to incorporate microwave imagery 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 depict cloud characteristics; i.e., cloud height, cloud thickness, phase, and rain areas. Techniques will also be developed to use satellite data to determine tropical storm location, intensity, and thermodynamic structure. A new effort, supported by DMSP, is underway to develop a tactical cloud analysis system using satellite-sensed data and imagery.

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. Climatological studies of rainrate duration modelling and analysis of high resolution cloud photographs taken in orbit are nearing conclusion. These studies are used to quantify the distribution of cloud sizes, of clear intervals, and of the variation in apparent cloud cover as viewing angle changes. Climatological studies supporting reentry vehicles will begin and research into methods of predicting triggered lightning strikes to aircraft and launch vehicles will continue.

In boundary layer meteorology, work on improving existing and developing new toxic chemical dispersion models for various scenarios will continue in FY 1992. The Air Force weather community will be fielding an updated version of its toxic chemical dispersion model for smooth terrain and uniform wind fields (AFTOX). A complex terrain dispersion model (Wind and Diffusion Over Complex Terrain (WADOCT)), which combines AFTOX and a terrain-induced wind flow model (AFWIND), has been written and is undergoing testing. The WADOCT user's manual will be published and the model will be delivered this year. A heavy gas dispersion model was developed and will soon be available to DOD users.

The major thrust of the cloud physics program is to develop computerized mathematical models for forecasting the micro physical structure of clouds and cloud systems, given macroscopic statements about the nature of the atmosphere. The weather attenuation program will continue extremely high frequency (EHF) data reduction and interpretation and will test the microphysics of the cloud model against available data sets. This program includes simultaneous measurements of EHF attenuation and detailed microphysics of the clouds, rain and snow, and snow in the melting layer.

The objective of the atmospheric density work is to develop very accurate methods to measure and predict 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 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.

The battlefield weather program will emphasize electro-optical tactical decision aids (EOTDAs) which are being developed for use on microcomputers in base weather stations and host command and control computer systems using an AFGWC provided database. This automated forecasting aid is used to predict acquisition and lock-on ranges for precision guided weapons used by the Air Force and the Army.

The present level of support for atmospheric sciences research will continue. In evaluating Air Force needs, it was decided to continue a new program in triggered lightning prediction at a modest level of support. Another initiative will investigate improved techniques for target area climatologies, and analytical efforts in satellite meteorology (e.g., lidar) for determining real-time target area weather. These new techniques will support current and next generation reentry vehicle requirements. Successful completion of the weather attenuation experiment and subsequent data analysis has made available the necessary resources for these new efforts and has provided flexibility to start a new project to develop a tactical cloud analysis program.

## UNITED STATES NAVY

### OVERVIEW/ORGANIZATION

Within the U.S. Navy, meteorological and oceanographic support is provided globally to units based ashore and at sea. These include environmental personnel and resources assigned to naval shore and afloat staffs, U.S. Marine Corps aviation weather units, test stations and ranges, shipboard weather offices, and activities of the Naval Oceanography Command. Personnel and resources from the naval research, development, logistic, and training components are also included. Naval Systems Commands, laboratories, research facilities, and training commands constitute various additional components.

Primary support is provided by activities and detachments assigned to the Naval Oceanography Command. Shore field activities within the Naval Oceanography Command having meteorological responsibilities include a primary numerical processing center, three regional Naval Oceanography Centers, two Naval Oceanography Command Centers, seven Naval Oceanography Command Facilities, 47 Naval Oceanography Command Detachments, and two Naval Oceanography Command components.

The Fleet Numerical Oceanography Center, Monterey, CA, operates the master computer center and functions as the hub of the Naval Environmental Data Network. The Naval Environmental Data Network is designed for product distribution among the major Naval Oceanography Command activities. Through linkage with DOD and NOAA environmental satellite systems and U.S. Air Force and NOAA data distribution centers, Fleet Numerical Oceanography Center acquires global coverage of environmental data. A joint agreement exists between the Air Force, Navy and NOAA to share processing tasks and environmental product lines of mutual interest to all parties from DMSP, GOES and NOAA TIROS satellites. From these data, basic and applied numerical (computer) products are generated for distribution via the Naval Environmental Data Network and other communications systems for use by other activities in producing specific support products and services.

The Naval Oceanographic Office (NAVOCEANO), Stennis Space Center, MS, operates an Operational Oceanography Center (OOC) that is responsible for providing real-time oceanographic support to the fleet.

The three regional Naval Oceanography Centers--the Naval Western Oceanography Center at Pearl Harbor, HI; the Naval Eastern Oceanography Center at Norfolk, VA; and the Naval Polar Oceanography Center at Suitland, MD--are assigned broad geographical fleet support services and related matters within their specific areas of responsibility. The Naval Western Oceanography Center is responsible for the Pacific and Indian Ocean areas; Naval Eastern Oceanography Center for the Atlantic and Mediterranean Sea areas; and the Naval Polar Oceanography Center for the Arctic and Antarctic areas. They utilize numerical products from the Fleet Numerical Oceanography Center to provide environmental broadcasts and tailored support in response to specific requests from the operating forces.

The two Naval Oceanography Command Centers are located at Rota, Spain, and on the island of Guam. Naval Oceanography Command Center, Rota, assists Naval Eastern Oceanography Center in the Mediterranean Sea area. Naval Oceanography Command Center, Guam, assists the Naval Western Oceanography Center with provision of environmental services in the Western Pacific and the Indian Ocean areas. Both of these centers provide fleet environmental broadcasts and tailored support in a manner similar to the regional centers. Naval Oceanography Command Center, Guam, has an additional responsibility for operation of the Joint Typhoon Warning Center (with the Air Weather Service of the U.S. Air Force), providing tropical warnings to USAF, issuing tropical cyclone warnings to U.S. interests in the Western Pacific and Indian Oceans.

Seven Naval Oceanography Command Facilities at Brunswick, ME, Jacksonville, FL, San Diego, CA, Yokosuka, Japan, Cubi Point, Republic of the Phillipines, Keflavik, Iceland, and Bermuda provide limited area, local and aviation environmental forecast services, as well as direct support for ship and submarine staffs. Five of these activities command detachments. Primary forecast guidance from Fleet Numerical Oceanography Center is utilized by all facilities; the overseas facilities augment this guidance with data from local sources.

There are 47 Naval Oceanography Command Detachments located worldwide. Although primarily located at Naval Air Stations, several are located at Naval Stations to provide services to sea-going units. Each is established under an Officer-in-Charge or Chief Petty Officer-in-Charge who reports to a designated shore/field activity. The majority of these detachments are oriented to provide direct environmental support, including aviation meteorological and oceanographic services, within their local areas. Detachments within the contiguous states utilize the basic and applied numerical products from both the National Meteorological Center and the Fleet Numerical Oceanography Center to provide meteorological and oceanographic services. Overseas detachments use foreign and Air Weather Service (AWS) products, as available, in addition to Fleet Numerical Oceanography Center numerical products. Three of the detachments are oriented to provide specific technical support; such functions include coordination of the Navy's climatological program at the National Climatic Data Center at Asheville, NC, coordination and circuit management with the USAF Automated Weather Network (AWN) at Carswell AFB, TX, and liaison and coordination with the USAF Global Weather Central at Offutt AFB, NE.

Oceanographic/meteorological units are permanently assigned to 39 aviation-capable U.S. Navy ships. These units, staffed with officer and enlisted personnel and equipped in accordance with their designated support functions, are integral to the command to which they are assigned. Smaller units, termed Mobile Environmental Teams are temporarily assigned to Navy ships upon request to meet short-term support requirements. These METs, available from six Naval Oceanography Command activities (Rota; Norfolk; San Diego; Yokosuka; Cubi Point, and Pearl Harbor) are outfitted with their own portable equipment. Navy ships without dedicated units also contribute by providing vital

meteorological and oceanographic observations, frequently from data-sparse oceanic areas. Technical guidance is provided by the Naval Oceanography Command.

U.S. Marine Corps (USMC) garrison aviation weather units are staffed with USMC meteorological personnel. They function and are supported in a manner similar to Naval Oceanography Command Detachments but under USMC management. These weather units are integral to Marine Corps aviation activities and provide support to assigned activities and tenant organizations thereof, which include nine major air stations in the contiguous United States, one in Hawaii, and two in Japan.

The Fleet Marine Force aviation units, also staffed with meteorological personnel, are indigenous to each of the twelve Marine Wing Support Squadrons. They operate and maintain meteorological mobile facilities to provide environmental support during tactical operations. The units are task organized to respond to the commander's requirements according to the mission, functioning independently as required. While in garrison, the weather personnel and equipment augment and support the host activity's weather unit.

## PROGRAM DESCRIPTION

The Navy's meteorological Operational Support programs are designed to satisfy validated fleet requirements. They include surface and upper atmospheric observations programs, flight forecasting services, Optimum Path Aircraft Routing System (OPARS), tailored forecasts, and optimum track ship routing for naval and naval contract vessels, local and operating area forecasts, tropical cyclone warnings, local severe weather forecasts, high seas and winds forecasts, manual and numerically-derived analyses and prognoses, microcomputer-based product dissemination and display capabilities, statistical and climatological studies, and a wide range of mission-specific and tactical support products to the operating forces of the U.S. Navy.

The FY 1991 budget includes programs that address a total of 147 validated requirements. Efforts are focused in three broad areas: shipboard tactical environmental support; upgrades to Fleet Numerical Oceanography Center, Naval Oceanographic Office and other Naval Oceanography Command centers and their data distribution networks; and, enhanced capabilities at Naval Oceanography Command shore-based aviation support activities. Efforts in the FY 1991 program address both the Systems Acquisition and Operations Support categories. They are highlighted below.

Tactical Environmental Support System (TESS). TESS is a modular, computer-based support system designed to provide Navy decision-makers with meteorological/oceanographic assessments and forecasts and to integrate air/ocean data with sensor/weapon platform parameters to assess system performance. Scheduled for initial operational deployment during FY 1991, TESS will function as the operational, resident air/ocean data base. Data sources will include in-situ sensors, meteorological and oceanographic satellites, U.S. and foreign radio weather broadcasts and data fields prepared ashore, principally at the Fleet Numerical Oceanography Center. Its applications and capabilities extend well beyond those of an automated weather information system (AWIS) because of the extensive ocean acoustic analysis and prediction capabilities, and data bases containing tactical sensor and weapon systems parameters for use in tactical decision aids hosted in the system.

Acquisition strategy for TESS is to build upon an interim capability based on the Navy-Standard Desktop Tactical Support Computer. This interim capability (known as TESS(1) and TESS(2)) was implemented as a non-research and development effort, and was completed during FY 1989. A total inventory of over 70 units exists with installations keyed to major fleet combatants and selected shore

activities with significant command and control responsibilities. The follow-on system, TESS (3), will rehost the existing TESS capabilities while providing significant new enhancements.

Primary Oceanographic Prediction System (POPS). Existing computer systems at the Naval Oceanographic Office (NAVOCEANO) and Fleet Numerical Oceanography Center have reached their limits in computational speed, memory and processing architecture. Further improvements in atmospheric models and the development of global, eddy-resolving ocean models require computational capabilities which exceed those of the current computer systems. Emergent requirements were documented, validated and funded, with the recommendation that the Primary Oceanographic Prediction System (POPS), which will consist of two Class VII supercomputers, be procured beginning in FY 1990. In FY 1991, the first of two POPS Class VII supercomputers (Cray Y-MP8) became operational at NAVOCEANO, Stennis Space Center, MS, to support ocean modeling and other research and development efforts. Replacement of the existing Class VI machine with a Class VII supercomputer at the Fleet Numerical Oceanography Center, Monterey, CA, is planned during FY 1992. This computer will significantly upgrade the ability to run Navy operational and developmental meteorological and oceanographic models. High speed communications links between these activities will provide backup capabilities.

Satellite Data Receiver/Recorder, AN/SMQ-11. The AN/SMQ-11 has been developed as the next generation satellite receiving-recording system for use aboard major afloat combatants and at selected sites ashore. It is replacing a variety of existing Navy satellite reception systems. The SMQ-11 is composed of a dual-planar array antenna system and two equipment cabinets for data processing. It has the capability to process encrypted transmissions from the Defense Meteorological Satellite Program (DMSP) as well as imagery from national civil satellite systems (TIROS, GOES). Satellite information from this system can be provided to the Tactical Environmental Support System (TESS) for additional processing and applications. Additional planning is underway to exploit data from other satellite systems (foreign and domestic) projected for the early 1990's. Production of the AN/SMQ-11 commenced in FY 1987. A total inventory of 74 units is programmed.

Atmospheric Modeling. The primary goal of this effort is to improve fleet readiness and safety of ships and aircraft, and to enhance weapon system performance through the application of new numerical modeling technology. Weather prediction problems contain three elements: observation, forecasting, and product utilization. Improvements in product utilization are primarily being addressed within the TESS program, previously described. Several efforts are underway to enhance the quantity, quality, and optimum utilization of observational data. Procurement of a portable mini-rainsonde system began in FY 1988, and was completed during FY 1989. The system consists of a surface receiver/processor and lightweight balloon-borne expendable sensor package capable of measurements of pressure, temperature, humidity, and wind speed and direction. The Shipboard Meteorological and Oceanographic Observing Program and the Automated Surface Observing System (ASOS) programs are developing shipboard and shore-based systems for improving the timeliness, quality, and reliability of meteorological and oceanographic measurements. Development efforts undertaken by the National Weather Service have been leveraged in Navy's selection of the NWS Automated Surface Observing System for Navy use ashore. Requirements at sea are unique to Navy, but will utilize proven, off-the-shelf technological components and equipments where possible. Efforts within the Shipboard Meteorological and Oceanographic Observing System have been merged with TESS(3) development, as the sensors provide inputs directly into TESS at sea. Significant efforts are underway to optimize the use of satellite data in Navy numerical modeling. Continued upgrades to the Navy's Operational Global Atmospheric Prediction System and Navy

Operational Regional Atmospheric Prediction System (NOGAPS/NORAPS) spectral model are planned, incorporating asynoptic and remotely-sensed data.

Next Generation Weather Radar (NEXRAD). Principle User Processing Station (PUPS) associated with NEXRAD will provide significant improvements in radar analysis of meteorological features and severe weather over the United States. Navy is participating in the NEXRAD program, and will draw upon NEXRAD radars for coverage over Navy forecast areas. In some cases, Navy property was made available for the installation of the radar. NEXRAD PUPS will be procured by Navy during FY 1991 to display imagery from NEXRAD systems covering operational areas. NEXRAD will not totally replace other meteorological radars for Navy, because a number of locations overseas will not be covered by the NEXRAD system.

Digital Ice Forecasting and Analysis System (DIFAS). The DIFAS system of the Joint Ice Center (Navy/NOAA) is a comprehensive workstation-based system which ingests data from a variety of sources, allows for interaction between data sets, and produces ice analysis and forecast products in the form of screen displays, hardcopy charts, alphanumeric messages and gridded output products. Implemented during FY 1989, but with improvements scheduled for the subsequent three fiscal years, the DIFAS will use the following data for all areas of ice coverage:

- ▶ TIROS AVHRR (Advanced Very High Resolution Radiometer) visible, IR and NIR imagery;
- ▶ NMC Guidance Products;
- ▶ Fleet Numerical Oceanography Center Guidance Products, including ice edge and SSM/I (Special Sensor Microwave Imager) ice parameters;
- ▶ Drifting buoy;
- ▶ Climatological Summaries and Bathymetry.

Products produced by DIFAS fall into three categories: graphic products, alphanumeric messages, and gridded data in a format chosen for ease of encoding, retrieval, and manipulation.

Summary. The impact of these programs on fleet readiness and operational capabilities is significant. By the end of FY 1991, a logical framework will be in place to ensure that a survivable, responsive and layered network can provide in-situ as well as shore-based support to the operating forces of the U.S. Navy.

## UNITED STATES ARMY

### OVERVIEW

#### Army Operational Support

The U.S. Army provides two kinds of direct weather support to the Army combat mission. These include the upper air observations for artillery fire support missions and limited surface weather observations to support tactical combat operations. The Army also provides operational support to Army ranges, test facilities, and research activities through the Test and Evaluation Command (TECOM) Atmospheric Sciences Division's Meteorological Teams. The TECOM operational support is described under Army Materiel Command in the Research, Development, Test and Evaluation section.

Artillery Meteorological Crews are trained at the Field Artillery School and assigned to Division Artillery, Field Artillery Brigades, and to Separate Brigades with a direct support Artillery Battalion. Army soldiers regularly take tactical upper air observations to support Artillery units during tactical

training exercises or at permanent Army Artillery ranges. Artillery Meteorological Crews also take limited surface observations at tactical locations on an "as needed" basis to support artillery operational requirements.

Artillery Meteorological Crews use the Meteorological Data System (MDS), the AN/TMQ-31, to take upper air observations during tactical operations. It is a mobile upper air sounding system on a 5-ton truck and trailer, which sends upper air data to the Field Artillery Tactical Data System for use in adjusting artillery fires, to the USAF Weather Teams, and to the Chemical Officer to support nuclear, biological, and chemical operations. In order to meet mobility requirements, the Army will start to procure the Meteorological Measuring System (MMS), AN/TMQ-38, as a nondevelopmental item in FY 1992 and continue through FY 1995. The MMS will be easily deployable on a small vehicle and reduce manning. As the MDS is replaced by the MMS, the MDS will be refurbished and issued to the Reserve Component. The MMS program is managed by the Program Manager for Electronic Warfare/Reconnaissance, Surveillance, and Target Acquisition (EW/RSTA), Fort Monmouth, NJ. The U.S. Army Field Artillery School (USAFAS), Fort Sill, OK developed the requirement documents for the MMS; and CECOM's Center for EW/RSTA provides technical assistance to the Program Manager.

Intelligence personnel within the Army take limited surface weather observations at the brigade and battalion tactical command post normally at sunrise, noon, and sunset or as scheduled. Present observing equipment, the Belt Weather Kit (BWK), is old and manpower intensive. In the early-to mid-90s, the Army will replace the BWK with the Automated Meteorological Sensor System (AMSS). The AMSS is a light weight, man portable or vehicle mounted system, which automatically collects and transmits surface weather information. These observations are electronically relayed to the G2/S2 and the USAF Weather Team (WETM) to support Intelligence Preparation of the Battlefield (IPB), aviation, NBC, and field artillery operations. The AMSS program, like the artillery MMS program, is managed by the Center for EW/RSTA and is a non-development item.

Army under joint agreement issues the tactical equipment and communications equipment to the USAF Weather Teams (WETMs) at echelons above corp (EAC) and below. Army major commands have purchased off-the-shelf nondevelopmental items to provide interim Army tactical equipment to USAF Weather Teams providing operational support until the Integrated Meteorological System (IMETS) is fielded beginning in the mid-1990's. IMETS is an automated system that receives, integrates, and processes weather data from multiple sources including AMSS and MSS. It provides near real-time weather information and forecasts to other processors for development of tactical decision aids. IMETS is vehicle mounted in standard military shelters. The IMETS program is managed by the Program Executive Officer for Command and Control Systems (PEO, CCS) with CECOM providing technical assistance. The U.S. Army Europe Automated Weather System (UAWS) is a tactical secure radio system to receive and transmit weather information and receive weather satellite imagery. UAWS is mounted in a 5-ton truck with a shelter. FORSCOM has developed a similar radio system, known as GOLDWING. It performs the same functions as UAWS but is light weight and transportable in boxes by two men. The UAWS program is completed, and GOLDWING is undergoing some equipment upgrades.

Headquarters, Department of Army, Office of the Deputy Chief of Staff for Intelligence (ODCSINT) is responsible for the Army umbrella weather support policy encompassing both tactical operations and peacetime training support. Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS) is responsible for validating and establishing the priority of weather support requirements.

## Army Operational Support Provided by the USAF

Under law and through joint agreements, the USAF provides both fixed installation and tactical weather support to the Army. This support includes tactical forecasting, observing and Staff Weather Officer (SWO) advisory services during tactical exercises, contingencies and wartime; and weather support services at fixed Army installations. Although fixed support is primarily for aviation training, it also supports maneuver, fire support and other combat service and combat service support mission areas daily. Another important support area includes weather warning services for Army installations and training areas. Under the joint agreement, the USAF provides the personnel and weather observing equipment for tactical support according to the joint weather support field manual. In return the Army provides the tactical vehicles, equipment, and communications to support the USAF Weather Teams (WETMs) assigned to tactical Army echelons.

## Army Corps of Engineers Civil Operational Activities

The Corps of Engineers operates a network of 1690 land-based limited observing sites, which measure precipitation in the continental United States to provide information for regulating Corps dams and other large water projects. The Corps of Engineers transfers funds to NOAA/National Weather Service to maintain and to collect, manually or automatically, precipitation information. This process makes the data available to DOC/NOAA and other Federal agencies as well as to the Corps of Engineers.

## TRADOC Programs

The Training and Doctrine Command (TRADOC) manages and develops training programs, writes both Army and joint weather support doctrine, establishes the weather requirements documents for Army tactical weather support equipment. The U.S. Army Field Artillery School (USAFAS), Fort Sill, OK, is the proponent for upper air meteorological support. The U.S. Army Intelligence Center, Fort Huachuca, AZ, is the proponent and users representative for the tactical weather support in wartime, contingencies, and peacetime tactical training. The Engineer School, Fort Leonard Wood, MO, coordinates weather support requirements in Terrain Analysis and Topographic Engineering. The Aviation Center, Fort Rucker, AL, and Chemical School, Fort McClellan, AL, and other TRADOC schools coordinate their requirements for weather support through the Combined Arms Center, Deputy Commanding General for Combat Developments, Fort Leavenworth, KS. HQ TRADOC manages TRADOC weather policy.

TRADOC Schools develop the requirements documents for weather equipment, write the concepts and manuals describing the operational doctrine for weather support procedures, write and teach weather training courses for Army personnel, and provide orientation training on Army procedures for the USAF personnel assigned to Army units.

USAFAS and USAICS write concepts to describe new organization, training, equipment, or doctrine needed to enhance the future capabilities of Army weather support and to eliminate known deficiencies. They work as a team with the Communications and Electronics Command (CECOM), the Materiel Developer, to acquire new weather support equipment. The Aviation Center, Chemical School, and Engineer School also incorporate weather support procedures into training programs in their mission areas. The Engineer School develops evaluation procedures considering the effects of weather conditions into terrain analysis, mobility, and counter-mobility doctrine, training, and planning. The Aviation Center has unique operational requirements for weather support at remote training locations that are without direct USAF support. Therefore, it maintains additional Army

observing and communications equipment in conjunction with the USAF weather support at the Army airfield.

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

The U.S. Army Intelligence Center, Fort Huachuca is the functional proponent for tactical Army weather support. It is responsible for writing tactical weather support doctrine, identifying deficiencies and base line weather data requirements, providing weather support training to intelligence and USAF personnel, and establishing requirements documents for weather support equipment, except in the artillery support area. The Intelligence Center has developed a new Army operations familiarization training course for USAF weather personnel to start in FY 1992. The Intelligence Center finalized its analysis of Army tactical weather and environmental data support requirements in 1991; it will serve as a primary document for future requirements in FY 1992 and beyond.

The Combined Arms Command, Deputy Commanding General for Combat Developments (CAC, DCGCD) is the next higher command, which integrates weather support into various branch, school, and functional activities on joint, combined and Army-only levels. DCGCD also exercises oversight to the combat development process as it applies to remedying weather related deficiencies and improving weather support.

Headquarters, TRADOC is the final TRADOC authority for weather support activities before they are submitted to the Department of the Army for approval.

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

### Corps of Engineers (COE)

The Chief of Engineers is responsible for RDTE programs in cold regions, climatic effects on materiel, and for the preparation of regulations prescribing climatic conditions for materiel RDTE. The COE also provides general climatological support for RDTE outside projects relating to electro-optics and obscurants.

The COE Engineer Topographic Laboratories, Fort Belvoir, VA, provides applied climatological support to Army research and development programs and coordinates the development of tactical decision aids (TDAs) that are based on weather and terrain data. The Airland Battlefield Environment (ALBE) TDAs demonstrate the weather and terrain effects on Army operational capabilities and display them in a form that shows the impact on Army war fighting capabilities. The ALBE software will be transitioned to terrain and weather systems such as the Integrated Meteorological System (IMETS), Digital Topographic Support System (DTSS), or Army Tactical Command and Control System (ATCCS).

The Cold Regions Research and Engineering Laboratory (CRREL). Hanover, NH, as part of its overall mission, provides weather support to Army research and development of weapon systems and to other missions in the winter environment. In FY 1992 it will investigate winter environmental conditions and forecasting capabilities relating to weapon system development in the following specific areas:

a. Mesoscale Prediction Data Denied Areas. CRREL will develop data bases for design analysis, demonstrate models that forecast winter conditions, develop test instrumentation to measure snow cover background measurements in conjunction with other investigation of target signatures, and evaluate precipitation forecasts against observed data.

b. Concepts for Spatial Winter Boundary Layer Description. CRREL will describe and model winter conditions, which degrade battlefield weapon systems and airborne operations.

c. Properties of Cold Regions Boundary Layer Constituents. CRREL will study the turbulence processes in cold atmospheric boundary layers, that affect the interaction of chemicals and obscurants with snowcover and affect self-contained munitions using electro-optical technology.

#### Medical Research and Development Command

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

Specific applied research efforts in human 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 temperature, dew point, 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 that envelope in an operational setting. USARIEM uses quantitative assessments of meteorological conditions to develop informational products and strategies to improve soldiers performance.

#### Army Materiel Command (AMC)

AMC is responsible for the design, development, test and evaluation of equipment to satisfy requirements for meteorological support equipment. AMC provides climatological 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 sub-commands and elements listed below, which carry out weather support responsibilities.

Test and Evaluation Command (TECOM). Army Regulation 115-10/Air Force Regulation 105-3 assigns the Army the responsibility for weather support and atmospheric characterization for Army RDTE. TECOM assumed the mission of meteorological operational support to Army RDTE from Laboratory Command (LABCOM) Atmospheric Sciences Laboratory (ASL) in FY 1991 per Defense Review and Memorandum 936. TECOM established the Atmospheric Sciences Division, White Sands Missile Range, NM, to support eleven Meteorological Teams at fourteen test sites including Alaska and Panama. They provide the following support services:

- a. Professional, meteorological consultation.
- b. Test-tailored data collection, analyses and reports (both fixed site and mobility) worldwide.
- c. Meteorological forecasts, advisories, watches and warnings.
- d. Installs, operates and maintains research quality, mesoscale instrumentation and support systems, i.e., NEXRAD doppler weather radars, atmospheric sounding and atmospheric transmissivity measurements systems.

These efforts expend all of TECOM's funding for Meteorological Team (Met Team) support. In FY 1991 the loss of \$3.5 million reduced Met Team manning and procurement supporting these

teams. Additional reduction in funding from \$11 million to \$9 million in FY 1992 will further reduce manning and program funding. In the near-term, supporting meteorological services for Army RDTE will be limited.

Atmospheric Sciences Laboratory (ASL). The Army has responsibility for atmospheric RDTE to support the Army ground combat mission. Future conflict will require a wide variety of forces using high technology weapon and support systems. Favorable battle outcomes will depend on the successful operation of these systems, which all have weather susceptibilities. In particular, stand-off, electro-optically guided munitions, robotic systems and target acquisition and identification sensors are susceptible to environmental conditions. To mitigate or circumvent these effects, ASL seeks continuous improvements in atmospheric research to: (a) optimize the effectiveness of Army operations and systems currently fielded or in development, (b) develop light weight mobile meteorological (met) sensors and processors to support present and future Army commitments, (c) develop and improve techniques for acquiring and processing meteorological data in data sparse regions through space and other technologies, and (d) develop, maintain and calibrate state-of-the-art meteorological equipment and data processing capabilities to support Army research and experimentation.

Four key ASL atmospheric fields of technical endeavor are atmospheric assessment, atmospheric simulation, battlefield weather data acquisition/processing, and mitigation of atmospheric effects. These efforts support basic research goals and three key AMC mission areas: development and acquisition of nonmajor systems and equipment, support to Program Managers, and acquisition of superior technologies. ASL basic research programs address advancing the understanding of the basic principles governing atmospheric behavior, structure, and specific phenomena affecting Army operations and systems.

Significant new starts in FY 1992 focus on new techniques for obtaining profiles of atmospheric wind, temperature and humidity. A Defense Development Sharing Program with Canada is planned for cooperative development of a tactical profiler to support field artillery requirements. New techniques for passive/covert wind sensing for artillery support will be explored along with methods for combining surface-based and satellite-based atmospheric profiles. In a parallel effort, new ballistic meteorology models will be developed supporting extended range munitions along with new ways of integrating target area weather data into enhanced artillery meteorology messages to enhance effectiveness of future smart weapons.

ASL is producing (1) mesoscale models to predict wind, turbulence, temperature, and relative humidity profiles over complex terrain, and (2) transport and diffusion models of atmospheric aerosols, obscurant, NBC agents and gases. These models lead to decision aids which predict the effects of weather elements on systems and operations. In addition, from the integration of available meteorological satellite and terrain data as model input, target area meteorological information for data denied areas will be produced for tactical Army operations. In a supporting effort, advanced processing and dissemination techniques are being configured and tested to produce model output and decision aids to support battlefield automated systems such as the Automated NBC Information System (ANBCIS) and to enhance Intelligence Preparation of the Battlefield (IPB).

An important aspect of ASL investigations involves the complex effects of the atmosphere on the propagation of electromagnetic energy and sound. Of particular interest for modelling are the linear and non-linear interaction effects of natural and battle-induced aerosols on propagation. The atmospheric turbulence effects on image propagation have also been modeled and enhanced with

improvements in Personal Computer power. Increased Army interest in acoustical propagation has triggered ASL investigations of atmospheric ducting and multi-reflective propagation of sound.

As the technology base developer of atmospheric sensors and systems for the Army, ASL is developing innovative sensing techniques for both tactical and research applications. For example, the mobile profiler being jointly developed with Canada will remotely sense atmospheric temperature, winds, and relative humidity using a combination of mobile surface and space-based sensors. An investigation of remote ultraviolet detection techniques through realistic atmospheres is leading to important contributions to the war against drugs and the remote detection of battlefield hazards. The Army's Program Executive Office (PEO) continues to be supported with innovative methodologies and specialized atmospheric sensors to characterize and measure turbulence and aerosol effects on fielded and new developmental systems.

As the DOD leader in boundary layer meteorology, ASL provides user models and computer codes describing realistic battlefield atmospheres and effects on surveillance, target acquisition, and new weapon systems relying on the propagation of electromagnetic and acoustical energy. In addition, realistic atmospheric factors are being incorporated into wargames and simulations to make them more representative of real-world environments. The effects of smoke, obscurant, and turbulence on existing and developing systems are included in ASL's continuing program to provide specialized measurements, propagation and predictions, and atmospheric data for system design, test planning, and environmental research and experimentation.

ASL provides highly specialized support in the form of sophisticated instrumentation for smoke and obscurant testing, atmospheric characterization for electro-optical (EO) systems testing and other unique meteorological measurement capabilities tailored to the needs of the Army RDTE community. This instrumentation includes:

- a. Simultaneous Multispectral Absolute Radiometer Transmissometer (SMART) measures the percentage of relative or absolute transmission of visible and infrared radiation through an environment degraded by obscurant.
- b. Target Contrast Characterizer (TCC). Collects target contrast information such that two distinct contributions to target contrast (inherent and propagated) can be properly modeled with respect to changing atmospheric conditions.
- c. Multispectral Imagery Data Analysis System/Atmospheric Transmittance Large Area System (MIDAS/ATLAS) measures smoke cloud growth and movement and estimates transmittance through smoke clouds by image processing techniques.
- d. Transportable Atmospheric Characterization System (TACS) provides an array of particle spectrometers for deriving aerosol size distributions, scintillometers for optical turbulence, infrared temperature sensors, and path integrated humidity sensors in addition to standard meteorological sensors.
- e. Research Visible and Infrared Transmissometer (REVIRT) measures percent relative transmission of visible and infrared radiation through degraded atmospheres.
- f. Multiple Path Transmissometer/Radiometer (MPTR) measures percent relative transmission of visible and infrared radiation through an environment degraded by smoke, dust, rain, fog, snow, etc.
- g. Mobile Atmospheric Profiling System (MAPS) measures spectral transmittance using high resolution Fourier transform spectrometer techniques.

h. FM-CW Radar Profiler measures vertical profiles of wind speed, wind direction, and small scale turbulence from the surface to an altitude of 2 km.

i. Noise Assessment and Prediction System (NAPS) predicts the propagation of objectionable noise levels for developing noise abatement techniques.

j. Atmospheric Turbulence Measurement and Observation System (ATMOS) measures the transverse coherence length, the isoplanatic angle, and determines the phase structure function for characterizing high energy laser and imaging environments.

k. Fluorescent Target Detection System utilizes UV laser-induced fluorescence to detect ground-based military materials and chemical substances.

Army Research Office (ARO). ARO, Research Triangle Park, NC, manages in cooperation with civilian universities and colleges, Army basic research programs in atmospheric sciences that support mesoscale weather forecasting, electromagnetic propagation in the atmosphere, and boundary layer atmospheric physics. ARO has oversight over the Army Center for Geophysics, Colorado State University, which performs broad-based, basic research in atmospheric sciences.

The basic research program is embodied in two programs in FY 1992: the individual investigator program and the University Research Initiative. Focus is on the processes of the atmospheric boundary layer where the Army operates on horizontal scales of 35 km and less. Objectives of the research are to develop, from first principles, the physical basis for understanding the processes, thereby leading to better understanding of atmospheric effects on soldiers, material, and weapon systems. The research examines turbulent dispersion of battlefield materials and effects of heterogeneous terrain features on air flow. It also explores the development of instruments to remotely sense the fields of wind velocity, temperature, and humidity. The University Research Initiative also includes research in hydrometeorology.

The principal change in the approach in FY 1992 is to decentralize the special program into smaller units, based on a new solicitation.

Communications and Electronics Command (CECOM). The CECOM CEW/RSTA developing three meteorological systems; the Integrated Meteorological System (IMETS), the Meteorological Measuring System (MMS), and the Meteorological Data System improvement program. FY 1992 will be the first year of fully funded IMETS research and development.

Missile Command (MICOM). The MICOM Research Development and Evaluation (RD&E) Center, Chemical and Material Sciences Group, Redstone Arsenal, AL, develops climatological models and reports on atmospheric criteria to support specific missile design efforts. Missile design climatology is used to establish criteria for weapon systems and program development efforts.

## APPENDIX C

### DEPARTMENT OF TRANSPORTATION WEATHER PROGRAMS

#### FEDERAL AVIATION ADMINISTRATION

#### RESPONSIBILITIES FOR AVIATION WEATHER

The Federal Aviation Administration (FAA) is responsible for the safety and separation of aircraft and the efficiency of flight operations. The adequacy of aviation weather information contributes significantly toward fulfilling these responsibilities. FAA makes recommendations to the U.S. Department of Commerce on civil aviation meteorological services, provides specialized equipment at certain airfields, observes and reports the weather at about 360 airports, distributes weather data over civil communications systems, and provides the principal means for disseminating weather advisories and information to pilots.

Weather information for pilots is made available through Flight Service Stations (FSS), recorded messages broadcast over navigational aids, special weather broadcasts, telephone answering systems, and by the Direct User Access Terminal (DUAT) system provided by private vendors. Air Route Traffic Control Centers have weather service units manned by National Weather Service (NWS) meteorologists to assure that vital weather information is available to controllers and pilots.

FAA maintains a continuing research program to improve aviation weather service to the users of the National Airspace System (NAS). FAA also engages in engineering efforts to improve weather observations and communications related to aviation.

The Aviation Weather Program is aimed at progressively improving the timeliness and accuracy of weather information provided to aircrews, dispatchers and the Air Traffic Control (ATC) system to reduce the number of weather related accidents and incidents and to increase both system capacity and fuel savings by reducing weather related delays. Wherever practical, the objectives of this program are accomplished by enhancing existing and planned air traffic control operations and procedures by providing improved aviation weather information services. Facets of the program are conducted in close cooperation with the NWS.

#### PROGRAMS FOR AVIATION WEATHER

##### En Route Weather Radar Program

This program supports the definition, development, and implementation of the Next Generation Weather Radar (NEXRAD) for enroute applications. NEXRAD will provide accurate aviation-oriented products concerning reflectivity, wind velocity, and turbulence indicators.

Improved weather data from NEXRAD provided to ATC through the Real-time Weather Processor (RWP) 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 so that projected maximum fuel savings and manpower productivity gains based on these improvements can be realized.

Implementation costs associated with NEXRAD are being funded jointly by the Department of Commerce, the Department of Defense, and the Federal Aviation Administration. The program is being managed within the Department of Commerce, and is being developed and acquired under the auspices of the NEXRAD Program Council within the Office of the Federal Coordinator.

NEXRAD implementation in the field began in 1990 and is expected to be completed by 1996. The number of NEXRAD units to be acquired is being determined by the participating agencies. FAA is emphasizing the development of algorithms that take advantage of the improved detection of precipitation, wind velocity, and turbulence, and provide new or improved aviation-oriented products.

To improve hazardous weather detection, reduce flight delays, and improve flight planning services, the joint NEXRAD program provides several aviation weather products related to wind, wind shear, turbulence, thunderstorm detection, storm movement prediction, precipitation, hail, frontal activity, and mesocyclones-tornadoes. In FY 1992, research activity will concentrate on the development of icing, wind shear, and other aviation-related algorithms.

#### Terminal Doppler Weather Radar (TDWR)

This 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 wind shear at selected high activity airports. In addition, it will have the capability to identify areas of precipitation, turbulence, thunderstorm location, and storm movement. TDWR's will be integrated with the existing Low Level Wind Shear Alert System (LLWAS) at many airports.

Microbursts are weather phenomenon that consist of an intense down draft with strong surface outflows. They are particularly dangerous to aircraft that are landing or departing. The TDWR scanning strategy will be optimized for microburst/wind shear detection. The radar will be located on or near the airport operating areas.

Algorithms for the automatic detection of microbursts, wind shear, and gust fronts are further being refined and tested by the FAA. Data collected with FAA's transportable Doppler weather radar facility (at Memphis, TN; Huntsville, AL; Denver, CO; Kansas City, MO, and Orlando, FL) provided the primary basis for development and validation of the algorithms. This facility was used to evaluate the operational aspects of TDWR and will continue to support the enhancement and development of wind shear algorithms at Orlando and Denver.

A contract was awarded in November 1988 for 47 turnkey TDWR installations at sites specified by FAA, of which 45 are operational units and 2 are support units for training and testing. Field implementation will occur in the 1992 to 1994 time frame. The alphanumeric display and the situation displays will be located in the tower cab and the TRACON. The displays have been tested operationally in 1988, 1989, 1990, and 1991 at Denver, Stapleton, Kansas City International Airports and Orlando. In 1992, the production displays will be utilized and further testing will be conducted at Orlando.

In FY 1992, a TDWR software upgrade package will be implemented. This package will integrate TDWR and LLWAS, and will provide microburst and storm movement prediction capability.

#### Other Weather Radar Programs

The present Air Route Surveillance Radars provides weather data for the Air Route Traffic Control Centers (ARTCC) out to 200 nautical miles. A new Air Route Surveillance Radars (ARSR-4) will provide the ARTCC's with accurate multiple weather levels out to 250 nautical miles. This will be the first en route radar with the ability to accurately report targets in weather. The ARSR-4 will be used to provide weather information until NEXRAD is operational in the Rocky

Mountain area. Even after NEXRAD is in place, ARSR-4 will provide supplemental weather information for areas NEXRAD does not cover.

The ARSR-4 is a joint Federal Aviation Administration/United States Air Force (FAA/USAF) funded project. Forty joint FAA/USAF radar sites will receive the new ARSR-4 radar during the 1992-1994 period.

#### Airport Surveillance Radar-9 (ASR-9) Weather Modular Enhancement

The Weather Modular Enhancement will be an add-on modification to the existing ASR-9 radars and will provide air traffic controllers information on low level wind shear associated with microbursts in the vicinity of the ASR-9 radars. Presently, the ASR-9 weather data that are available consist of the six levels as defined by the National Weather Service. In addition, the feasibility of gust front detection is being investigated.

#### New Generation Runway Visual Range (RVR)

The runway visual range 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. New generation RVRs will be procured for all new qualifying locations and will replace many existing RVRs in the NAS inventory.

The RVR provides for near real-time measurement of visibility condition 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, using forward scatter meters replacing the transmissometers currently in use; a runway light intensity monitor of both runway edge and center line lights; and an ambient light sensor controlling computer calculations using a day or night algorithm. The data processing unit calculates RVR products and distributes the products to controllers and other users.

#### Low Level Wind Shear Alert System (LLWAS)

LLWAS provides pilots with information on hazardous wind conditions that create unsafe conditions for aircraft landings or departures. The majority of the systems have been installed and are operational. The final few systems will be installed by 1991 resulting in a total of 110 airports which will 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 wind shear conditions to air traffic controllers for relay to pilots.

Both near and long-term modifications of LLWAS will lead to the implementation of the enhanced LLWAS. Near-term modifications consist of improving the algorithms associated with the basic system, correcting sensor siting (including height), incorporating data recorders, and updating the computers. Field implementation of these modifications will be completed in FY 1991.

The next improvement phase referred to as LLWAS-EN (Expanded Network) will include expanding the network of sensors, developing improved algorithms for the expanded network, and installing new information/alert displays which enable controllers to provide pilots with head wind gain or loss estimates for specific runways. These improvements will increase the system's wind shear detection capability and reduce false alarms. Improvements are also expected to reduce maintenance

costs. Initially, 17 airports were identified to receive LLWAS-EN. Budgetary constraints required the FAA to scale the selection back to include only the 7 most critical airports. Funding for LLWAS-EN is programmed to begin in 1992. LLWAS-EN is scheduled to replace all the existing LLWAS's by 1998.

In the future, LLWAS-EN and TDWR may work in conjunction providing a synchronous alarm of wind shear to the air traffic. Studies are being conducted on how these systems can be integrated into a single wind shear display for the air traffic controller. Development of a system is underway that will integrate the information from these two systems into a single wind shear display for the air traffic controller. Investigation is also underway on how integrated wind shear 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 wind shear detection out to three miles from the touchdown zone.

#### Automated Surface Weather Observing Program

The FAA is acquiring automated surface weather observing systems; acquiring related data acquisition systems; and development, test, and evaluation of weather sensors in cooperation with the National Weather Service.

AWOS/ASOS Acquisition. Automated surface weather observations will provide aviation-critical weather data (e.g., wind velocity, temperature, dew point, barometric pressure, cloud height, visibility, precipitation type, occurrence and accumulation) through the use of automated sensors. It will process these data, and allow dissemination of output information to a variety of users, including pilots via computer-generated voice.

The FAA has a need to deploy as soon as possible Automated Weather Observing Systems (AWOS) at 200 airports to provide the basic aviation weather products directly to pilots approaching the airport. The majority of these systems would be 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 currently do not have local weather reporting capability. Some of these systems will be used to support an air traffic operational evaluation at former flight service locations that currently employ contract weather observers. 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. A contract has been awarded by the FAA to acquire 200 of these systems.

The FAA has negotiated with NOAA to procure, install, operate, and maintain Automated Surface Observing Systems (ASOS) systems at the remaining airports where the FAA provides observations and at additional non-towered airports without current weather reporting capabilities. A production contract was awarded in February 1991. The FAA will be sponsoring, as part of a reimbursable agreement with NOAA, at least 537 systems with an option for 204 additional systems.

Automated Weather Observing Systems (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 necessary of the system. 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 readings. The AWOS I system contains sensors to measure wind speed and direction, ambient and dew point temperature, altimeter setting, and density altitude. The AWOS II contains the AWOS I sensors plus a visibility sensor, and an AWOS III adds a cloud height sensor to an AWOS II. An AWOS IV will include AWOS III plus the option for precipitation identification, thunderstorms and/or runway surface condition. Most important, 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 (or other user) to call the AWOS on a telephone and obtain the current weather observation during his preflight activities. In addition, the observation may be transmitted to the data bank within the national weather network.

AWOS/ASOS Data Acquisition System (ADAS). ADAS will function primarily as a message concentrator collecting weather messages from AWOS and ASOS automated surface observation equipment located at controlled and non-controlled airports within each air traffic control center's area of responsibility. ADAS will distribute minute-by-minute AWOS/ASOS data to RWP, and within the center in which it is installed. It will also distribute AWOS data to the National Airspace Data Interchange Network (NADIN) which will forward the data to WMSCR for further distribution. This will make weather observation data available to pilots and air traffic controllers on a timely basis within the "local" area, and provide necessary distribution of the data to NWS, and other users. Field implementation of ADAS is planned to start in 1991 and be completed in 1993.

Weather Sensor Development, Test and Evaluation. This activity (1) evaluates new systems and techniques for the measurement of surface weather parameters, (2) tests the capabilities of improved weather sensors, and (3) supports research studies on weather conditions that are hazardous to flight operations.

Because of the importance of reliable, complete and timely surface observations for aviation safety, and the need to reduce the cost of obtaining these observations, the FAA supports advanced weather sensor development activities. The work is conducted primarily by the NWS and the National Oceanic and Atmospheric Administration's (NOAA) Environmental Research Laboratory. Technologies being investigated include sensors for: (1) improved visibility detection; 2) current type and amount of precipitation; 3) lightning detection systems; 4) runway surface conditions; and 5) sensors which can detect freezing rain.

#### Flight Service Station Automation System (FSSAS)

This program will improve user access to weather and Notice to Airmen (NOTAM) information, simplify flight plan filing, and provide a flight service station automation system that will meet the projected increases in demand for flight services without proportional increases in staff. Automation is being implemented in two stages: 1) FSSAS Model 1 (limited automation), and 2) Model 1 Full Capacity (full automation).

The first Model 1 system was commissioned in 1986. As of December 1988, there were 39 Automated Flight Service Stations (AFSS) and 13 Flight Service Data Processing Systems (FSDPS's) operating with Model 1. In addition to the 39 Model 1 AFSS's, there are seven AFSS's operating with the American Satellite Leased Service A & B System (LABS). Fifteen more AFSS's will be

commissioned by 1993 for a total of 61 AFSS's. All of these facilities will be converted to Model 1 Full Capacity (MIFC). The first field MIFC hardware was delivered March 1990 and the software is still under test and development. MIFC will provide sufficient hardware and software to drive all of the terminals in the 61 AFSS's.

The Direct Users Access Terminal (DUAT) system has been operational since February 1990. Pilot users are able to access Weather and NOTAMs and file their IFR and/or VFR flight plans from their home or office personal computer through DUATS.

Graphics Weather Displays Systems (GWDS) in the APSS's consists of a variety of different systems. FAA intends to provide a Standard National GWDS to replace the interim systems now in use.

#### Weather Message Switching Center Replacement (WMSCR)

WMSCR replaces the weather message switching center (WMSC) located at FAA's National Communications Center (NATCOM), Kansas City, MO, 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 Notices to Airmen (NOTAM). It will rely on FAA's National Airspace Data Interchange Network (NADIN) for a majority of its communications support. The system will accommodate graphic data and function as the primary FAA gateway to the National Meteorological Center (NMC) and, therefore, will be the principle source of NWS products for the National Airspace System (NAS).

To provide for geographic redundancy, the system will have nodes in the NADIN buildings in Atlanta, GA, and Salt Lake City, UT. Each node will support approximately one-half of the United States and continuously exchange information with the other to ensure that both have identical national data bases. In the event of a nodal failure, the surviving one will assume responsibility for the entire network. The implementation of WMSCR will allow the closing of NATCOM. The system is expected to be operational by 1992.

#### Aeronautical Data Link Program (ADLP)

The 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 system. It will receive down link requests for weather products from aircraft, formulate replies and return them to the pilot via the data link. This will improve air-ground communications 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 such access.

Initially, the data link services to be implemented will be those for which automated data bases currently exist, or are planned to be operational in the near term. These include alphanumeric products such as SIGMET, AIRMET, surface observations, terminal forecasts, winds aloft, pilot reports and alphanumeric radar summary information. Installation of this system is scheduled to begin in 1991 and is continuing as programmed. The ADLP will be enhanced in 1995 to support additional weather and ATC tower applications and to provide expanded data link communications functions in support of ATC data link services.

### National Airspace Data Interchange Network (NADIN)

The NADIN II Packet Switched Network is being 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 in order to provide extremely high data flow capacity and efficiency to the network users. NADIN II will consist 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 and Atlanta. It will interface directly to such systems as the Weather Message Switching Center Replacement (WMSCR), Real-Time Weather Processor (RWP), Meteorological Weather Processor (MWP), Aeronautical Data Link Processor (ADLP), AWOS/ASOS Data Acquisition System (ADAS), Traffic Management System (TMS), Consolidated NOTAM System (CNS), and Area Control Computer Complex (ACCC), and may be used as the intrafacility communications system between these (collocated) users during transition to end-state.

### Central Weather Processor (CWP)

CWP will improve the dissemination of weather information throughout the National Airspace System (NAS), to pilots, air traffic controllers, flight service specialists, traffic management specialists, and NWS meteorologists assigned to weather service units in the air traffic control centers and the central flow control facility. It will provide 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. CWP will also provide for a near-real-time, area mosaic of weather radars (NEXRAD) for subsequent distribution to controller displays. These improvements are necessary to help reduce the high percentage of accidents and delays directly related to weather.

The CWP is composed of two elements. The first is a commercially-available Meteorological Weather Processor (MWP) which will be procured through a series of 5-year leases. This will provide current meteorological data for the preparation of short-term aviation forecasts and severe weather advisories by the NWS meteorologists assigned to the FAA centers. The second element is a Real-time Weather Processor (RWP) which will automatically create unique NEXRAD-based mosaic products. The RWP will send these products, along with other time-critical weather information to controllers through the Advanced Automation System (AAS) and to pilots via the enhanced Weather Communications Processor and Mode S data link.

The deployment of MWP will be completed in 1991. The MWP leased in the second 5-year period will interface with the RWP which should become operational in 1995. The MWP will also interface 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 AWIPS-90 (Advanced Weather Interactive Processing System) sponsored by the National Weather Service.

Requirements for the CWP and other agencies' automated weather information systems are being integrated by the Committee for Automated Weather Information Systems (CAWIS) working under the auspices of the AWIS Program Council. The intent of this activity is to avoid unnecessary duplication of development effort and to assure the sharing of information and products in the operational phase.

### Weather Processing

The Working Group for Automated Weather Information Systems (WG/AWIS), under the direction of the Program Council within the Office of the Federal Coordinator, developed a National Plan which integrates requirements, development and implementation activities associated with AWIS programs and projects of the Departments of Commerce, Defense, and Transportation. Under this plan, the departments are cooperating in the review, clarification, and allocation of requirements to the various specialized elements of the planned National AWIS. New interface requirements are being defined and plans for product sharing are being developed. In addition, new interfaces with elements of the NAS will be developed to support the CWP weather information dissemination function. Included is an interface with the DLP to provide NEXRAD mosaics for communication to the pilot and receive Pilot Weather Reports from aircraft in flight.

This project translates these new interface requirements into verified interface designs and product specifications which, when they are approved for implementation, will be included in the CWP program.

### Centralized Weather Information Processing

This project will develop an integrated weather data base for generating route-oriented, alphanumeric, and graphic products that are consistent and machine readable. Activities include the identification of weather-information sources appropriate for a centralized data base, development of a suitable structure for this data base, specification of machine-readable output products, and development of a rigorous set of algorithms for the generation of these products.

### Airborne Wind Shear Detection and Avoidance

This project will develop requirements for airborne wind shear devices that provide the flight crew with the ability to reliably detect hazardous wind shear along the intended flight path, with sufficient time to avoid it.

In 1987, the FAA and NASA entered into a Memorandum of Agreement through which NASA will provide unique national resources for the study, analysis and verification of requirements for "forward-looking" sensors such as Doppler radar and Doppler lidar. These resources include NASA's Aircraft Landing Dynamics Facility to evaluate the full-scale effects of heavy rain, aircraft simulation capabilities, the ability to perform four-dimensional microscale atmospheric modeling, and instrumented flight-test facilities. The two agencies will develop the functional and performance requirements for airborne wind shear detection and avoidance, and will transfer the results of this effort to manufacturers to accelerate their development and certification programs.

In FY 1989, the effort focused on full-scale simulation tests of candidate system configurations of sensors, flight controls and cockpit displays. FY 1990 was the first opportunity to perform flight tests of candidate airborne wind shear detection and avoidance concepts based upon the previous year's analysis and experiments.

It is projected that in FY 1991 airborne remote detection technology and onboard processing of ground-based data will be developed, evaluated and flight tested.

### Improved Aircraft Icing Forecasts

This initiative is to establish a comprehensive multi-year 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 the Federal Coordinator for Meteorological Services and Supporting Research by the Department of Transportation, Department of Defense, Department of Commerce, National Aeronautics and Space Administration, and the National Science Foundation to provide the National Weather Service with an improved aircraft icing forecast capability. The objectives of this program for FY 1991 are to develop an icing severity index, develop icing guidance models, and to develop a better comprehension of synoptic and mesoscale conditions leading to icing. The end result of this effort will be improved icing forecasting capability, to be operational in 1996. Pilots will be provided with more timely and accurate forecasts of actual and expected icing areas by location, altitude, duration, and potential severity.

## UNITED STATES COAST GUARD

Among the U.S. Coast Guard's activities is the collection and dissemination of meteorological information for the benefit of the marine community. In pursuit of this aim, the Coast Guard provides use of information and facilities to the National Oceanic and Atmospheric Administration (NOAA), specifically the National Weather Service (NWS) and the National Data Buoy Center (NDBC).

Coast Guard seagoing cutters submit weather observations to the National Weather Service and the U.S. Navy. Certain coastal stations submit weather observations to the National Weather Service. Additionally, NWS sensors on Coast Guard Large Navigational Buoys automatically transmit data to NWS centers. These data are utilized by the NWS in formulating its forecast products. NWS weather forecasts are disseminated in part by the Coast Guard through radio broadcasts to commercial and private vessels. Certain shore stations maintain visual displays authorized by the NWS to provide weather warnings to boaters.

In 1989 the International Ice Patrol, a Coast Guard unit, began air-deploying satellite-tracked drifting buoys equipped with barometric sensors in the northwest Atlantic. These data are available to all users through GTS.

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

The Coast Guard supplies a staff of up to 15 personnel to the NDBC (costs reimbursed by NOAA at its facility in Mississippi) to provide technical expertise in the operation and management of the project. In addition, the Coast Guard makes available vessel, shore and aircraft support for stationing, monitoring and maintaining buoys.

Meteorological activities are coordinated by the Ice Operations Division of the Office of Navigation Safety and Waterway Services at Coast Guard Headquarters. The Coast Guard NDBC operation is managed at the Coast Guard Headquarters by the Short Range Aids to Navigation Division of the Office of Navigation Safety and Waterway Services. Field management of meteorological activities is a collateral function of the Coast Guard 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.

## FEDERAL HIGHWAY ADMINISTRATION

In the 1987 Highway Act, Congress authorized the expenditure of \$150 million for the Strategic Highway Research Program (SHRP). SHRP is administered by the National Research Council through an agreement with the American Association of State Highway and Transportation Officials and the Federal Highway Administration.

SHRP is conducting research over five years in four specific areas: asphalt, concrete and structures, long-term pavement performance, and highway operations. In highway operations, research is concentrated primarily in improving maintenance cost-effectiveness and snow-and-ice control. Research is being conducted to investigate technologies to help reduce costs in snow-and-ice control through more efficient and timely assignments and uses of resources. One objective is to reduce the time delay between input of pavement condition data and output of the local weather forecast. This will produce a more timely and accurate road weather forecast, yielding a large cost savings. SHRP is also investigating the applicability of pavement sensors and micrometeorological stations for providing real-time information on pavement condition.

## 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 certain grains has exceeded production the last three 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 the weather information and in disseminating such information to them.

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

Historically, the Forest Service (FS) has collected meteorological data to assist in the control of forest fires and the management of smoke from prescribed burning. However, other FS 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: improve quality control of weather data, improve the design and operation of data collection networks, increase data recovery from the weather stations, and upgrade station maintenance. Meteorological data collected by 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 the Regional Climate Centers of the National Climate Program. The Forest Service monitoring network will provide essential data for use in Global Change work.

The Forest Service currently operates more than 300 remote automatic weather stations (RAWS), mostly in the western United States. Air temperature, relative humidity, soil moisture, wind direction, speed, and precipitation are transmitted via GOES telemetry. These data are received via a direct readout ground site in Boise, ID, operated by the Bureau of Land Management. The main use of the data is in the calculation of the fire danger rating for the Forest Service 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, ecologists, and soil specialists and fisheries biologists monitoring the effects of runoff. The main secondary user of these RAWS data is NOAA National Weather Service for fire weather forecasting and flood warnings.

The Soil Conservation Service (SCS) operates a network of 1400 manual snow courses and over 550 automated data collection sites in conjunction with a snow telemetry project (SNOTEL) for the western United States and Alaska. The primary objective of the project is to forecast streamflow for the coming spring runoff 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 United States 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, SCS implemented a new 5-year initiative to upgrade 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 gages, antennas, towers, solar panels, batteries 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 an abundance of high-quality commodities and products while minimizing any adverse effects of agriculture in the environment.

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 atmospheric production and the environment.

The Cooperative State Research Service (CSRS) coordinates research programs in the state agricultural experiment stations, the 1890 Land Grant Distributions, and cooperating forestry schools. These institutions conduct a wide variety for 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 are therefore the focal point of much of this research. Work begun in FY 1990 to evaluate plant response to changes in levels of ultraviolet radiation as part of the Global Change research program will be significantly expanded through the CSRS competitive grants program in FY 1991. The work is coordinated with EPA's ultraviolet radiation program and will support assessment efforts to develop related national policy on environment.

Forest Service research includes efforts to: understand and control forest fire initiation by lightning; improve the translation of mid-range forecast elements to describe forestry conditions, incorporate drought information into fine management decision-making and 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 Global Change research work.

Investigations by the National Agricultural Statistics Service (NASS) support domestic crop estimating programs for major commodities. Promising studies are underway to develop models relating weather parameters and associated variables to corn ear weight and wheat head weight. Results from previous efforts to develop models for short term forecasting have also 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.

The NASS program to explore the use of satellite and weather data for assessing crop conditions is continuing. A preliminary investigation of polar orbiting meteorological satellite data showed a good relationship between crop condition 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.

## DEPARTMENT OF THE INTERIOR

Specific financial data for the Department of the Interior's (DOI) Atmospheric Science Research Programs are reported through the Subcommittee for Atmospheric Research; however, operational program budgets are reported in this Plan. The narrative below describes the full range of meteorological activity in the Interior Department.

The Bureau of Reclamation activities including water scheduling, flood hydrology, irrigation project management, and reservoir operations, as well as projects related to the development of wind and solar energy resources, require the collection and use of meteorological data. Currently, Reclamation operates approximately 400 hydrometeorological data collection platforms (DCPs) and collects near real-time data through a NOAA Geostationary Operational Environmental Satellite (GOES) Direct Readout Ground Stations (DRGS) in Boise, ID. Multi-agency work is also proceeding in projecting potential effects of climate change on western water resources and Bureau operations. Bureau of Reclamation's weather modification research program has not been funded since FY 1989 except for reimbursable work.

The Geological Survey's Water Resources Division collects precipitation, stream flow, and other climatological data for a number of projects concerning rainfall/runoff and hydrologic processes. Currently, the Geological Survey collects hydrometeorological data from approximately 1,800 GOES DCPs through seven DRGS. In January 1991, the Survey's Colorado Office installed the first direct readout terminal (DROT) to receive domestic satellite (DOMSAT) retransmission of all data collected on NOAA's GOES data collection system. This prototype system is being developed into a much more efficient and economical data source as compared with conventional DRGS receivers. Precipitation and dryfall atmospheric deposition samples are collected 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 desposition on water quality and the aquatic environment.

The Geological Survey is continuing a joint research program with NASA to map snowpack water equivalent using satellite passive microwave techniques. Comparison of data collected by the Department of Agriculture's Soil Conservation Service Snow Telemetry (SNOTEL) sites, by Survey field teams, and through instrumentation by other agencies is being made to test the feasibility of making near real-time assessments of snowpack from space. The Survey also carries out research in past climate change, regional hydrology, the carbon cycle, coastal erosion, volcanic activity, and glaciology.

The Bureau of Land Management's (BLM) Initial Attack Management System (IAMS) provides real-time data access and modeling for the fire management organization. The system enables rapid evaluation, assessment, and decision making capabilities for the BLM's wildfire responsibilities. The principal inputs are Remote Automatic Weather Station (RAWS) meteorological data, Automatic Lightning Detection System (ALDS) information, vegetation, slope, elevation, and terrain data. These real-time data sources are coupled to advanced fire modeling capabilities to facilitate the BLM's fire and resource management objectives.

The BLM's RAWS Program collects meteorological data from a network of stations located throughout the eleven western states and Alaska. This network is comprised of three classes of systems placed at strategic remote locations. All data are recovered via the GOES system by the BLM's DRGS located at the Boise Interagency Fire Center (BIFC) in Boise, Idaho. The Bureau presently owns 339 systems with 191 of these being fielded and another 20 scheduled for purchase in FY 1991. The network is planned to ultimately reach 359 fielded systems. Completion of the

network as planned is based on acquiring the personnel to implement and maintain the total number of planned systems.

The BLM's RAWs Support Facility at BIFC provides a full range of management, maintenance, data, and support services for the BLM and numerous other Government agencies. This work is performed under long-term interagency agreements with those agencies having similar equipment and requirements.

The BLM's ALDS covers the eleven western states and Alaska. The western U.S. ALDS is comprised of 36 direction finders (DF) providing high detection efficiency coverage of cloud-to-ground activity for 95 percent of the western United States. The system provides data via a satellite telecommunications system for the BLM's IAMS. Data are also supplied to the National Weather Service, State University of New York (SUNY), New Mexico Institute of Mining and Technology, and several Department of Defense installations. The Alaska ALDS is comprised of nine DFs providing the required coverage for Alaska Fire Service's needs.

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 FY 1991, the BLM Global Change Research Program will establish 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.

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

The National Park Service monitors air quality in several national parks and monuments. Approximately 20 GOES DCPs are used to collect these data. The Service has contracted research to develop and test models to assess long-range transport of anthropogenic pollutants including sulfur dioxide and sulfur deposition.

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 Boise Interagency Fire Center.

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

### Operations

The National Aeronautics and Space Administration (NASA) Headquarters Weather Support Office, through its Weather Working Group, has continued to improve NASA's weather support capabilities for both manned and unmanned launch vehicles. Improved weather information begins with improved observing systems and includes better communications, integrated data management systems and displays, an automated network of observing stations/systems, and improved forecasting techniques and methods.

NASA has upgraded weather observing capabilities at the shuttle landing and alternate landing sites as well as Kennedy Space Center (KSC) launch sites. The elements comprising the operations program are intended to provide the specialized meteorological data that are required for the support of both manned and unmanned launch vehicles.

The Doppler Radar Vertical Wind Profiler installed at the Kennedy Space Center to monitor the variation of wind aloft is being evaluated. This involves the releases of Jimspheres and Windsondes at selected times each week for a one year period. The NOAA Lidar will be used in the evaluation in mid-1991 at Kennedy Space Center.

NASA has upgraded a network of lightning sensors to monitor and aid in predicting the occurrence of lightning in the Kennedy Space Center area. NASA is in the process of building ground-based field mills to continue the upgrading of the lightning prediction system.

NASA is in the process of installing a Meteorological Interactive Data Display System (MIDDS) that facilitates the transfer of meteorological data, reduces the time required to evaluate weather situations, and increases the forecaster's confidence in their recommendations for launches, landings, and operations of both manned and unmanned space vehicles at the Huntsville Operations Support Center (HOSC), Marshall Space Flight Center. The newest system allows remote and local access to a wide range of data from satellites and conventional observations, time lapse displays of imagery data, overlaid graphics, current and past meteorological data, etc. This technology also provides for operational redundancy and increases safety.

None of these improvements are intended to depart from NASA's operational principles. These improvements are designed to strengthen this approach and enhance information available to the launch/operations control decision makers, astronaut observers, and management team for space vehicle launches, flight, and landings.

### Supporting Research

The NASA Atmospheric Sciences Research Program conducts research using space technology to improve our understanding of atmospheric behavior on scales ranging from the mesoscale to the planetary scale and from periods of hours to decades. NASA's role in this endeavor is based upon the unique perspective of the Earth's atmosphere and surface provided by space platforms. Satellite sensors can and do provide not only global coverage, but obtain repetitive observations of limited areas more cost-effectively than by other means. Space observations can and do provide information essential to advancing our knowledge of atmospheric processes.

The NASA program includes the following major components:

- ▶ Development of space-borne observing systems and supporting ground-based systems to observe the state of the atmosphere, and important atmospheric and surface parameters such as temperature, moisture, winds, albedo, clouds, etc.
- ▶ Development of algorithms and inversion techniques to derive useful atmospheric parameters from remote observations.
- ▶ Development of data processing and data assimilation techniques to address the problems peculiar to the use of satellite data in atmospheric analyses and modeling.
- ▶ Analysis of satellite data to improve our understanding of atmospheric processes on temporal and spatial scales consistent with satellite observing capabilities.
- ▶ Development of models to exploit the spatial densities and temporal frequencies inherent in satellite data to initialize and verify models and assess their predictive value.
- ▶ Development of parameterization schemes which permit the representation of space observations of sub-grid scale phenomena in atmospheric models.
- ▶ Assessment of the performance of satellite sensors through numerical simulation experiments which compare model output with and without satellite sensor data.

NASA continues to support research and development activities to improve our remote sensing capabilities for possible future deployment on satellites. Studies involve remote sensing of atmospheric temperature, pressure, moisture, and winds using passive and active techniques. Successful flights of remote sensing instruments on several aircraft have been made using sensors to study the dynamics and radiative properties of cloud tops, and the fluxes of heat, moisture, and momentum between land and ocean surfaces and the atmosphere.

In studying atmospheric phenomena, NASA uses geosynchronous satellite data (especially, NASA-developed temperature soundings), aircraft instrumentation (e.g., Doppler lidar wind measurements), and ground-based techniques, in addition to conventional observations, to obtain data that will improve our understanding of the processes involved in the generation, propagation, and decay of weather phenomena over various temporal and spatial scales. Models have been developed to use the quantitative information provided by these remote sensors.

NASA's scatterometer (NSCAT), which continues in development, will measure surface wind velocity over the oceans with high accuracy. This instrument has been proposed as a candidate for launch aboard Japan's Advanced Earth Observing System (ADEOS) satellite in 1994.

NASA has completed instrument concept, design, and cost reviews, and has made its final selection of instruments for the first EOS platform. Launch of the first NASA polar platform is planned for late 1997 or early 1998. This will be followed by a European platform, a Japanese platform, a second NASA platform and a second European platform. The plan is to continue the observations for approximately 15 years to acquire data sets sufficient to serve as the basis for analysis and scientific studies. EOS does represent the most significant and unifying approach ever taken to understand the Earth's sciences as a single system.

The Upper Atmosphere Research Satellite (UARS) development is near completion. The UARS will address the coupling of chemical, radiative, and dynamic processes in the stratosphere and mesosphere. The launch is scheduled for October 1991.

## ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) is responsible for working with state, local, and other Federal Government agencies to ensure adequate air quality meteorological programs to support regulatory applications. Applied research and meteorological support is provided by EPA's Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC. Meteorological support to the EPA Office of Air and Radiation, the EPA Regional Offices, and to state and local agencies includes: review of the meteorological aspects of environmental impact statements, state implementation plans, and variance requests; development and application of air quality dispersion models for pollution control and exposure assessment strategies; and preparation of dispersion studies and model evaluations. Meteorological expertise and guidance is also provided for the air quality standard, modeling guideline, and policy development activities of the EPA.

In the light of recent changes to the Clean Air Act, air quality models and the manner in which they are used are expected to evolve considerably over the next five years. In the area of acid deposition, the evaluation of nitrogen and oxidant chemistry in addition to the sulfur chemistry will be completed within the framework of meteorological dispersion model formulations. Further development and evaluation of existing air quality models will take place to permit the inter-pollutant effects resulting from the variety of control programs that are now or will be in place. These inter-pollutant effects include trade-offs between oxidant, ozone, sulfur oxides, nitrogen oxides, and volatile organic compound controls as well as developing predictable methods of forecasting impacts on visibility and acid aerosol effects.

With respect to inhalable particulate model development, dispersion grid models will be enhanced to accurately predict aerosol growth from precursors over regional transport distances. To assist in the evaluation of the contribution of various sources to regional air quality, inert tracer and tagged species numerical models will be developed. These models would introduce separate calculations for inert or reactive chemical species emitted from a particular source or region. The calculations would 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 role of biogenic volatile organic compounds must be elucidated along with the development of a better understanding of the fundamental aspects of the ozone nonattainment problem such as multi-day transport.

Atmospheric research in the areas of climate and climate change include the chemistry of the global troposphere that affects the distribution and fate of reactive green house gases, and regional climate studies addressing the interaction of climate with the biosphere. The climatology program involves both analytical and statistical climatology as well as regional scale climate model development. Climate change issues and their feedbacks with the biosphere will be stressed.

In addition to these three 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, mesoscale, and regional. Other efforts include the construction and application of air pollution climatologies; determination and description of pollutant effects on atmospheric parameters; and determination of meteorological effects on air quality. Measurement data obtained during field programs and from wind tunnel and water channel/towing tank experiments will be used to continue development and evaluation of these models in the FY 1991-92 period.

## DEPARTMENT OF STATE

The Department of State is assuming a much more active role in international climate/meteorological policy making as a result of growing public concern with possible substantial warming of the global atmosphere due to the "greenhouse gas effect." The Assistant Secretary of State for Oceans, International Environmental and Scientific Affairs, chairs the U.S. Delegation to the Intergovernmental Panel on Climate Change (IPCC) which held its first meeting at Geneva in November 1988. The purpose of the IPCC is to serve as a government forum to call for scientific examination and assessment of future global climate change due to atmospheric warming from the greenhouse effect. It is anticipated that the IPCC will draw upon scientific assessment support from the World Meteorological Organization (WMO), the United Nations Environmental Program (UNEP), the International Council of Scientific Unions (ICSU) and their various international climate assessment programs.

The Department of State is also active on the Committee on Earth and Environmental Sciences (CEES) of the Federal Coordinating Committee on Science, Engineering and Technology (FCCSET). The CEES was established in 1987 by the President's Science Advisor to coordinate all domestic programs dealing with global change, including global climate change assessments. The CEES is the chief Federal interface with the National Research Council's global change program which is a part of the ICSU's emerging International Geosphere/ Biosphere Program (IGBP) which is charged with assessing and analyzing Earth systems science and changes in the Earth systems as a whole. Through the CEES, the State Department is able to help shape and define U.S. international science policies regarding global change, including global climate change.

These new responsibilities are in addition to, but do not replace, traditional Department responsibilities set forth in earlier annual Federal Plans, i.e., international aspects of global food policies, disaster warnings and assistance, WMO activities, international meteorological programs, and concern with some programs which start as operating programs but develop international interest and concern such as the possibility of seeding Pacific storms.

Finally, the Department is monitoring and implementing international actions to enforce the provisions of the 1985 Vienna Convention on the Preservation of the Ozone and the subsequent Montreal Convention Protocols on enforcement of chloroflourocarbon (CFC) reduction.

All of the above activities -- especially IPCC, IGBP and CEES responsibilities, and the ozone monitoring and implementation actions will be continued for many years.

## NUCLEAR REGULATORY COMMISSION

The 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 nuclear facilities require identification of meteorological 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, the Offices of Nuclear Reactor Regulation and Nuclear Material Safety and Safeguards review facility siting, design, construction, and operation. These reviews include consideration of meteorological factors. The Office for Analysis and Evaluation of Operational Data and the Regional Offices assure that commitments by NRC applicants, permittees and licensees are carried out, and conduct NRC responses to nuclear facility emergencies. The Office of Nuclear Regulatory Research develops regulations, guides, criteria, and other standards relating to the protection of public health and safety and the environment in the licensing 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.

There are several meteorological areas in which the NRC will have an interest during FY 1992 and beyond. Paleoclimatic reconstruction and climatic change models for high-level radioactive waste repositories will continue to be evaluated. Improvements in the meteorological capabilities of the NRC and the operators of nuclear facilities to cope with emergencies involving unplanned releases of radioactive material are expected to continue. The NRC is also concerned with the dispersion of hazardous non-radioactive materials and their potential effects on the safe operation of nuclear facilities.

## DEPARTMENT OF ENERGY

The Department of Energy (DOE) supports meteorological services at nine of its laboratories and at the Nevada Test Site. Services include climatological summaries, general weather forecasts, and items specifically in support of laboratory operations such as environmental monitoring, atmospheric sciences research, and hazardous material release assessments. The National Weather Service Nuclear Support Office at the Nuclear Test Site provides continuing meteorological services required by the safety and technical programs associated with all forms of nuclear and non-nuclear experiments conducted at the test site and other locations.

## FEDERAL EMERGENCY MANAGEMENT AGENCY

Under direction of the President, the mission of the Federal Emergency Management Agency (FEMA) is to plan for and coordinate the protection of the civilian population and resources of the Nation, and to include planning for the continuity of constitutional government in time of emergency. FEMA replaced five former agencies, integrating a number of emergency activities which include development of community awareness for meteorological emergencies and coordination of all emergency warnings to the public.

FEMA's principal involvement with meteorology results from the coordinating role of FEMA in support of preparedness for national security emergencies, and for carrying out statutory disaster relief responsibilities involved with the extremes of meteorologically-related phenomena. These responsibilities have been listed in Executive Order 12656 which forms the basis for FEMA's continuing relationship with the Executive line agencies.

In carrying out its role, FEMA works with all of the agencies to assure that the delivery of meteorological and climatological-related information is conducted in keeping with established preparedness goals and objectives. As administrator of the National Flood Insurance Program, FEMA publishes a system of Flood Insurance Rate Maps (FIRM) which serve as the official demarcation for flood insurance risk. Recently, FEMA was given responsibility by the 100th Congress for coordinating the preparation of a national coastal erosion and flood plain database.

FEMA's priority interests with the Office of the Federal Coordinator are in promoting standards and procedures which will enhance the ability of the Nation to mitigate and recover from national security emergencies, and to coordinate its statutory responsibilities by enhancing integrated services under off-standard conditions. These interests extend to national standards for geographic information systems which serve as vehicles for delivery of meteorological services by other agencies.

For meteorologically-related matters, the National Preparedness Directorate is the principal contact point within FEMA. Developments involving flooding and erosion impacts are coordinated within the Insurance Administration offices of FEMA.

## 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 in coordinating the 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 and has obviated 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. This Appendix was prepared by the Working Group for World Weather Program (WG/WWP) of the Committee for Basic Services within the Federal meteorological coordination mechanism.

#### GOALS AND ORGANIZATION OF THE WORLD WEATHER PROGRAM

The goals of the World Weather Program (WWP) are to extend the time, accuracy, range, and scope of weather prediction and to understand the physical basis of climate and of climatic changes. 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 barely adequate over 20 percent of the Earth while the remaining 80 percent, mostly over the oceans, remain inadequately observed.

Development of the technology and the systems to obtain these observations, especially over the oceans, presents formidable problems. However, with the use of satellites, aircraft, ships, radar, anchored and drifting buoys, and balloons, a system can be developed that will be able to observe and collect comprehensive daily data about the atmosphere of the entire globe. This system is too complex to be implemented by a single nation. This has been clearly recognized by the leaders of many nations whose international cooperation in meteorology has been a tradition for more than a century. The continuing need for international cooperation prompted the President of the United States to propose to the United Nations (UN) in 1961 the establishment of an international effort in weather prediction. The United Nations 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 knowledge of the basic physical forces that determine climate.

The WMO, with 160 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.

The responsibilities of U. S. Federal agencies in the WWP follow:

Department of Commerce (DOC): Represents the U. S. at WMO and provides the focal point (NOAA) 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 as related to its responsibilities.

Department of State (DOS): Maintains relations with developing nations and through the WMO assists developing nations in improving their national weather services; and 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 the Department of Defense (DOD) weather services is basically internal, the nature of DOD's operations is global. As such, the observation, telecommunication 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. The observation and telecommunication programs of the Department of Transportation (DOT) also provide significant indirect support to the World Weather Watch through DOT's interface with NOAA's National Weather Service.

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: 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. 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. The Systems Support Activity provides guidance, technical and scientific information, and training to those involved in the planning, development, and operation of WWW components. 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 surface-based subsystem are:

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

Other elements are:

Aeronautical Meteorological Stations  
Research and Special Purpose Vessels  
Climatological Stations  
Agricultural Meteorological Stations  
Weather Radar Stations  
Meteorological Reconnaissance Aircraft  
Wind Profilers

Solar Radiation Stations  
Atmospheric Detection Stations  
Meteorological Rocket Stations  
Ozone Stations  
Background Pollution Stations  
Tide Gage Stations

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 locales. Two categories of satellites are used; those in near-polar orbits and those in geostationary orbits.

Satellites in near-polar orbits provide global coverage twice a day (in daylight and darkness) by circling from pole to pole as Earth rotates beneath. They usually orbit at altitudes under 1000 km. They are equipped with instruments to collect precise radiance measurements for numerical analysis and prediction applications, as well as instruments/systems for other applications. Typical products derived from their primary instruments are: atmospheric temperature and water vapor soundings; sea surface temperatures; radiation fluxes; cloud cover information; and ice/snow extent. Additionally, they are used to monitor, among others, ozone, volcanic eruptions, global vegetation greenness, and the distribution of energetic particles in the upper atmosphere. Systems aboard these satellites may include those to collect and relay data from in situ platforms and to provide the detection and tracking of signals from emergency transmitters used in Search and Rescue programs.

Presently, operational meteorological satellites in polar orbits are operated by the Union of Soviet Socialist Republics (those of the METEOR-3 series) and the United States (those of the NOAA series). NOAA currently launches satellites, alternately, into afternoon and morning orbits on a planning schedule of 15 1/2 months between launches. The current operational NOAA polar satellites are NOAA-10 (launched in September 1986) and NOAA-11 (launched in September 1988). NOAA-9 (launched in December 1984), although not in full service, continues to provide ozone and radiation budget measurements. NOAA-D (which will become NOAA-12 when operational) is scheduled for launch into an afternoon orbit in May 1991.

Operational geostationary meteorological satellites provide the repetitive, day and night observations of the Earth-disk in their fields of view that are needed to provide a "continuous weather watch." From their geostationary altitude (36,000 km) over the Equator, and with orbital speed matched to Earth's rotation rate, each remains fixed above its assigned equatorial subpoint on Earth. They monitor the Earth scene below in the visible and the infrared bands and, by providing observations of an area every few- or few-tens of minutes, are well-suited to tracking the progress of mesoscale and/or short-lived environmental events. In addition to imagery, products derived from geostationary satellite data include surface temperature fields and atmospheric winds (from cloud displacements over time). Some geostationary weather satellites are equipped to provide atmospheric temperature and water vapor soundings, image atmospheric water vapor distributions and transport, and monitor solar particle flux, (including solar x-rays), at the spacecraft. Systems for collecting and relaying data from automatic sensor platforms are included in the payload, a Search and Rescue Satellite-Aided Tracking capability may be aboard, and communications functions are provided to support users. Data from these satellites are proving increasingly important in climatic monitoring and research.

Presently, operational geostationary weather satellites are operated by Japan, India, 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; and EUMETSAT's METEOSAT is at 0°. The United States normally operates two Geostationary Operational Environmental Satellites (GOES); one at 75°W, the other at 135°W. An earlier launch failure resulted in GOES-7 (launched in February 1987) becoming the sole operational GOES when GOES-6 failed in 1989. Since 1989, GOES-7 has been alternately positioned at 108°W (winter season) and 98°W (hurricane season). NOAA plans to launch the next satellite in this series (GOES-I, to become GOES-8 when operational) in 1992.

Both the NOAA and the GOES series of U.S. satellites broadcast their data directly to any properly equipped ground station within line of sight. Reception of these broadcasts is unrestricted and does not require any pre-notification. The United States, through NOAA, develops information and products from these data for further distribution over the Global Telecommunications System (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.

During the last few years, several systems have been under development and/or have been partially deployed which will contribute to improving the GOS. Among these are the family of automated aircraft reporting systems (AMDAR) including the Aircraft to Satellite Data Relay (ASDAR) and Airline Communications Addressing and Reporting System (ACARS). British certification testing for airworthiness/safety is currently underway for the ASDAR Systems that will be flown over data sparse areas such as the Atlantic, Pacific, and Southern Hemisphere Oceans. U.S./FAA certification, which will follow issuance of the British certification, is expected to be completed in late 1991. A cooperative effort among Aeronautical Radio Inc (ARINC), NWS and the FAA is underway to provide thousands of meteorological reports from ACARS equipped aircraft flying over the U.S., Europe, and the Atlantic and Pacific Oceans. Initially, twelve thousand reports a day in varied formats and internal codes will be received by ARINC and the quantity is expected to increase to 150,000 (mostly automated ACARS) reports by the mid-1990's. The ARINC Meteorological Data Collection and Reporting System (MDCRS) will collect, organize, and disseminate automated position/weather reports to the NWS. This will result in standardized weather data being sent to the NWS in the Binary Universal Format Representation (BUFR) code. Greater quantities, particularly over oceanic and data sparse areas will be realized via satellite navigation systems.

In addition to these aircraft-based systems, others are also being developed and deployed to improve the GOS. The Automated Shipboard Aerological Program (ASAP) has, for example, about 15 of its systems now reporting regularly. During the same period there has also been deployment of substantial numbers of drifting buoys. A number of nations, including the U.S., are in the process of implementing test networks of ground based doppler radars called wind profilers to provide soundings of wind on a near-continuous basis. In 1990 several wind profilers were installed and began operating as part of a network of 29 of these systems being deployed primarily in the central U.S. The remaining systems are expected to be implemented by early 1992. In response to the threat to Alaskan aviation interests posed by volcanic ash plumes coming from Mt. Redoubt, a program was established to put several profilers in southern Alaska. One of these units was installed near Homer, AK at the end of 1990.

The concept of the Operational World Weather Watch Systems Evaluation (OWSE) has also been developed as a framework for regional implementation. The OWSE-North Atlantic was begun in January 1987 and was completed in 1989. Data have been gathered and reports produced on the quality and reliability of the information. Data impact studies have been performed with results that are important to planning changes to the mix of observing systems. A final report has been submitted to the WMO citing the lessons learned and recommendations appropriate for members of WMO. A continuing organization has been formed to continue to coordinate implementation and operations on the North Atlantic. The OWSE-Africa has been initiated 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. Specifically, it is designed to implement and test the data collection system for receipt of meteorological observations from various countries in Africa. Thus far, 36 data collection platforms have been installed in Kenya, Ethiopia, Ghana, Sudan, Nigeria, Sierra Leone, Zaire, Egypt, Madagascar, St. Helena, Guinea, and Cape Verde. When completed it is expected 150 of these platforms will have been deployed and activated. Evaluations are being carried out to gauge the improvement of observations.

In 1986, the U.S. agreed to undertake the development of a plan and evaluation of the feasibility of satellite sounding improvement techniques through the use of a baseline upper air network consisting of rawinsonde, rocketsonde and ASAP observing systems. With the cooperation of a number of foreign meteorological services, the observational phase of the project took place during the period January 15 - July 15, 1988. The final report on the project summarizing the results was completed and submitted to WMO's Commission for Basic Systems in October 1990. While the results did not warrant operational implementation, research is continuing on this important goal.

#### Global Data Processing System (GDPS)

The purpose of the GDPS is to make available all processed information required for both real-time and non-real time applications. The GDPS produces products and processed information, based on recent advances in atmospheric science, using powerful numerical computer methods. Members have real-time 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 (WMCs), Regional/Specialized Meteorological Centers (RSMCs) together with National Meteorological Centers (NMCs) which carry out GDPS functions at the national level. In general, real-time functions of the system involve preprocessing of data, analysis and prognosis, including derivation of appropriate meteorological parameters. The non-real-time functions include data collection and archival, quality control, storage and retrieval, as well as cataloging of 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 are located at Algiers, Algeria; Antananarivo, Malagasy; Beijing, People's Republic of China; Bracknell, England; Brasilia, Brazil; Buenos Aires, Argentina; Cairo, Egypt; Dakar, Senegal; Darwin, Australia; Jeddah, Saudi Arabia; Khabarovsk, USSR; Lagos, Nigeria; Melbourne, Australia; Miami, USA; Montreal, Canada; Moscow, USSR; Nairobi, Kenya; New Delhi, India; Novosibirsk, USSR; Offenbach, Germany; Rome, Italy; Tashkent, USSR; Tokyo, Japan; Tunis, Tunisia;

Washington, USA, and Wellington, New Zealand. The European Center for Medium Range Forecasting is also an RSMC. These centers provide regional products used for short and medium-range forecasting of small, meso 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 International Civil Aviation Organization (ICAO) as World Area Forecast Centers (WAFCs). They issue upper wind and temperature forecasts with global coverage to associated Regional Area Forecast Centers (RAFCs). This information is to be redistributed as required within each regional center's service area. The regional centers also prepare and distribute forecasts of weather elements defined by ICAO as significant weather. Washington and London WAFCs as well as other RAFCs have functioned in their role since 1984. RAFCs associated with WAFS Washington include Brasilia, Buenos Aires, Tokyo, Wellington, Melbourne, New Delhi and Washington. RAFCs associated with WAFS London are Paris, Frankfurt, London, Moscow, Nairobi, Cairo, Las Palmas and Dakar.

The preceding paragraph deals with efforts towards implementation of the interim phase of the WAFS. In the planned implementation of the final phase, the two world centers 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 may begin to be realized in the early 1990's through forecaster initiated graphic interaction.

The dissemination of aeronautical information via satellite during the interim and final phases of WAFS awaits implementation. The U.S. will provide 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 from the WMCs, RSMCs and NMCs operating within the GDPS of the WWW, to meet the needs of Members for operational and research purposes which involve real-time or quasi-real-time exchange of information. The GTS also supports other WMO programs, joint programs with other international organizations, and environmental programs as decided by the WMO Congress.

The GTS 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 telecommunication functions of the WMCs, Regional Telecommunications Hubs (RTHs), RSMCs, and NMCs.

The MTN links the WMCs at Melbourne, Moscow, and Washington with the RTHs at Beijing, Bracknell, Brasilia, Buenos Aires, Cairo, Dakar, Nairobi, New Delhi, Offenbach, Paris, Prague, Sofia, Tokyo, and Jeddah. 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 Members.

In summary, the GTS enables the NMCs to receive and distribute observational data and meteorological information to meet the requirements of Members.

Planned WWW activities for FY 1991 include:

- ▶ Improvement of the capacity of MTN links and inclusion of graphics (e.g., Washington-Bracknell, Washington-Brasilia, Washington-Buenos Aires, Washington-Montreal, and Washington-Tokyo);
- ▶ Implementation of upgraded regional networks;
- ▶ 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 Co-operation Program (VCP)

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

The WMO-VCP Program helps the developing countries to implement the WWW program by providing equipment, services, and long 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, electrolytic hydrogen generators, 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 U.S. has contributed annually from \$1.5 million to \$2.3 million to VCP since 1969. Other nations contribute a total of approximately \$2.0 million annually and this continues to increase. Contributions are in three categories; equipment and services (80 percent), financial contributions (about 10 percent), education and training (about 10 percent).

The Department of State (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 1990, DOS funding for WWW/VCF programs was \$2.00 million. In FY 1991, \$2.00 million was approved and in FY 1992, \$2.30 million has been requested.

The Climate Computing (CLICOM) project of the WMO's World Climate Program has become a major and very successful WMO project in which the U.S. has played a leading role. Each CLICOM unit consists of a small network of 1 to 6 personal computers, peripherals and resident data management software which together provides developing countries with the capability to digitize and better use their climatological data. The resulting climate information can be used for better management of each country's agricultural, hydrologic and other natural resources. It is also important in determining the potential impact of the changing global climate. The U.S. VCP has provided major funding for the original development of the data management software and also funded hardware and training for installation of CLICOM in countries in Africa, Central and South America. The system has been installed in 75 countries with funding coming from France, Finland, the United Kingdom, the United States and the United Nations Development Program. Fifteen instructors have been trained and nearly 150 systems are in use.

Planned VCP activities for FY 1991 include:

- ▶ Continued support for data collection and telecommunications capabilities in Africa;
- ▶ Implementation and updating of surface and upper-air observational programs in the tropics, the Southern Hemisphere, and Africa as resources and priorities permit;
- ▶ Continued support for the implementation of VCP projects in Latin America and the Caribbean areas in support of the hurricane and tropical storm programs;
- ▶ Installation and training on the CLICOM climate data management system for countries in Africa, Central and South America, and Eastern Europe, and implementation of enhanced graphic output capabilities.

## BILATERAL AND REGIONAL INTERNATIONAL COOPERATIVE PROGRAMS

### United States - Peoples Republic of China Protocol in Atmospheric Science and Technology

This U.S.-P.R.C. Protocol includes a program on Monsoon Research. Collaborative projects between U.S. and P.R.C. scientists that were completed in 1989-90 include two studies (Yu/Young at the University of Wisconsin at Madison and Zhou/Chen at Iowa State University) on large-scale dynamic features of the (summer and winter) monsoon circulations. Two other studies (Lu/Krishnamurti at Florida State University and Wang/Johnson at Colorado State University), on the relationships between these features and interannual variations of major precipitation regions, have been initiated and are currently under way. A lecture tour on these topics was conducted by Dr. Johnson over several weeks in May 1989 at a number of meteorological institutions in Beijing and Guangshu.

The fourth Monsoon Workshop, attended by 45 scientists and students, was hosted by the U.S. at Pennsylvania State University in October 1989. At this workshop the Chinese requested an extensive set of satellite-based thermal radiation measurements in conjunction with the forthcoming launch of the second P.R.C. polar-orbiting meteorological satellite (FY-1B). The data was forwarded in 1990. YB-1B was successfully launched in September 1990. The P.R.C. has offered to host a fifth Monsoon workshop in late 1991 or early 1992.

## APPENDIX F

### SELECTED ACRONYMS AND ABBREVIATIONS

AAODL	Atmospheric Aerosols and Optics Data Library
ADAS	AWOS/ASOS Data Acquisition System
AF	Air Force (USAF)
AFB	Air Force Base
AFCC	Air Force Communications Command
AFGWC	Air Force Global Weather Central
AFOS	Automation of Field Operations and Services
AFRES	Air Force Reserve
AFS	Air Force Station
AHOS	Automated Hydrologic Observing System
AI	Artificial Intelligence
AID	Agency for International Development
AIP	Airport Improvement Program
ALBE	AirLand Battlefield Environment
AMR	Aircraft Microwave Refractometer
APT	Automatic Picture Transmission
ARGOS	French Satellite Data Collection System
ARSR	Air Route Surveillance Radar (FAA)
ARTCC	Air Route Traffic Control Center
ASL	Atmospheric Sciences Laboratory (U.S. Army)
ASOS	Automated Surface Observing System (NOAA)
ASR	Airport Surveillance Radar (FAA)
ATC	Air Traffic Control
AVHRR	Advanced Very High Resolution Radiometer
AWDS	Automated Weather Distribution System
AWIPS	Advanced Weather Interactive Processing Systems
AWIS	Automated Weather Information Systems
AWOS	Automated Weather Observing System (FAA)
AWN	Automated Weather Network
AWS	Air Weather Service
CAC	Climate Analysis Center
CAS	Committee for Aviation Services (OFCM)
CAT	Clear Air Turbulence
CAWIS	Committee for Automated Weather Information Systems (OFCM)
CBS	Committee for Basic Services (OFCM)
CDA	Command and Data Acquisition
CDAS	Command and Data Acquisition Station
CDDF	Central Data Distribution Facility
CECOM	Communications and Electronics Command (U.S. Army)
COES	Committee for Operational Environmental Satellites (OFCM)
CONUS	Continental United States
CSEF	Committee for Space Environment Forecasting (OFCM)
CWP	Central Weather Processor (FAA)
CWSU	Center Weather Service Unit (FAA)
DACS	Data Acquisition and Control Subsystem
DCPLS	Data Collection and Platform Location System
DCS	Data Collection System (NOAA/NESDIS)
DMSP	Defense Meteorological Satellite Program (DOD)

DLC	Data Link Processor
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOS	Department of State
DOT	Department of Transportation
DPSS	Data Processing and Services Subsystem
DUAT	Direct User Access Terminal
EO	Electro-Optical
EOSAEL	Electro-Optical Systems Atmospheric Effects Library
EPA	Environmental Protection Agency
ERBE	Earth Radiation Budget Experiment
ERBSS	Earth Radiation Budget Satellite System
ERL	Environmental Research Laboratories
FAA	Federal Aviation Administration
FCMSSR	Federal Committee for Meteorological Services and Supporting Research
FEMA	Federal Emergency Management Agency
FNOC	Fleet Numerical Oceanography Center
FSAS	Flight Service Automation System
FSS	Flight Service Station
FY	Fiscal Year
GAO	General Accounting Office
GARP	Global Atmospheric Research Program
GDPS	Global Data Processing System
GL	Geophysics Laboratory (AFSC)
GOES	Geostationary Operational Environmental Satellite
GOS	Global Observing System
GSFC	Goddard Space Flight Center
GTS	Global Telecommunications System
HRIS/2	Modified High Resolution Infrared Sounder
HRPT	High Resolution Picture Transmission
ICMSSR	Interdepartmental Committee for Meteorological Services and Supporting Research
ICSU	International Council of Scientific Unions
IMETS	Integrated Meteorological System
IR	Infrared
ITOS	Improved TIROS Operational Satellite
IWRS	Improved Weather Reconnaissance Systems
JAWOP	Joint Automated Weather Observation Program (OFCM)
JSPO	Joint System Program Office (NEXRAD)
JTWC	Joint Typhoon Warning Center
LLWAS	Low Level Wind Shear Alert System
M	Million
MAC	Military Airlift Command
McIDAS	Man-computer Interactive Data Access System
MMS	Meteorological Measuring System

MOPP	Mission Oriented Protective Posture
MSU	Microwave Sounding Unit
MWP	Meteorological Weather Processor (FAA)
NADIN	National Airspace Data Interchange Network (FAA)
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NBC	Nuclear, Biological, and Chemical
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCP	National Climate Program
NCPO	National Climate Program Office
NDBC	NOAA Data Buoy Center
NEDN	Naval Environmental Data Network
NEDS	Naval Environmental Display Station
NESDIS	National Environmental Satellite, Data, and Information Service
NEXRAD	Next Generation Weather Radar (WSR-88D)
NGDC	National Geophysical Data Center
NHC	National Hurricane Center
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center (NOAA)
NOMSS	Naval Oceanographic and Meteorological Support System (NAVY)
NOTAM	Notice to Airmen
NRC	Nuclear Regulatory Commission
NSF	National Science Foundation
NSSFC	National Severe Storms Forecast Center
NSSL	National Severe Storms Laboratory
NTSB	National Transportation Safety Board
NWR	NOAA Weather Radio
NWS	National Weather Service
OFCM	Office of the Federal Coordinator for Meteorology
OMB	Office of Management and Budget
PATWAS	Pilot Automatic Telephone Weather Service
PROFS	Prototype Regional Observing and Forecasting Service
RAMOS	Remote Automatic Meteorological Observing System
R&D	Research and Development
RD/T&E	Research and Development, Test and Evaluation
RFC	River Forecast Center
ROMS	Remote Ocean Surface Measuring System
RWP	Real-time Weather Processor (FAA)
SATCOM	Satellite Communications System (NOAA)
SBUV	Solar Backscatter Ultraviolet Instrument
SDHS	Satellite Data Handling System (DOD)
SEL	Space Environment Laboratory (NOAA)
SEM	Space Environment Monitor
SFSS	Satellite Field Services Station (NOAA)
SIO	Scripps Institution of Oceanography
SMCC	Systems Monitoring and Coordination Center
SOCC	Satellite Operations Control Center (NOAA)
SSU	Stratospheric Sounding Unit

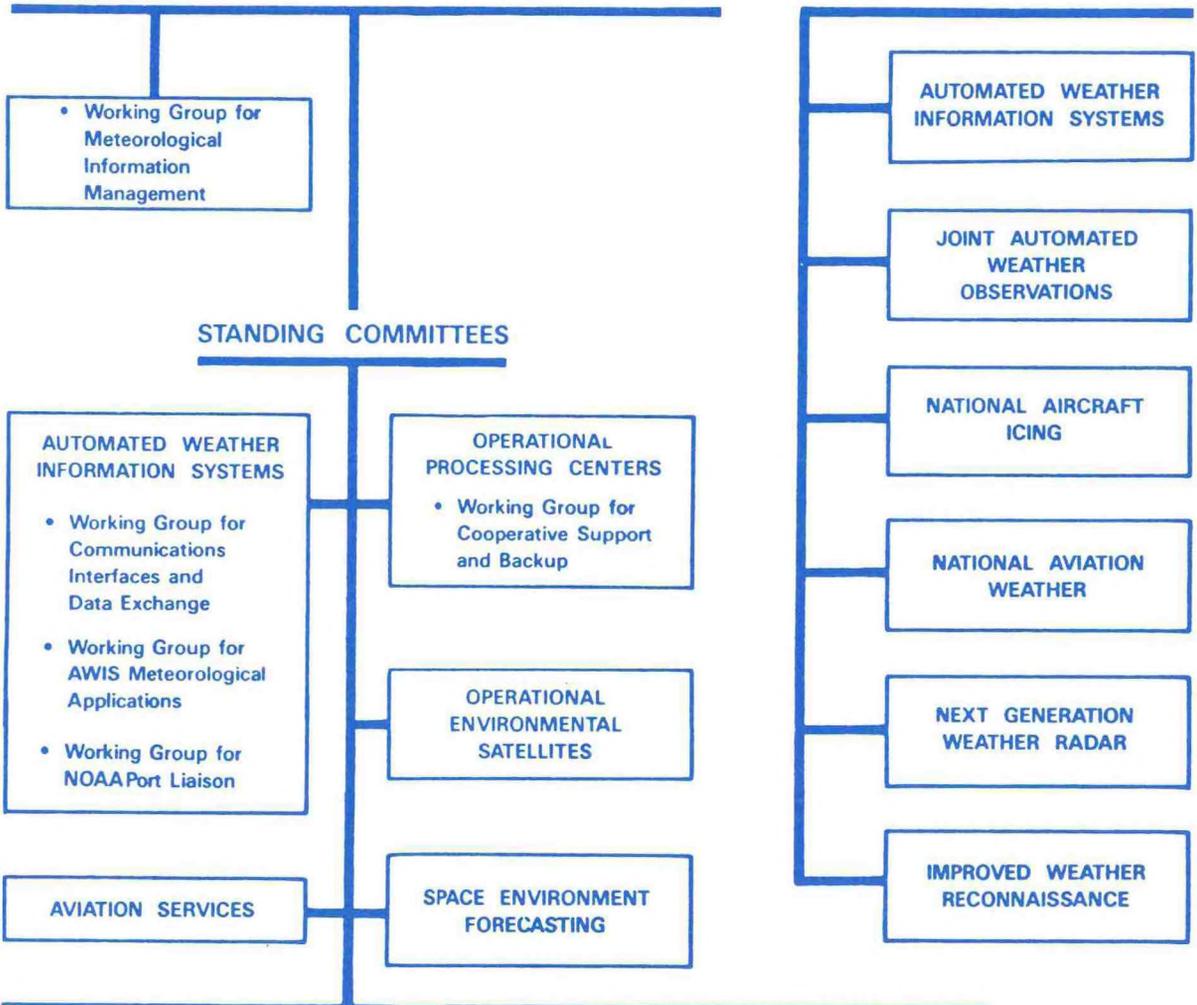
STIWG	Satellite Telemetry Interagency Working Group (OFCM)
TDWR	Terminal Doppler Weather Radar
TDA	Tactical Decision Aid
TESS	Tactical Environmental Support System
TIROS	Television Infrared Observation Satellite
TOGA	Tropical Ocean and Global Atmosphere
TOVS	TIROS N Operational Vertical Sounder
TRADOC	U.S. Army Training and Doctrine Command
TWEB	Transcribed Weather Broadcast
UAV	Unmanned Aerial Vehicles (Army)
UN	United Nations
USAF	U.S. Air Force
USAFETAC	USAF Environmental Technical Applications Center
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USN	U.S. Navy
UTC	Universal Coordinated Time (US usage)
VAS	VISSR Atmospheric Sounder
VHF	Very High Frequency
VHRR	Very High Resolution Radiometer
VISSR	Visible and Infrared Spin Scan Radiometer
VRS	Voice Response System
VTPR	Vertical Temperature Profile Radiometer
WEFAX	Weather Facsimile
WMC	World Meteorological Center(s)
WMO	World Meteorological Organization
WMSC	Weather Message Switching Center
WMSCR	Weather Message Switching Center Replacement
WRP	Weather Research Program (ERL)
WSCMO	Weather Service Contract Meteorological Office
WSFO	Weather Service Forecast Office
WSMO	Weather Service Meteorological Office
WSO	Weather Service Office
WSR-88D	Next Generation Weather Radar (NEXRAD)
WWP	World Weather Program
WWW	World Weather Watch

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